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Basics of MAGIC (Multi-parent Advanced Generation Intercrosses) Population Development

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Breeding of the crop plants is the most promising method for getting a combination of novel and desirable characters all in a single plant. From the early stage of agriculture conventional breeding has played an important role to identify prominent varieties and germplasms with novel characters and develop high yielding varieties with better agronomic traits. But with time environment has also changed. Environmental stress due to its biotic and abiotic factors has become a major concern for today's breeders. So to overcome such situations scientists have developed different molecular biology tools to assist and enhance the breeding process and reduce time to get the ultimate yield and other desirable agronomic traits. In this article we have discussed how the modern plant breeders use molecular biology tools along with the concepts of conventional breeding to produce a diverse population (maintaining the genetic diversity) like MAGIC.

MAGIC are a collection of RILs produced from a complex cross or outbred population involving several parental lines. Parental lines may be inbreed lines, clones or individuals selected on the basis of their origin or use. Basically MAGIC populations are the extention of advanced inbreed lines. MAGIC concept was first used in mice to develop a 'heterogeneous stock' and later was used in the crop breeding programs.

MAGIC populations present novel challenges and opportunities in crop breeding due to their complex pedigree structure. They offer great potential both for dissecting genomic structure and for improving breeding populations.

Four steps are involved in MAGIC population development

1. Founder selection

1. Based on genetic or phenotypic diversity, either in a constrained set of material (e.g., elite cultivars, geographical adaptation) or material of more diverse origins (worldwide germplasm collections, distant relatives).
2. Use of landraces as founders may introduce greater diversity, but simultaneously reduce the generalizability to the current breeding populations.
3. Variety-specific gross chromosomal differences such as rearrangements or alien or wild introgressions may also affect the production of the final population and its use for genetic mapping.
4. Narrow genetic diversity can be problematic for estimating founder probabilities and prevent researchers from fully exploiting the potential of their populations.
5. Ultimately the selection of the founders is one of the most important steps and depends heavily on the goals of the breeder. More diverse founder sets may provide biological insight into a wide variety of traits.
6. Founders selected based on relevance to a breeding program for specific traits may result in a MAGIC population which more quickly translates into superior breeding lines.

2. Mixing:

1. Multiple parents are intercrossed to form a broad genetic base.
2. The inbred founders are paired off and inter-mated, known as funnel.
3. In this stage we get such lines whose genome is contributed by each of the founders.

3. Advanced Intercrossing:

1. Mixed lines from different funnels are randomly and sequentially intercrossed as in the

advanced intercross.

2. Main goal is to increase the number of recombinations.

3. At least six cycles of intercrosses are required for constructing a good QTL map.

4. Inbreeding:-

1. Development of homozygous individuals.

2. RILs produced through single seed descent (SSD) or double haploid production.

3. Albeit doubled haploid production is often faster, multiple generations of selfing introduces additional recombinations which are although lesser than produced during the mixing and advanced intercrossing stages.

4. The progeny of the population will not be fully inbred in practice except for double haploid lines. This residual heterozygosity can both be useful and problematic.

5. In genotyping, it may cause issues due to the inability to distinguish heterozygotes for some markers, particularly for polyploids and 'genotyping by sequencing (GBS)' approaches.

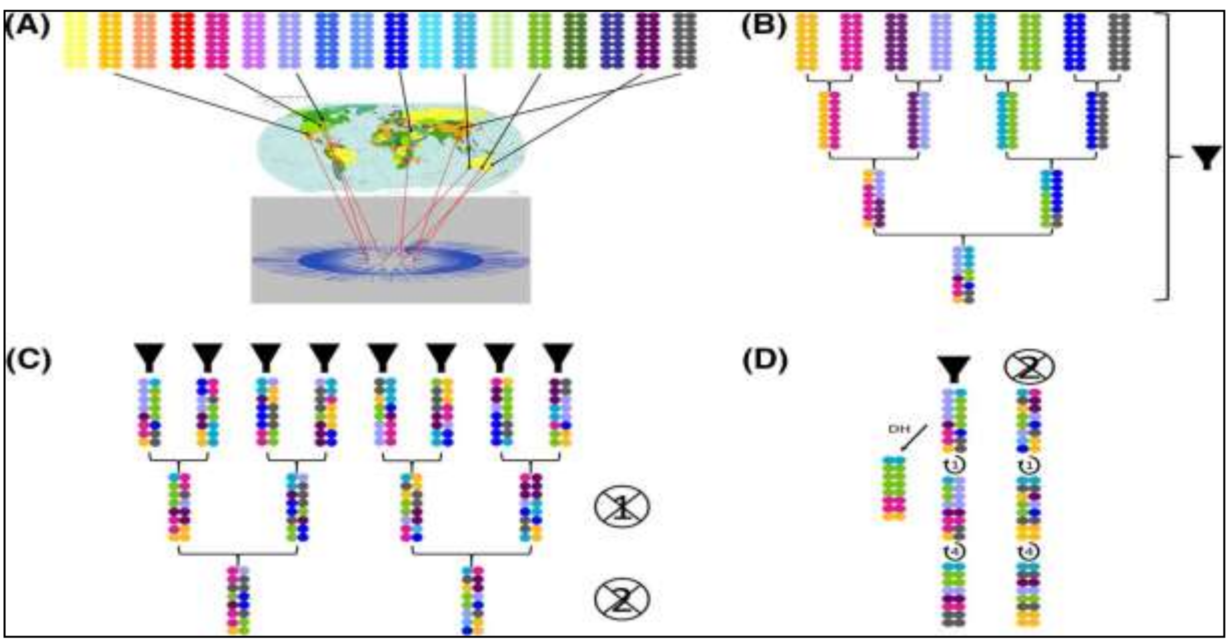

Fig. 1. Stages of MAGIC population development design for eight founders.

A. selection of founders based on geographic, genetic, phenotypic diversity. The maternal pedigree tree is presented at the bottom for an eight-way MAGIC population with each ring representing a subsequent generation; **B.** mixing of parents together in predefined patterns, or funnels (denoted by symbol on right); **C.** intercrossing of individuals (generations denoted by number within crossed circle) derived from different funnels for additional generations; **D.** Selfing (generations denoted by number within circular arrow) or double haploidization of individuals either directly from funnels or after advanced intercrossing to form inbred lines.

❖ Use of MAGIC in crop breeding :

1. Development of variety with several agronomically beneficial traits.

2. Variety which can adapt to several diverse regions of the world and suitable for diverse climatic conditions.

3. MAGIC populations may be used directly as a source material for the extraction and development of breeding lines and varieties.

4. MAGIC can provide to a range of production constraints (Biotic and abiotic)

5. It can help to create a novel diversity.

6. It is a powerful method to increase the precision of genetic markers linked to the quantitative trait loci (QTL) for fine-mapping of multiple QTLs for multiple traits in the same population.

❖ Advantage of MAGIC :

1. MAGIC populations can capture the majority of variation present in a given gene pool.

2. Shuffling the genes across different parents enables accurate ordering of the genes.

3. Increased recombination.

4. Best combination of the genes for important trait development.

5. Facilitates the discovery, identification and manipulation of new forms of diversity.

6. MAGIC populations can be directly used as a commercial variety.

❖ Disadvantages of MAGIC :

1. Extensive segregation

2. Takes more time

3. Necessity of large scale phenotyping
4. Incompatibility between the parents
5. Requirement of better marker systems to identify QTLs.

Comparisn between biparental population association mapping and MAGIC

	Bi-parental population	**Association**	**MAGIC**
Founder parents	2	100	8
Crossing requirement	Yes	No	Yes
Stability for fine mapping	No	Yes	Yes
Require time	Moderate	Low	Long
Stability foe course mapping	Yes	No	Yes
Population size	~200	~100	~1000
Amount of genotyping required	Low	High	High
Amount of phenotyping required	Low	High	High
Practical utility	Low	High	High
Use of germplasm variation	Low	High	High

Development of MAGIC population for rice improvement

A) **B)**

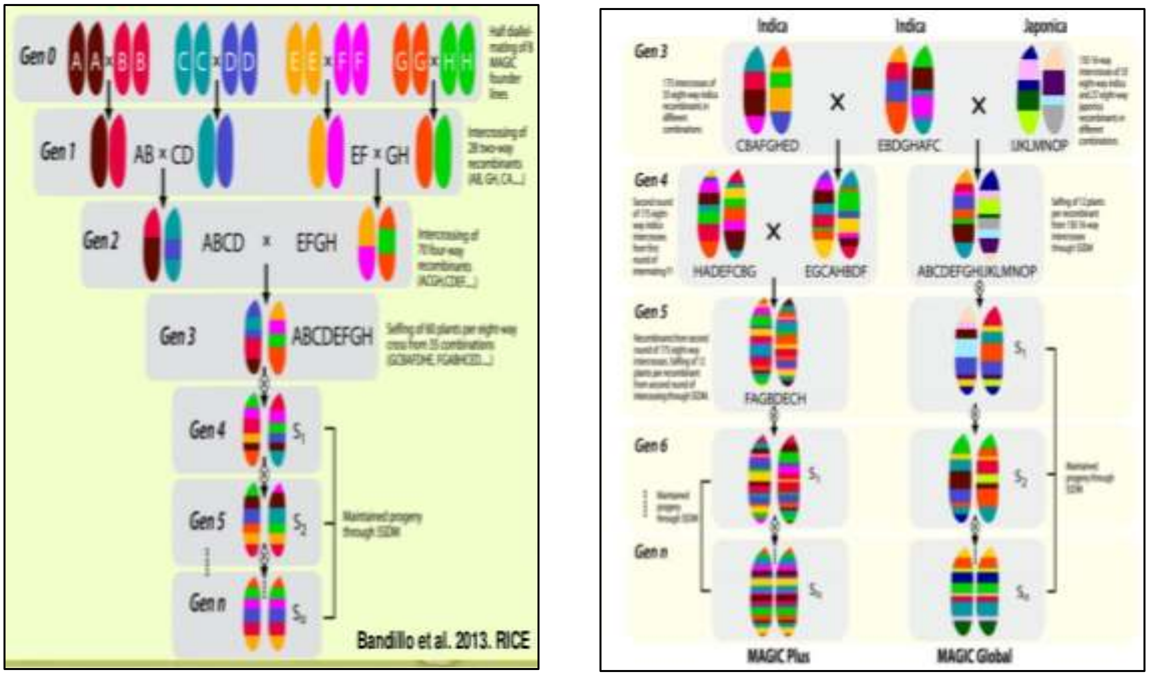

Fig:2 Rice MAGIC population; A. Developmen of MAGIC population for indica

B. Development of MAGIC-Plus and MAGIC Global Populations

Indica MAGIC and MAGIC PLUS populations are derived from eight indica parents and intercrossed for zero and two generations respectively. The indica MAGIC population having 60 plants from each of 35 funnels generated a population of 2100 RILs. The MAGIC PLUS population has the same first mixing stage, but produces 12 lines from each of the 175 crosses in the second AI stage, generating the same-sized population. The other two populations incorporate japonica lines, which are the subtypes to which the reference sequence (cultivar Nipponbare) belongs. The japonica MAGIC population is also produced in the same manner as the indica MAGIC population is produced, while the Global 16-parent MAGIC eight-way lines are produced from the indica MAGIC and japonica MAGIC prior to inbreeding via production of RILs. The rice MAGIC populations developed to get the Rice MAGIC lines are phenotyped, presenting new challenges for dissection of complex traits such as yield, drought tolerance and quantitative disease resistance. Over 1000 lines have been extracted from different MAGIC populations by IRRI breeders and are being tested in the market for use in breeding programs. High-yielding lines with favorable agronomic traits have been identified. Rice breeders consider the MAGIC lines a good pre-breeding material with huge diversity, which they can be further used for breeding against any type of biotic and abiotic stresses.

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