Quadrant II – Transcript and Related Materials

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Unit: Introduction to plant breeding

Module Name: Important achievements and undesirable consequences of plant breeding.

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Notes:

Plant breeding is the art and science of genetic improvement of crops for the benefit of mankind. Its main focus is on global food security and fight against hunger.

Development of plant breeding:

Plant breeding activity has been carried out since ancient times (approx. 9000-11000 yrs. ago) when humans started undertaking settled farming. At the end of the nineteenth century, with the rediscovery of Mendel's work on hybridization, scientific basis was firmly established in plant breeding. Modern plant breeding involves different fields like genetics, biotechnology, molecular biology, microbiology, plant pathology, agronomy, horticulture, biostatistics etc.

Important achievements of plant breeding:

- Improvement in crop yield
- Improvement in quality of crops.
- Semi dwarf varieties of wheat and rice.
- Hybrid varieties of millets.
- Nobilization of sugarcane.
- Hybrid cotton.
- Transgenic varieties.
- Molecular breeding.

Improvement in crop yield:
In mid-20 the century with the beginning of the green revolution, the world saw a progressive increase in yield of the all major crops. Major crops like wheat, rice and maize showed almost two fold increase from 1961 to 2009.

Improvement in quality of crops:
Significant achievements have been made in improving various qualities of crop plants.
Examples:

- Sugarcane & sugar beet varieties: with high sugar content.
- Cotton varieties: with high yield, quality cotton fiber and disease resistance.
- Oil seed crops: with high oil content.
- Fruits & vegetable varieties: with attractive features and good keeping quality.
- Early maturing crop varieties:
- Resistant crop varieties to various biotic and abiotic stresses:

Semi dwarf wheat varieties:
These varieties were developed by N.E. Borlaug and his co-workers at CIMMYT (International center of wheat and maize improvement) Mexico.
They used a Japanese variety Norin 10 as the source of dwarfing gene (carrying Norin gene for dwarfing). Dwarfing genes Rht1, Rht2 or both together when incorporated in wheat plant.
Semi dwarf varieties are also photoperiod insensitive due to genes Ppd1 or Ppd2
Best combination :
Rht1 + Ppd1 or Ppd2
Rht2 + Ppd1 or Ppd2
Rht gene encode DELLA domain proteins that repress transcription of gibberellins responsive genes.

Qualities of semi dwarf wheat varieties:

- High yielding: atleast 15% more than tall isogenic lines.
- Harvest index (HI): higher than tall varieties.
- Photo-insensitive:
- Resistant: to rusts and other major diseases.
- Lodging resistant: shorter and stronger straw.
- Fertilizer responsive:
- Suitable for late planting.

In India:

In 1963, ICAR obtained these varieties from Mexico and introduced in India.

Kalyan Sona and Sonalika were selected from these varieties. A great majority of semi dwarf varieties now grown in India are semi dwarf.

These varieties are high yielding, photo-insensitive (grow under short as well as long day conditions), resistant to rusts and other major diseases, have shorter and stronger straw, capable of responding to the heavy fertilizer application and suitable for late planting.

Semi dwarf varieties of Rice:

The development of semi dwarf rice varieties has revolutionized rice cultivation.

These varieties were derived from Dee-geo-woo gen, a dwarf early maturing variety of japonica rice from Taiwan.

Taichung Native 1 (TN 1) developed in Taiwan and IR 8, developed at IRRI (International Rice Research Institute) Philippines, was introduced in India in 1966.

Later these varieties were replaced by superior semi dwarf varieties developed in India for e.g., Jaya, Ratna etc.

These varieties are:

i. Lodging resistant
ii. Fertilizer responsive
iii. High yielding and
iv. Photo insensitive.

The development of semi-dwarf varieties of wheat and rice has revolutionized rice and wheat collection. This has greatly increased and stabilized their production in country. The photosensitivity of these varieties enabled their cultivation in non-traditional areas like West Bengal (cultivation of wheat) and Punjab (cultivation of rice).

Hybrid millets:

Hybrid varieties were produced in number of crops for e.g., maize, Jowar (sorghum), and bajra (pearl millet).

Maize:

Programme to develop hybrid maize began in India in 1957 in collaboration with Rockefeller and Ford foundations.

Subsequently many hybrids mainly double cross hybrids were developed.

Composite varieties like Manjari, Vikram, Sona, CO1, NLD, Renuka were developed which gave same yield as hybrid varieties and farmers did not have to replace their seed every year.
Current emphasis has been to produce single cross hybrids like Vivek maize hybrid 9, Vivek QPM 9 etc.
Development of hybrid sorghum and bajra varieties began in 1961.
First hybrid varieties CSH1 in sorghum and HB1 in Bajra were released in 1964.
Since then several varieties have been released

In Jowar:

CSH2, CSH3, CSH4, CSH5, CSH6, CSH9, CSH10, CSH11 etc.

IN Bajra:

PHB10, PHB14, BJ104, and Bk560 etc.

Nobilisation of sugarcane:

Another noteworthy achievement is nobilisation of sugarcane.
Indian canes were of Saccharum barberi origin.
They were largely grown in North India.
They were hardy but poor in yield and sugar content.
The tropical noble canes were of Saccharum officinarum origin.
They had thicker stem and higher sugar content but were not hardy.
They performed badly in north India mainly due to low temperature in this region.
C.A Barber, T.S Venkataraman and others at sugarcane breeding institute, Coimbatore transferred the thicker stem, higher sugar content and other desirable characters from noble to the Indian canes. This is commonly referred as nobilisation of Indian canes.
They also crossed Saccharum spontaneum a wild species to transfer disease resistance and other desirable characteristics to the cultivated varieties.
Several high yielding varieties with high sugar content and good adaptation to local climate have resulted from this breeding program. At present sugarcane breeding all over the world is based on nobilisation technique.

Hybrid Cotton:

India has achieved the distinction of commercially exploiting heterosis in cotton.
In 1970 first hybrid variety of cotton H4 was developed by crossing two Gossipium hirsutum strains by Gujarat Agriculture University.
Since then several hybrid varieties are developed.

Examples:

JK Hy1, Godavary, Sugana, H6 and AkH468, Savitri, Jayalaxmi,, CBS 156 and H_2HC.

The hybrid varieties are high yielding
Have high ginning outturn
Have good fiber quality.
According to estimate they occupied about 70% of total area under irrigated cotton in 1885-86.
Also efforts are ongoing to utilize cytoplasmic male sterility (CMS)for hybrid seed production.
Recently 2 hybrid varieties of desi cotton viz., G-Cot. Dh-7 and G-Cot.Dh-9 were released.

Transgenic varieties:

Recombinant DNA technology or transgene technology is the most powerful tool for creating crops with novel desired phenotypes or designer crops.
Transgenic traits with novel traits have been developed in several crops.
In India, insect resistant Bt-cotton hybrids are being cultivated since 2002.
In 2009 more than 131 different varieties of Bt-cotton hybrids were used for planting in nearly 8.4million hectors.
Recently an indigenous insect resistant Bt-cotton variety called Bikaneri Narma and a hybrid NH-4 has been released.
It is noteworthy that till 2003-04 India was importer on cotton but now ahs become exporter of same.
Indigenously developed insect resistant Bt-Brinjal is under consideration for approval of its commercial cultivation.

Molecular Breeding:

Molecular breeding utilizes molecular biology techniques to achieve plant breeding objectives.
Marker assisted selection (MAS) enable dependable indirect selection for desirable genes using highly reproducible DNA markers.

Examples of varieties developed through MAS:

Improved Pusa Basmati 1 & Improved Sambha Mahsuri , bacterial leaf blight resistant rice varieties.
Swarna sub -1: submergence tolerant rice variety.
Vivek QPM-9: improved protein quality maize variety.

Undesirable consequences of plant breeding:

Genetic erosion:

In general improvement in performance of crop species is accompanied with a reduction in variability among their cultivated varieties.

2 potent factors responsible for this reduction are:

Replacement of numerous heterogenous local varieties by few more homogenous improved varieties

Use of similar/related varieties as parents in breeding programmes.

Improved varieties are commonly purelines (self-pollinated),or hybrids(cross pollinated) which are much more homogenous than the unimproved local and open-pollinated varieties.

A few varieties become more dominant and rapidly replace the heterogenous local varieties leading to depletion of genetic variability what we call as genetic erosion

This in turn limits the prospects of further improvement in crop species since variability is the prerequisite for any modification in their characteristics.

Thus successful crop improvement has depleted the very basic resource that is so essential for its continuing success.

Germplasm collections aim at minimizing the detrimental effects of genetic erosion by collecting and preserving the variability in crops and their related species.

Narrow genetic base:

Genetic base can be defined as the genetic variability present among the cultivated varieties of a crop species.

Improves varieties of a crop species are becoming increasingly similar to each other due to commonness of one or more parents in their ancestry .

This has led to the narrowing down of the genetic base of these varieties.

Example:

Many semi dwarf varieties of rice developed in 70's and 80's had IR-8 or TN1 as their parents. These both were developed from common parent Dee-Woo-gen, the source of their semi dwarfing gene.

Similarly almost all semi dwarf varieties have Rht1 or Rht2 or both the genes for reduced height. These genes are derived from single variety i.e. Norin -10

The narrow genetic base has created genetic vulnerability which refers to susceptibility of most of the cultivated varieties of a crop species to a disease, insect pest or some other stress due to a similarity in their genotypes.

Example:

Outbreak in epidemic proportions of southern leaf blight of maize in 1970 in USA. This occurred due to extreme susceptibility of most of the commercial hybrids to a new race, T-race of the leaf blight pathogen *Helmintosporium maydis.*

Increased susceptibility to minor diseases

Focus of plant breeding programme is mainly on developing varieties for resistance to major diseases and insect pests.

This has resulted in an increased susceptibility to minor diseases. In some cases they have produced severe epidemics.

Example:

Epidemic caused by Botrytis cinera(grey mold) in chickpea during 1980-81 and 1981-82 crop seasons in Punjab, Haryana, parts of U.P and Bihar.

This problem is difficult to overcome since resource constraints may never permit a breeder to screen his material against all the diseases and pests of a crop species.

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Yield Plateau:

Sooner or later ,the variability for yield in a crop species is exhausted and no further yield increases are obtained through breeding. i.e. yield reaches a plateau.

Such plateau was evident in wheat and rice yields before the exploitation of semi dwarfing genes and are being experienced ones again.

In such cases new variability has to be introduced in the breeding populations in order to break the plateau.

There is increasing evidence that wild relatives of cultivated species may provide yield genes for breaking yield plateau.

In some cases novel breeding approach may be useful in raising crop yields beyond the plateau.

Conclusion:

There is no doubt that Plant breeding has done lot of positive things specially increasing crop productivity exponentially and saving millions of lives from hunger.

But current 7.6 billion people on this planet is estimated to increase to about 10 billion by 2050.

The current rate of annual yield improvement for major crops ranges between 0.8 and 1.2%, which must be doubled in order to meet the highly increased future demand.

To achieve these sustainable, new approaches must be developed to boost crops productivity otherwise global food security will be severely compromised in the next two to three decades.