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1. Landmarks and Scope in Plant Breeding

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Abstract:

Plant breeding, a pivotal discipline in agricultural advancement, continuously seeks to enhance crop varieties for improved yield, quality, and resilience. Its scope encompasses a wide array of techniques, from traditional selection to modern molecular methods, aimed at manipulating plant genetic traits. Landmark achievements in plant breeding include the Green Revolution's high-yielding varieties and the development of disease-resistant cultivars. These milestones revolutionized agricultural productivity, ensuring food security for burgeoning populations. The scope of plant breeding extends to addressing contemporary challenges such as climate change and nutritional deficiencies, driving innovation towards sustainable agriculture and global food sovereignty.

Keywords:

Green Revolution, Yield, HYVs, Resistant Cultivar, Food Security

1.1 Introduction:

Landmarks: It is a type of achievement or discovery that has created huge success and benefits for either living or living elements.

1.2 Landmarks in Plant Breeding:

1.2.1 Pre Mendelian-Era:

A. Selective Breeding in Early Agriculture:

Ancient farmers began selection and propagation in plants for desirable traits such as shape, size, taste and resistance. Happened thousands of years ago in ancient time.

Role of Selective Breeding:

i. By this method crop yield and quality improved

ii. It enhanced the nutritional values of crops like taste and flavor.
iii. Enhanced disease resistance.

B. Crop Domestication: In this many crops were taken into human control from wild areas to cultivated areas. It includes crops like wheat, barley and rice. Took place between 10,000 BCE to 3000 BCE.

Role of Crop Domestication:

i. Prevented several crops from extinction: When crops were taken under human control, they were managed, grown and harvested properly along with they were protected from biotic and abiotic stress by using traditional prevention methods.

ii. Enhanced storage and processing qualities: Humans made several facilities for increasing the durability of storage and along with it carried out some traditional methods of processing like drying, cleaning and packaging them.

iii. Culinary Diversity: Domestication enhanced the range of edible varieties expanding the culinary diversity.

iv. Cultural significance: Due to domestication several crops become part of the early society cultures and traditions influencing rituals, ceremonies and daily life.

v. Enhanced propagation Knowledge: With domestication farmers started noticing and using different propagation methods to increase the yield.

C. Introduction of Controlled Pollination by Chinese Agriculturists: Agriculturists and farmers started controlled pollination to produce crops with desired pollens and traits. Happened around 1000 BCE.

Role of Controlled Pollination:

i. Efficient Trait Improvement: With the help of the controlled pollination the desired traits carrying desired features were improved in the plants.

ii. Reduction of Undesirable traits: With the help of this method agriculturists started emitting the not required features to improve crops.

D. Work of Carolus Linnaeus: He worked during 18^{th} century and carried the classification of plants based on their features, laying a beginning for organized plant breeding.

E. Gregor Mendel's Experiments: Mendel carried several experiments on pea plants during 1856-1863 and recorded their data. He gave several terms and principles in Plant Breeding which include:

i. Principle of Dominance: It describes that during a cross between two parents few traits will be expressed more which were called dominant traits and several traits which were recessive in the F1 generation were recessive traits and this law is called Law of Dominance.

ii. Principle of Segregation: During the experiments on pea plants Mendel observed that during the F1 generation the dominant traits expressed themselves but in the next generation the recessive traits appeared in a specific ratio of (3:1).

iii. Principle of Independent Assortment: During his experiments Mendel used multiple traits and found that the inheritance of one trait did not affect the inheritance of another trait.

iv. Introduction of Terminologies: Mendel denoted several terms like “allele”, “homozygous”, and “heterozygous” to elaborate the genetic makeup of organisms.

v. Introduced Three - to - One Ratio: During the monohybrid crosses carried out by Mendel, he consistently observed a 3:1 ratio of dominant to recessive traits in F2 generation.

vi. Introduced Nine-to-Three-to-Three -to-One Ratio: In his dihybrid crosses, he observed a ratio of 9:3:3:1 ratio of different trait combining in F2 generation.

F. Development of Hybrid Maize: Hybrid maize was developed by William Beal in 1870. It has a huge scope in the field of agriculture for several reasons:

i. Pioneer of Hybridization: Beal had used the hybridization principles in plant breeding which help him understood the potential of producing new varieties with required traits.

ii. Description of Hybrid Vigor: His experiments on maize showed heterosis which describes the phenomenon in which offspring produced from crosses between different inbred lines demonstrate superiority in contrast with their parents. This help to understand the advantages of hybrid breeding for better yield and vigor.

iii. Influential in Shaping the Modern Agriculture: His work helped in broader understanding of plant genetics and breeding, which helped in enhancing the demand and direction for utilizing these processes.

G. Rediscovery of Mendel Principles: In the early 20th century Mendel’s laws were again found by three scientists independently. Those scientists were:

i. Hugo de Vries (1900): He was a Dutch botanist who referred Mendel’s principles as “Mendelian inheritance” and “Mendelian segregation”.

ii. Carl Correns (1900): The German botanist conducted experiments on the inheritance of variegated leaf patterns in four o’clock plants and confirmed Mendelian principles.

iii. Erich von Tschermark (1900): The Austrian botanist conducted experiments on the inheritance of flower color in peas and confirmed Mendel’s laws independently.

1.2.2 Post Mendel Era:

A. Introduction of Pure Line Selection: First introduced by Wilhelm Johannsen in 1903. Scope of this discovery:

i. Genetic Purity: With the help of pure line selection plants can be selected and propagated that are genetically uniform for a specific trait which led to development of stable and true breeding line.

ii. Consistency in Trait Expression: Pure lines demonstrate a high degree of consistency for the expression of selected trait. This prediction is important for agricultural practices and allow farmers to rely on the performance of a specific variety.

B. Introduction of Backcrossing: First introduced by Edward M. East and G. N. Collins in 1908.

Scope of Backcrossing:

i. Disease and Pest Resistance: This method is used to introduce disease and pest resistance into elite plant varieties help to fight several pathogens and prevent yield losses.

ii. Abiotic Stress Tolerance: This method enhances the ability of plant to tolerate environment stresses like drought, salinity and high or low temperature.

iii. Quality Traits: Backcrossing help to enhance the quality attributes of crops such as taste, texture, processing and nutritional content.

iv. End-Use Characteristics: This method can be used to develop crops with traits tailored to specific end uses, like baking quality in wheat or malting quality in barley.

C. Introduction of Heterosis: It was first introduced by Shull in 1908.

Scope of Heterosis:

i. Increased Yield: The primary benefit of heterosis is enhancing the crop yield as it can produce more biomass, higher grain yields, larger fruits in contrast with their parent lines.

ii. Improved Uniformity: It enhances the uniformity in characteristics of plants resulting in more consistency in quality and quantity.

iii. Customization of Traits: By using this method breeders can select the desired traits of their choice or according to market demand and produce crop containing those features.

vi. Conservation of Genetic Diversity: This method helps in creating combinations of diverse genetic material, helping to maintain genetic diversity within the crop population.

D. Introduction of Double Hybrid Maize:

Developed by Jones in 1918, double hybrid maize is also known as triple hybrid maize, it is a specific type of hybrid maize developed by a two-stage hybridization method.

Scope of Double Hybrid Maize:

i. Enhanced Yield Potential: This type of maize contains high yield attributes compared to traditional single-cross hybrids.

ii. Flexibility in Parental Lines: Breeders have the flexibility of choosing specific inbred lines based on desired traits so that they can produce the offspring with desired features.

iii Advances in Seed Production: This type of maize has helped to create advanced hybrid seed production techniques, contributing to the affordability and availability of high-quality seeds for farmers.

iv. Enhanced Livestock Feed: Maize is commonly used as livestock feed and double hybrid maize is high in nutritional quality, directly enhancing the livestock production.

E. Introduction of Induced Mutation:

First demonstrated by Lewis J. Stadler in 1928.

Scope of Induced Mutation:

i. Acceleration of Breeding Programs: This mutation helped in enhancement of breeding efforts of breeders by creating new genetic variation more rapidly than traditional breeding methods.

ii. Genetic Diversity: With the help of Induced mutation new genetic variations were introduced leading breeders to use improved traits such as diseases, drought, pest resistance to produce new plants.

iii. Crop Adaptation: Induced mutation help to enhance the adaptability of different plants in different environmental conditions, such as different climates, soils, or altitudes.

iv. Creation of Unique Varieties: With the help of induced mutation novel plant varieties can be produced with unique characteristics which may not be present in the original parent lines.

v. Crop Improvement for Non-Food Purposes: With the help of induced mutation breeders can develop crops for non-food purposes, such as biofuel production, fiber production, or ornamental horticulture.

F. Development of Wide Crosses: Developed by Emerson in 1930s-1940s

Scope of wide crosses in plant breeding:

i. Introducing Novel Traits: These crosses can introduce new and unique traits that may not be present within a plant's immediate genetic pool. This can help in adding traits like disease resistance, pest resistance or biochemical properties into the plants.

ii. Overcoming Incompatibility Barriers: Wide crosses help to overcome natural barriers of reproduction that exist between species allowing for the combination of important traits that would otherwise be isolated.

iii. Developing Rootstocks: These crosses are often used to develop rootstocks which are used for grafting purposes.

These rootstocks help in introducing specific growth characteristics, pest and disease resistance and environment tolerance in the grafted plants.

iv. Improvement of Ornamental Plants: Wide crosses have been widely used to enhance and develop new and unique ornamental varieties like introducing new flower colors, or shapes.

v. Preservation of Wild Traits: Wide crosses help in conserving wild features or traits of several species which can be utilized in future for generating new plant varieties.

G. Development of Male Sterility Systems in maize: First introduced by Marcus Rhoades in 1930s-1940s.

Scope of Male Sterlity:

i. Efficient Hybrid Seed Production: With the help of male sterility systems the production of hybrid maize seeds facilitates which help in production of hybrid varieties which are widely utilized in modern agriculture.

ii. Heterosis Utilization: Male sterility-systems enable breeders to harness the benefits of heterosis which help in higher productivity and yields.

iii. Synchronization of Flowering: Male sterility ensures that male parents do not produce pollens thus preventing undesired self-pollination which help in maintaining the genetic purity.

iv. Greater Seed Quality and Uniformity: The hybrid seeds produced by male sterility systems help to enhance genetic purity and uniformity, resulting in consistent performance across different environments.

H. Introduction of Cytoplasmic Male Sterility: First demonstrated by M.L. Kaul in 1950s.

Scope of Cytoplasmic Male Sterility:

i. Efficient Hybrid Seed Production: This method helps in production of hybrid seeds in a wide range of crops. It also eliminates the need of manual emasculation for hybrid seed production.

ii. Reduction of Labor Costs: When the need of manual emasculation is eliminated it automatically reduce the labour requirement, which ultimately reduce the cost of labour.

iii. Ease of Large-Scale Production: CMS help in increasing the rate of hybrid seeds production ultimately increasing the seed diversity and availability.

iv. Preservation of Parental Lines: This sterility helps to maintain the genetic integrity of parental lines, ensuring their stability and reliability for future breeding efforts.

I. Discovery of DNA Structure: It was discovered by James Watson and Francis Crick in 1953.

Role of Identification of DNA Structure:

i. Foundation of Molecular Biology: DNA double helix structure help DNA as the genetic material responsible for transferring traits from one generation to the next.

ii. Clarification of Heredity Mechanisms: With the help of DNA scientists can track the method by which genetic information is passed from parent to offspring, providing a molecular basis for Mendelian principles and some other theories of inheritance.

iii. Advancements in Molecular Genetics: The discovery of DNA structure enhanced the development of molecular genetics, leading to breakthroughs in several areas like gene regulation, genetic engineering and gene regulation.

iv. Forensic Science and DNA Profiling: The DNA structure is efficiently used in investigating several criminal cases and to identify individuals during incidents of deaths or murder.

v. Medical Advances and Genetic Medicine: With the help of DNA structure various medicines and disease or pest resistance crops are generated.

J. The Green Revolution: It was introduced to the world by Norman Borlaug who is also known as Father of Green Revolution and in India by Dr. M.S. Swaminathan, who is Father of Green Revolution in India. It was introduced in India in 1966-67.

Role of Green Revolution:

i. Development of High Yielding Crop Varieties: Green revolution helped in producing crops with high yielding quality such as wheat, rice and maize.

ii. Food Security: The enhanced crop productivity by green revolution helped to Figureht the food shortages and improved food security mainly in densely populated nations like India.

iii. Intensification of Crop Production: By increased input use the output was generated in large quantity and several cropping patterns and new cropping methods evolved which helped in increasing the crop diversity.

iv. Economic growth and Poverty Reduction: Due to use of pesticides and fertilizers the quantity of yield was increased which facilitated the exports of agricultural goods to other countries, gradually enhancing the GDP of the nation.

v. Research and Development in Agriculture: The Green Revolution gradually increased people’s taste in investing into research in agriculture which ultimately leading to advancement in plant breeding, sustainable farming practices and biotechnology.

K. Development of First Genetically Engineered Plant: First transgenic Tobacco plant was produced in 1983.

Scope of Biotech Crops:

i. Introduction of Novel Traits: In the first genetically engineered plant introduced new traits like herbicide or pest resistance, which help to protect crop losses.

ii. Crop Improvement: The use of genetically engineered enhanced the quality, yield and resistance to biotic and abiotic stress of crops contributing to global food security.

iii. Reduced Chemical Inputs: When certain diseases and pest resistances were incorporated in plants it automatically decreases the need of chemical pesticides, ultimately reducing the cost of pesticides.

iv. Environment Benefits: Few genetically engineered plants were used for nitrogen fixation, phytoremediation, helping in environment conservation.

v. Precision Breeding Techniques: Genetically engineered plants facilitate precision breeding by allowing for the targeted introduction or modification of specific genes to achieve desired changes and output.

L. Introduction of Marker-Assisted Selection: Introduced in late 20^{th} century (1980s onwards).

Scope Marker Assisted Selection:

i. Efficient Trait Introgression: MAS contribute in the introgression of particular traits from wild or unadopted germplasm into elite varieties, helping in countering the challenges like of abiotic stress tolerance or disease resistance.

ii. Combining Multiple Traits: With the help of MAS breeders can select multiple traits according to their interest or need enabling the development of new varieties with desired traits and features.

iii. Preservation of Desirable Traits: With the help of MAS during the breeding processes several tarits can be preserved thus preventing the loss of important characteristics.

M. Emergence of CRISPR-Cas9 Technology: Introduced in early 21^{st} century (2012).

Scope of CRISPR-Cas Techniques:

This technique had a deep impact on various fields. It is been extensively used in genetic research enabling precise genome editing in a wide range of organisms. In medicine it helps in treating genetic disorders and developing therapies. In agriculture, this technique led to improved crop yields, disease resistance and nutritional content.

1.3 Important Achievements:

India's important achievements in plant breeding programs are:

- Present day crop has mainly arrived through plant breeding of wild weed varieties by humans initiated through naturally domestication practices.
- Sometimes due to extent of breeding the cultivated plants become quite different from original wild variety. Few examples of extensive plant breeding in India are - Semi-dwarf wheat and rice-
- First developed by N.E. Borlaug at CIMMYT (international center for wheat and maize improvement), Mexico.
- They used the dwarfing gene of a Japanese variety Norin 10.
- In India major wheat varieties grown today are semi-dwarf varieties.
- Semi-dwarf varieties were first introduced in 1963 in India.
- Major examples of these semi-dwarf varieties are Kalyan Sona and Sonalika.
- These semi-dwarf varieties are resistant to diseases like rust, photosensitive. The photo insensitivity has enabled farmers to grow such crops in non-traditional areas also, e.g. west Bengal.
- Dwarfing genes are Rht1 and Rht2.These are mainly dwarfing genes but their side effect can increase the yield of crop plants.
- Similarly, photoperiod sensitive genes are Ppd1 and Ppd2, which when present together give low yields. But when present singly i.e. either Ppd1 alone or Ppd2 alone give better yield due to photo insensitivity.
- So, the best combination which due to plant breeding a semi-dwarf variety of wheat has been – Rht1 + Ppd1 or Ppd2 and Rht2 + Ppd1 or Ppd2.
- Semi-dwarf rice varieties have been developed from Dee-geo-woo-gen variety of dwarf and early maturing Japonica rice from Taiwan.
- First semi-dwarf rice varieties introduced in India in 1966 were Taichung Native 1 (TN 1), developed in Taiwan and IR 8, developed by International Rice Research Institute, Philippines.

- Now even these varieties have been replaced by even more superior semi-dwarf rice varieties developed in India itself like Jaya, Ratna, etc.
- These varies in comparison to wild varieties are lodging resistant, more fertilizer responsive, high yielding and photo insensitive.
- photo insensitivity has again enabled us to grow rice in non-traditional states like Punjab. Semi-dwarf rice variety Semi-dwarf wheat variety

1.3.1 Sugarcane Improvement:

- *Saccharum barberi* (Indian sugarcane) had hard stem but poor yield and low sugar content and could only grow in North India, while Saccharum officinarum (noble sugarcane) were having high sugar content but couldn't be grown in north India.
- C.A. Barber and T.S. Venkatraman at sugarcane breeding institute, Coimbatore took out genes for desired characters like thicker stem and high sugar content from noble cane i.e. Saccharum officinarum and introduced them into Indian cane i.e. *Saccharum barberi*. This is called Noblisation of Indian cane.
- Today, the sugarcane breeding in whole world is done by noblisation technique. Sugarcane (Saccharum officinarum L.)

1.3.2 Hybrid Millets (Maize, Jowar and Bajra Hybrids):

- Hybrid maize development programme was launched in India in 1957 in collaboration with Rockfeller and Ford Foundations.
- In 1961 they released four successful hybrid varieties of maize.
- After that several hybrid Hybrid Millets (maize, jowar and bajra hybrids)- varieties were developed which became popular in few states like Karnataka.
- Popularity was limited in other states because farmers had to replace their seeds every year as these hybrid varieties were double crossed hybrids. So, composite varieties were developed, e.g., Manjari, Vikram, Sona, Kisan, CO 1, Renuka, etc.
- Current emphasis is on development of single crossed varieties of maize, like, Vivek Maize hybrid 9, Malviya Hybrid Makka 2, Vivek QPM 9, etc.
- Some hybrid varieties of maize: Deccan Hybrid Makka, DHM 101, Varun, DHM 103, DHM 107, DHM etc. developed by IIMR, Hyderabad
- These hybrid maizes give 40% more yield than local open-pollinated (not controlled pollinated) varieties.
- Programmes for development of hybrid jowar(sorghum) and bajra (pearl millet) was started in 1961 and their first hybrid varieties were introduced in 1962.
- First hybrid sorghum was CSH 1 and first hybrid pearl millet was HB 1.
- Today India has several hybrid varieties of these crops as follows- sorghum- CHS (2,3,4,5,6,9,10,11, etc), Pearl millet - PHB 10, PHB 14, BJ 104, BK 560, etc.

1.3.3 Hybrid Cottons:

- Cotton accounts for 85% of raw material for textile industries in India. ICAR in 1967 Launched All India Co-ordinated Cotton Improvement Project, establishing headquarters at Coimbatore (Tamil Nadu)

- ICAR also established Central Institute for Cotton research at Nagpur and two regional stations at Coimbatore and Sirsa (Haryana) for multidisciplinary research on Cotton
- Laxmi, Jalandhar, Suvin, MCU5, Bikaneri Nerma Savitri, Jayalaxmi etc. are some important cotton varieties.
- First hybrid cotton variety was H4 which was developed in 1970 by Gujarat Agriculture University from two *G. hirsutum* strains.
- G- cot. Dh-7 and G- cot. Dh-9 are recently released varieties. Recently, cytoplasmic male sterility (CMS) is being used to produce hybrid cotton varieties. But hand pollination and hand emasculation are essential for CMS hybrids.

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