

Ideotype Breeding: An Approach for Crop Improvement

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Abstract

A change in environment poses a thrust to the plant breeders to develop new varieties/cultivars that are well adapted to the global climatic conditions. Ideotype breeding, an alternative to conventional breeding focuses majorly this aspect by combining yield, morphological and the physiological traits that can withstand these situations. These ideotypes are weak competitors individually but not in a population making it feasible to use at commercial level. Ideotype breeding involves various steps in a systematic way such as developing a model plant, selection of source(s), incorporation of desired traits into one plant and selection of plants with an ideal combination of traits. But characteristics of the ideotype may vary with changing climate and demands. It can be considered as one of the efficient methods of breaking yield barriers, finding solutions and developing cultivars required for a specific environment. As this is a slow, tedious and a continuous process, usage of recent advances in technology may help the breeders in developing ideotypes early than before. Success in developing a specific ideotype is difficult thus making this technique as a supplement to conventional breeding rather than a substitute.

Keywords: Ideotype breeding, Ideotype, conventional breeding

I. INTRODUCTION

Ideotype: Ideotype/Crop ideotype defines a model plant that is expected to yield high as a cultivar for suitable for a particular environment. The term ideotype was first proposed by Donald in the year 1968 while working on wheat.

Ideotype Breeding: A method used to strengthen the yield potential of the crop through manipulation of its genetic character.

Characteristics of ideotype(s):

- It should be a weak competitor
- It is a moving goal as it changes with changing time.

- Includes the physiological and morphological characteristics that result in high harvest index.
- Efficient in utilizing the environmental resources.

Features of Ideotype breeding:

- Focus on individual traits mainly yield
- Selection
- Designing of the model
- Exploitation of physiological variation
- Slow, continuous and an interdisciplinary approach.
 - In ideotype breeding, emphasis is laid on each morphological and physiological trait that increases the yield.
 - The value of each trait and its correlation with other traits is observed before initiating the breeding work. The positively associated traits with yield are included in the model.
 - It makes use of genetically entrapped physiological variation.
 - It is a slow, continuous and a long term method of cultivar development because of the incorporation of required traits from different sources into a single genotype. Sometimes undesirable linkage affects the progress adversely.
 - It is an interdisciplinary approach as scientists from the various branches like genetics, breeding, physiology, pathology, entomology etc will also play a role.

II. STEPS IN IDEOTYPE BREEDING

The major step(s) involved in ideotype breeding include:

- **Development of Conceptual Model** - specified morphological and physiological traits are considered to develop a conceptual theoretical model and attempts are made to attain this.
- **Selection of Base Material** – this step follows the first step where genotypes having broad genetic base, wider adaptability, tolerant to drought, salinity, alkalinity, pests and diseases need to be considered.
- **Incorporation of Desirable Traits** – possible through various breeding procedures like single cross, three way cross, multiple cross, backcross, composite crossing, intermating, mutation breeding, heterosis breeding etc.
- **Selection of Ideal Plant Type** – genotypes having prudent traits are selected in segregating populations and are intermated to attain the desired plant type and then they are examined [morphologically by visual observation(s), physiologically for physiological parameters with the help of instrument(s) and screening for resistance to drought, soil salinity, alkalinity, disease and pests under controlled condition(s)].



Factors Affecting Ideotypes

- **Crop species:** Ideotype differs from crop to crop and species to species. Eg: Monocot(s) model vary from those of dicot(s) where tillering and branching are important respectively (Peng *et al.*, 2008).
- **Cultivation:** Ideotype of a crop changes with regard to its cultivation i.e., irrigated crops differ from that of rainfed. The rainfed crop needs drought resistance, fewer and smaller leaves and indeterminate types whereas these are not the priority for irrigated conditions.
- **Socio-economic Condition & economic use of Farmers:** Varies from region to region depending on the financial situation of farmers. Eg: In USA, dwarf Sorghum is ideal for mechanical harvesting whereas in Africa stalks are used for constructing huts or for fuel. Dwarf types are useful in Sorghum and pearl millet for grain purpose whereas for fodder, tall stature is desirable (Saidaiyah *et al.*, 2008).

III. IDENTIFICATION OF TRAITS FOR ANALYSIS

There are different traits of crop plants that control the yield and growth of the plant which includes (Austin, 1993).

- (1) Morphological and anatomical traits
- (2) Compositional traits
- (3) Process rate and process control traits

- 1. Morphological and Anatomical Traits:** These are mostly used by the breeders as they are easy to identify, measure and are highly heritable
- 2. Compositional Traits:** These traits change with environment and age and they mostly cover the concentration of specific biochemicals in plants tissues (levels of proline, ABA etc.).

- 3. Process Rate and Process Control Traits:** Process rate traits limit the growth and yield of the plant whereas process control traits limit photosynthesis. These traits are sensitive to environments, because of which careful standardization is necessary in order to get relevant genetic comparisons.

Examples of trait analysis (Austin, 1993)

Crop	Traits considered
Cotton	Drought tolerance
Groundnut	Yield components
Maize	Early flowering, cold tolerance
Soybean	Maturity, height, lodging
Sugarbeet	Tap root, shoot ratio
Wheat	Ears/m ² , drought-induced ABA accumulation, plant height.

IV. IDEOTYPES OF VARIOUS CROPS

An ideotype varies from crop to crop and within the crop too, depending on its requirement. The important features of some crop models are:

Wheat: The term ideotype was given by Donald in 1968 while working on wheat. The main features of his ideotype are as follows:

- A short and a strong stem - provides lodging resistance.
- Erect leaves - provide proper light distribution i.e., high photosynthesis.
- Few small leaves - less transpiration and more CO₂ fixation.
- Larger & erect ear - more grains per ear and proper grain development.
- Awns – provides protection and also helps in photosynthesis.
- A single culm.

Rice: It was introduced by Jennings in 1964 which includes

- Dwarf or Semi dwarf stature
- High tillering
- Short and erect leaves
- More panicles/m²
- High harvest index (55% more).

Maize: Mock and Pearce proposed ideal plant type for maize, in 1975 with the following features.

- Vertical leaves above the ear with high photosynthetic efficiency.
- Efficient translocation of photosynthate(s) into the grain(s).
- Short time period between silk emergence and pollen shedding.
- Small size of tassel.
- Insensitivity to photoperiod
- Cold tolerance

Barley: Rasmusson (1987) suggested the ideotype of six rowed barley which includes,

- Short stature
- Long awns
- High biomass and harvest index

Cotton: For irrigated cultivation

- Short heighted (90-120 cm)
- Compact and sympodial growth habit with determinate fruiting.
- Short duration (150-165 days)
- Response to fertilizers
- Resistance to insect pests and diseases
- For rainfed conditions (Singh, 1998)
- Earliness (150-165 days)
- Few small and thick leaves
- Compact, short stature & indeterminate habit
- Sparse hairiness
- Medium to large size bolls with synchronous boll formation
- Good response to nutrient(s).
- Resistance to pests and disease(s).

Classification/Types of ideotype(s): The concept of types of ideotypes was proposed by Donald and Hamblin in 1976 with special reference to Cereals. It includes:

- **Isolation ideotype:** it performs best when the plants are spaced planted rather than dense planting. For cereals, the isolation ideotype can help to spread much and tiller high.
- **Competition ideotype:** this performs well in segregation generations and varietal mixtures planted at crop densities. For cereals, this ideotype is tall and free tillering.
- **Crop or communal ideotype:** this ideotype is a poor competitor but, is highly competitive even though they are surrounded by the plants of their own type. Its performance is high in commercial crop densities.

V. MERITS AND DEMERITS

Merits of ideotype breeding:

- Develops cultivars required for a particular environment.
- Exploits both the morphological and physiological traits.
- Involves experts from various disciplines like plant breeding, physiology, biochemistry, entomology, plant pathology and others.
- Effective method of breaking yield barriers.

Limitations of ideotype breeding:

- Difficult to recognize a single trait that controls yield in a limited genetic and environmental situation.
- Requires information on complex topics involving genes, traits and environment.
- Require new methodologies, techniques and instruments.
- Transfer of traits from gene pool is necessary which is difficult.
- Slow and a tedious method.
- May narrow the genetic diversity within the crop which leads to increased susceptibility of the crop.

VI. PRACTICAL TRIUMPH

Ideotype breeding has significantly contributed in enhancing the yields of cereal(s) (wheat and rice) and millet(s) (Sorghum and pearl millet) than the other crops using the dwarf genes, resulting in green revolution. Eg: The CGMS systems in Sorghum and pearl millet, semidwarf varieties of wheat and rice, Norin 10 in wheat, Dee-geo-Woo-gen in rice.

REFERENCES

- [1] R.B. Austin. Augmenting yield based selection. *Plant Breeding, Principles and prospects*, 1993, pp 391-405.
- [2] P. Singh, A. K. Singh and A. Singh. Breeding of crop ideotypes, *Plant Breeding and Cultivar Development*, Academic Press. 2021. pp 497-516. <https://doi.org/10.1016/B978-0-12-817563-7.00021-0>.
- [3] M. Donald. The breeding of crop ideotypes. *Euphytica*. 1968. 17: 385-403.
- [4] C.M. Donald and J. Hamblin. The convergent evolution of annual seed crops in agriculture. *Adv. Agron.* 1983. 36: 97-143.
- [5] P.R. Jennings. Plant type as a rice breeding objective. *Crop Sci.* 1964. 4: 13-15.
- [6] J.J. Mock and R.B. Pearce. An ideotype of maize. *Euphytica*. 1975. 24: 613-623.
- [7] S. Peng, G.S. Khush, P. Virk, Q. Tang and Y. Zou. Progress in ideotype breeding to increase rice yield potential. *Field Crops Res.* 2008. 108: 32-38.
- [8] D.C. Rasmusson. An evaluation of ideotype breeding. *Crop Sci.* 1987. 27: 1140-1146.
- [9] P. Saidaiah, E. Satyanarayana and S. S. Kumar. Association path coefficient analysis in maize (*Zea mays* L.). *Agric. Sci.* 2008. 2: 79-83.
- [10] P. Singh. *Cotton Breeding*. Kalyani Publishers, New Delhi. 1998.