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# Philosophy of Plant Breeding: Ideotype Breeding

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**Abstract**

The philosophy of conventional plant breeding approach is to select for yield which bases selection on yield without giving consideration to how and why yield is achieved. The ideotype concept has been developed and modified for a number of different crops. It is concluded that ideotypes are a useful tool for visualizing and conceptualizing how to combine specific rare combinations of visible and invisible traits, aimed at the maximization of Harvest Index, even when the traits are only weakly related.

Most breeding programs uses grain yield as the main selection criterium to improve the agronomic performance of crop varieties. An alternative approach to improve productivity is the ideotype breeding. According to this philosophy, breeders should define an ideal plant type for a specific environment and then breed for this ideotype. Breeding through crop ideotypes is positive in terms of integrating principies of physiology, ecology and plant breeding, encoraging the generation of hypothesis about how yield is achieved and providing a holistic view about production systems.

**Keywords:** Ideotype breeding; Plant breeding; Criterium

## Introduction

In a more general sense, DONALD described an Ideotype as a biological model that is anticipated to function or behave predictably in a specific setting. Breeding with specific breeding goals for each attribute is known as "Ideotype breeding," which aims to increase genetic yield potential through individual trait modification.

Donald was the first to propose the idea of ideotype breeding (1968). According to Chahal and Gosal (2002), an ideotype is a hypothetical plant frame or architecture that is represented by characters that may effectively utilize the resources at hand in order to maximize economic yield. In this instance, selection is solely determined by yield components (Smith, 1987; Singh, 2002).

The genetic expression of various qualities and the degree and pattern of their interaction with grain yield typically fluctuate with changes in the environment, therefore the attractiveness of a trait may be environment specific and a common ideotype may not fit all situations. As mentioned above, variations in stress severity may make certain features more important for grain output than others.

In general, morphological, physiological, biochemical, anatomical, phenological, or their combinations are the traits to be taken into account in the ideotype breeding method (Singh, 2002). Although the idea of ideotype breeding is appealing in and of itself, it has proven challenging to characterize the "model" components for the intended environment since several genotypes may produce the same yield through various paths leading to the yield component (Gemechu K, 2017) [1].

Grain yield is typically the primary selection criterion used in breeding operations to enhance crop varieties' agronomic performance. Ideotype breeding is an alternate strategy for increasing output. This school of thought holds that breeders ought to identify the optimum plant type for a given environment before selecting plants that fit this Ideotype. Crop Ideotype breeding promotes the integration of physiology, ecology, and plant breeding principles; it also fosters the development of theories regarding the attainment of yield and offers a comprehensive perspective on production systems. However, there are drawbacks to stereotype breeding as well. These include the challenge of pinpointing specific features that increase yield consistently, the lack of sufficient genetic diversity for traits that may enhance yield, and the requirement to select for multiple characters at once rather than just yield, which expands the size of the segregating population that must be assessed. Ideotype breeding has yielded significant benefits, but they have been conceptual and analytical in nature rather than immediately manifesting as increases in yield [2].

The ability to select for features relevant to yield has allowed for improvements in yield over time, which is one advantage of adopting the ideotype technique to breed new kinds. The creation of semi-dwarf wheat types (REITZ and SALMON, 1968) and short-stature, erect Leal rice cultivars (JENNINGS, 1964) are arguably the best-known instances of that. AUSTIN et al. (1980), HAMID et al. (1978), TAKEDA and FRY (1985), and SHARMA (1993) have also identified increases in harvest index, biomass output, and yield components as the fundamental causes of the rise in yield of various crops. Additionally, the United States' range of adoption and productivity of these commodities have been greatly impacted by changed maturity in soybeans and decreased height in sorghum (RASMUSSON, 1987).

Single traits can result in grain yield either directly or indirectly. The breeder of Ideotype acquires genetic variety for qualities that are thought to be crucial for yield. Without a significant effort to achieve diversity and combine the features in a single plant, it may not be possible to find the perfect character combination for optimal production [3].

The ideotype breeding may provide an effective way of bridging the gap between elite gene pools and unimproved germplasm collections. In the traditional breeding procedures, breeders almost always work with elite materiais, because this decreases the amount of time, money and effort necessary to produce a new variety. So, the objective of this

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article is to review the Ideotype of plant breeding.

## Ideotype of plant breeding

Ideotype breeding aimed at modifying the plant architecture is a time tested strategy to achieve increases in yield potential. A tried-and-true method for increasing yield potential is ideotype breeding, which modifies the plant architecture. Selection for short-statured grains, like sorghum, rice, and wheat, doubled the potential yield. The harvest index (HI) and total dry matter or biomass influence yield potential. For example, the total biomass of tall and traditional rice was around 12 tons per hectare, and the HI was approximately 0.3. They may thus produce up to 4 tons per hectare at most. According to the (Shalimar Campus, Srinagar (J&K) 2015), applying nitrogenous fertilizers could not improve their biomass.

The plants grew excessively tall, lodged improperly, and produced less rather than more. Improving the harvest index and nitrogen responsiveness by raising the lodging resistance is required to raise the production potential of crops. This was achieved by introducing a recessive gene for small stature, which decreased the height of the plant [4].

A new sort of plant was conceived in order to further boost the crop's potential production. Particularly when grown under direct sowing conditions, modern semi-dwarf plants generate a lot of ineffective tillers and an excessive amount of leaf area, which diminish canopy photosynthesis and sink size and induce mutual shade. The method of Ideotype breeding will be used to solve this.

The goal of plant breeding is to enhance a plant's qualities to make it more agronomically and commercially acceptable. The particular goals may differ significantly based on the crop being studied.

- **Higher yield:** Enhancing the yield of commercially viable product is the ultimate goal of plant breeding. Depending on the crop species, it could be the yield of grains, fodder, fiber, tubers, cane, or oil. Either hybrids or high yielding types can be evolved to increase yield.

- **Improved quality:** Another major goal in plant breeding is produce quality. The characteristics of quality differ amongst crops. For instance, the size, color, milling, and backing quality of wheat grains. Rice cooking quality, barley malting quality, fruit size, color, and quality, vegetable nutrition and preservation quality, pulse protein content, oilseed oil content, cotton fiber length, strength, and fineness [5].

- **Abiotic resistance:** Abiotic elements that affect crop plants include drought, salinity in the soil, high temperatures, wind, cold, and frost. To prepare for these conditions, breeders must create kinds of crops that are resistant to these stresses.

- **Biotic resistance:** Crop plants are attacked by various diseases and insects, resulting in considerable yield losses. Genetic resistance is the cheapest and the best method of minimizing such losses. Resistant varieties are developed through the use of resistant donor parents available in the gene pool.

- **Change in maturity duration/earliness:** Earliness is the most desirable character which has several advantages. It requires less crop management period, less insecticidal sprays, permits new crop rotations and often extends the crop area.

- **Elimination of toxic substances:** It is essential to develop varieties free from toxic compounds in some crops to make them safe for human consumption. For example, removal of neurotoxin in Khesari (Lathyruys sativus) which leads to paralysis of lower limbs, erucic acid from Brassica which is harmful for human health and gossypol from the seed of cotton is necessary to make them fit for human consumption. Removal of such toxic substances would increase the nutritional value of these crops.

- **Photo insensitivity:** The creation of temperature-and light-insensitive cultivars aids in extending crop plant cultivation boundaries. Wheat and rice may now be grown in new places thanks to photo-and thermosensitive cultivars. Punjab now grows rice, whereas West Bengal's main rabi crop is wheat (Figure 1).

## The conceptual dimensions of ideotypes

Since they represent the optimal gene combination (or QTL) to produce and achieve the desired phenotypes, ideals, which were initially established by and for plant breeders, contain a certain genetic component. But this genetic perspective was soon superseded by an agronomic one as Ideotype began to be seen as the plant component of a cropping system. Since stereotypes can only be defined in reference to a production aim, they also have a particular socio-economic component. This is particularly true in terms of its acceptability; it is hard to envision the ideal plant kind in the event that farmers reject it [6].

Lastly, Ideotype are essentially digital depictions of plants that were conceived before they were real. Consequently, they are conceptual models that are based on sets of decision rules that enable one to select which qualities to assemble and how best to combine them; they may or may not be mathematically codified (Andrivon C. 2012).

## Features of ideotype breeding

Plant type breeding, also known as genotype breeding, is a technique for improving crops that involves genetically modifying specific plant features to increase yield potential. Each character is selected to contribute to a higher economic output.

## Emphasis on selection of individual trait

Ideotype breeding emphasizes selection on the unique characteristics of each plant, increasing yields. Additionally, focus is placed on each individual's morphological and physiological characteristics that improve yield. Prior to starting the breeding process, each character's value is set.

## Includes yield enhancing traits

Through correlation analysis, several plant features that should be

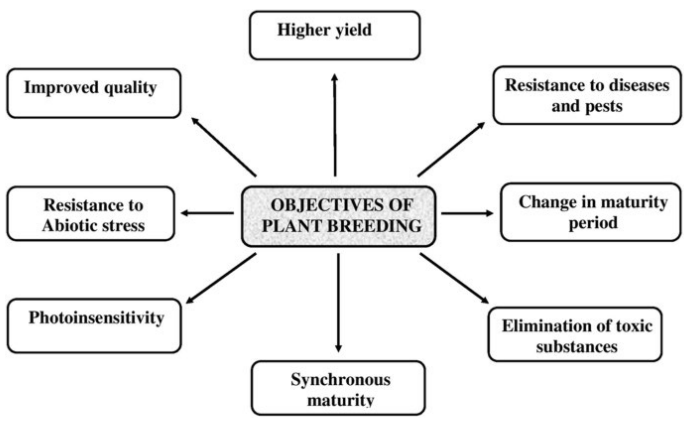


**Figure 1:** Objectives of plant breeding. Source: Anderson E, 1956.

included in the Ideotype are found. The characters in the model are limited to those that show a positive correlation with yield.

## Exploits physiological variation

There are genetic differences for a number of physiological traits, including photosynthetic efficiency, nutrition uptake, photorespiration, etc. In addition to different agronomic variables, genotype-controlled physiological variation is used in genotype breeding to increase crop yields.

## Slow progress

Ideotype breeding is a sluggish approach of developing cultivars because it takes a long time to incorporate diverse desired traits from different sources into a single genotype. Furthermore, unfavorable linkages might occasionally have a negative impact on progress.

## Designing of model

The phenotypes of a new variety to be generated in ideal breed breeding are predetermined in terms of physical and physiological features. Numerous interrelated biochemical, morphological, and physiological processes that occur at various temporal and spatial scales at the crop level are what lead to crop growth and development (Martre et al., 2015).

With the introduction of the super hybrid rice variety "Lianyoupeijuu," the idea of plant type or Ideotype breeding was first applied to rice as the first instance of model-aided ideotype design and, ultimately, the first successful implementation of ideotype breeding. It is not unexpected that irrigated rice was the first crop to use the ideotype design as ideotyping is simpler and easier in this situation than in rain-fed agriculture conditions (Semenov et al., 2014) [7].

## Interdisciplinary approach

In the past, crop modelers have worked with agronomists, breeders, and geneticists on a variety of cereal crops to develop various methods for (i) more accurately forecasting a cultivar's performance in a given environment and/or (ii) crop ideotyping to support the development of new cultivars that are better suited to target environmental conditions (Martre et al., 2015).

In actuality, stereotype breeding is an interdisciplinary field of study. Scientists from the fields of pathology, entomology, physiology, etc. are involved.

## A continuous process

The process of developing new ideologies to satisfy ever-changing and rising wants is what makes stereotype breeding a constant endeavor. Ideotype development is therefore a dynamic goal. In contrast to conventional breeding, which works toward achieving a model, idealistic breeding specifies values for individual attributes; in traditional breeding, these values are not fixed. These models are not created prior to the start of breeding programs in traditional breeding. Ideotype breeding and traditional breeding differ in a number of ways (Table 1).

## Steps in ideotype breeding

**Development of conceptual ideotype model:** Ideotype consists of various morphological and physiological traits. In order to create a conceptual theoretical model, the values of many morphological and physiological traits are given. For instance, values are given for plant height, maturity period, number and size of leaves, leaf angle, photosynthetic rate, etc. After that, attempts are made to realize this model http://agriinfo.in 2121.

**Selection of base material:** Once the conceptual model of the prototype has been developed, choosing the base material is a crucial next step. According to Blixt and Vose (1984), the genotype used to create a model plant type should have a broad genetic foundation and greater flexibility. This will enable the new plant type to be successfully grown in a variety of environmental conditions while maintaining a consistent yield. Plant stature, leaf size, angles, and maturity time genotypes are chosen from the worldwide gene pool of the relevant crop species. With the assistance of physiologists, soil scientists, pathologists, and entomologists, genotypes resistant or tolerant to drought, soil salinity, alkalinity, disease, and insects are chosen from the gene pool [8].

**Incorporation of desirable traits:** Combining distinct morphological and physiological features from several genotypes that have been chosen into a single genotype is a crucial next step. Before beginning a hybridization program, understanding the relationships between different characters is crucial as it facilitates the blending of different personalities. For example, the majority of field crops use linkage between processes such as single cross, three way cross, multiple cross, backcross, composite crossing, etc. to generate perfect plant kinds.

**Selection of ideal plant type:** To create the desired plant type, plants with a combination of desirable morphological and physiological qualities are chosen from a segregating population and interbred. Visual observation is used to evaluate morphological traits, and advanced technologies are used to capture physiological information. Under controlled conditions, resistance to disease, insects, salinity, alkalinity, and drought is screened for. Scientists from the fields of pathology, entomology, soil science, and physiology assist in the completion of this assignment. Lastly, genotypes that combine the features listed in the conceptual model are chosen, multiplied, evaluated across many sites, and made available for commercial production http://agriinfo.in/defaultpage.

**Use of ideotype breeding:** Plant and canopy structures are effective tools to control inoculum production, dispersion, and/or

**Table 1:** Differentiation of traditional breeding and ideotype breeding.

| No | Traditional Breeding | Ideotype Breeding |
|---|---|---|
| 1 | The main objective is defined before initiating the breeding work. | The conceptual model is prepared before initiation of breeding work. |
| 2 | Selection is focused on yield and some other character. | Selection is focused on individual plant characters. |
| 3 | It usually includes various morphological and economic characters. | It includes various morphological, physiological, and biochemical plant characters. |
| 4 | Value of each character is not fixed in advance | Value of each trait is defined in advance. |
| 5 | This is simple and rapid method of cultivar development. | This is difficult and slow method of cultivar development. |
| 6 | The phenotype of a new variety is not specified in advance. | Phenotype of new variety to be developed is specified in advance. |

efficacy, at least in some pathosystems (Tivoli et al. 2012). This helps to impede the spread of epidemics. Additionally, it may alter an organ's susceptibility to an infection, favor mechanisms that help an organ escape an infection, or improve tolerance (Ney et al. 2012). Although there is a significant genetic component to architecture (Bendokas et al. 2012), aspects of the agricultural production system can also be used to control it (Simon et al. 2012). This allows for the design and construction of plants or canopies that reduce the ability for one or more pests to spread, at least theoretically.

**Features of crop ideotype:** A crop ideotype is a plant model, which is expected to perform or yield a greater quantity or quality of grain, oil or other useful product when developed as a cultivar, model plant type, ideal model plant type (Ronaldo Vigo,2014).

A number of morphological and physiological characteristics make up the crop ideotype, which contributes to a yield that is higher than that of currently popular crop varieties. Crop Ideotype's physical and physiological characteristics are necessary for rainfed or irrigated farming. The ideal plant, regardless of whether irrigation or rain-fed cultivation calls for the Ideotype. Model plants or ideal plant types have been discussed for a number of crops, including cotton, beans, maize, barley, wheat, and rice.

## Wheat

Donald first used the term "Ideotype" in 1968 while working on wheat with a short, robust stem. It lessens hotel-related losses and imparts resistance to lodging. Erect leaves: these leaves are better arranged to distribute light properly, which increases photosynthesis or CO2 fixation. A few little leaves are the key components of respiration, transpiration, and photosynthesis. Tiny and sparse decrease transpiration related water loss. It will yield more grains per ear if its ear is larger. Awns contribute towards photosynthesis.

Tillering is regarded as one of the key characteristics of the wheat flag type. A wheat plant with a long flag leaf sheath, a short ear extrusion with a long ear, a relatively high tillering capacity, and a moderately short but broad flag leaf should yield a yield per plant (Hsu and Watson, 1917). Wheat Ideotype was expanded by recent workers to include both physiological and morphological characteristics.

## Rice

Jennings developed the concept of plant Ideotype in rice breeding in 1964. Donald used the term "Ideotype" in 1968. He proposed that a semi-dwarf height is the first characteristic of an ideal or model rice plant. Jennings, 1964; Beachell and Jennings, 1965) Short, upright, thick, and sharply angled leaves; 2) High tillering capacity. Jennings' model also took morphological characteristics into account. Physiological characteristics are now prioritized in the development of the rice archetype.

## Maize

Mock and Pearce presented the optimal maize plant type in 1975. Higher yields of maize were produced by plants with the following characteristics: 1) large cobs, 2) low tillers, and 3) angled leaves for effective light interception. Higher yields were obtained by planting this type of seed at closer intervals.

## Barley

In addition to reviewing the research on Ideotype breeding, Rasmusson (1987) proposed the best plant type for six-row barley. He suggested that a combination of 1) Short stature, 2) Long awns, 3) High harvest index, and 4) High biomass can result in a better yield in barley. It was discovered that increasing the weight and quantity of kernels increased yield.

## Cotton

To increase output levels in cotton, genotypes with zero branches, compact plants, short stature, small leaves, and fewer sympodia were taken into consideration. Singh and colleagues (1974) suggested the appropriate plant species for the uplant cotton growing region. The suggested Ideotype has a short stature (between 90 and 120 cm). Compact and sympodial plant habit forming a pyramid; identify the fruiting habit using bolling distributed unimodally; Short lifespan (150-165 days), high fertilizer dose responsiveness, strong interplant competitiveness, high resilience to diseases and insect pests, and high physiological efficiency, An Ideotype of the two species mentioned above was proposed by Singh and Narayana (1993) for rainfed environments. The suggested Ideotype's primary characteristics are its early maturity (150-165 days), reduced number of small and thick leaves, compact and low stature, interminate habit, sparing hair, medium-large boll size, synchronous bolling, high nutrient response, and resilience to pests and diseases (2014/01/ideotype-breeding).

## Sorghum and pearl millet

Improvement in plant type has been achieved in Sorghum and Pearl millet through the use of dwarfing genes. In these crops dwarf F1 hybrids have been developed which have made combiner harvesting possible.

In a number of crop species, genetic advancements have been made through complete plant type alteration. For most crop plants, new genotypes have been proposed. In his 1972 list of ideal crop Ideotype qualities, Swaminathan specifically mentioned multiple cropping in the tropics and subtropics. Superior population performance, high daily productivity, low photorespiration, high photosynthetic ability, high sensitivity to light and temperature, high reaction to nutrients, high productivity per unit of water, and numerous resistances to diseases and pests are some of these characteristics, ideotype-breeding.

## Merits and demerits of ideotype breeding

**Merits of Ideotype breeding:** Ideotype breeding is an efficient method for increasing yield by manipulating different physiological and morphological traits of crops. As a result, it makes use of a variety of physiological and morphological features that are described, each of which adds to increased production. Experts in the fields of physiology, biochemistry, entomology, plant pathology, and plant breeding are involved. Every specialist makes a contribution to the creation of model plants for characteristics associated with his profession (https://agriinfo.in/merits-and-demerits-of-ideotype-breeding-2096/).

Ideotype is an efficient technique of breaking yield barriers through the use of genetically controlled physiological variation for various characters contributing towards higher yield. It also provides solution to several problems at a time like disease, insect and lodging resistance, drought tolerant, maturity duration, yield and quality by combining desirable genes for these traits from different sources into a single genotype. It is efficient method of developing cultivars for specific or environment thttp://agriinfo.in/default.aspx?page=topic&superid.

**Demerits:** It is challenging to combine multiple desirable physiological, anatomical, and disease-resistant features from various sources into a single genotype. Sometimes there is a strong correlation between desirable and unpleasant characters, making it impossible to combine certain characters. The development of stereotype breeding is impeded by the existence of such linkage.

Ideotype breeding, which improves yield and one or two additional qualities, is a sluggish way of cultivar creation because it takes longer to combine multiple morphological and physiological features from different sources. Conventional or traditional breeding methods cannot be replaced by stereotype breeding. It is an addition to the earlier https //agriinfo.in/merits-and-demerits-of-ideotype-breeding-2096/.

Ideotype is a moving object which changes with change in knowledge, new requirements, national policy, etc [9]. Thus new Ideotype have to evolved to meet the changing and increasing demands of economic products http://agriinfo.in/default.aspx.

## Summary and Conclusion

The majority of plant breeding is focused on yield selection or defect eradication. Crop Ideotype plants having model traits known to affect photosynthesis, growth, and grain in cereal production are bred, offering a useful supplementary strategy. There are a few examples of this type of model character being used successfully again.

Numerous harvests have led to the development and modification of the Ideotype idea. The conclusion is that, even in cases when the qualities are only tangentially related, Ideotype can be a helpful tool for conceiving and visualizing how to combine particular, uncommon combinations of visible and unseen features in order to maximize Harvest Index. A crop Ideotype will use the fewest resources possible for each unit of dry matter generated.

Further, in cereals, each unit of dry matter will include such a number of florets as to ensure that the ear has sufficient capacity to accept all photosynthates either from its own green surfaces or from other parts of the plant. A wheat Ideotype is described. It has a short, strong stem; few, small, erect leaves; a large ear this specifically means many florets per unit of dry matter of the tops; an erect ear; awns; and a single culm. Ideotype breeding exploits various morphological and physiological traits are specified and each character or trait contributes towards enhanced yield but it has its own draw back Incorporation of different sources into a single genotype is a difficult task.

It is concluded that ideotypes are a useful tool for visualizing and conceptualizing how to combine specific rare combinations of visible and invisible traits, aimed at the maximization of Harvest Index, even when the traits are only weakly related.

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