VANTAGENS E LIMITAÇÕES DA UTILIZAÇÃO DE IDEOTIPOS NO MELHORAMENTO DE PLANTAS DE LAVOURA

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RESUMO – A maioria dos programas de melhoramento tem utilizado o rendimento de grãos como o principal critério de seleção para melhorar a performance das principais espécies cultivadas. Um método alternativo para incrementar a produtividade das culturas é o melhoramento através de ideotipos. De acordo com esta filosofia, os melhoristas deveriam definir um fenótipo ideal de planta para um determinado ambiente e direcionar o programa de melhoramento para obter este ideotipo. O melhoramento através de ideotipos é positivo em termos de integrar princípios de fisiologia, ecologia e melhoramento, estimulando a geração de hipóteses sobre a definição do rendimento de grãos, e promovendo uma visão holística sobre os sistemas de produção. O desenvolvimento de ideotipos também apresenta alguns problemas, tais como a dificuldade de identificação de caracteres individuais que incrementem o rendimento, a falta de variabilidade genética para características importantes ao incremento do rendimento e a necessidade de selecionar simultaneamente diversos caracteres em substituição ao rendimento de grãos, aumentando o tamanho das populações segregantes a serem avaliadas. Os maiores benefícios do melhoramento através de ideotipos tem sido mais expressos a nível conceptual e analítico do que através de incrementos imediatos no rendimento de grãos.

Palavras-chave: modelo biológico, melhoramento vegetal, rendimento, grão

ADVANTAGES AND LIMITATIONS OF USING IDEOTYPES TO BREED CROP PLANTS

ABSTRACT – 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 principles of physiology, ecology and plant breeding, encoraging the generation of hypothesis about how yield is achieved and providing a holistic view about production systems. Ideotype breeding also presents some problems, such as the difficulty of identifying individual traits that enhance yield universally, abscence of adequate genetic variability for potentially yield enhancing traits and the need to select simultaneously for many characters rather than just for yield, increasing the size of the segregating population to evaluate. The major benefits of ideotype breeding have been expressed at a conceptual and analytical level rather than in immediate direct yield improvements.

Key words: biologic model, plant breeding, grain yield

INTRODUCTION

Increasing grain yield has been regarded by many breeders as the most important and high priority objective over the years (CROSBIE, 1982). There are two ways commercial yield can be increased: (a) directly, by increasing yield potential per se above that of standard varieties in the same environment; (b) indirectly, by improving the extent to which the yield potential of a crop is realized in practice.

In order to accomplish the objective of improving grain yield, plant breeders have developed a wide range of techniques, such as mutation breeding, polyploidy, the exploitation of hybrid vigor, embryo culture, advanced statistical design and analysis, and more recently, the utilization of molecular markers to identify and manipulate potentially useful genes. Even though the scope of techniques used is rather broad, there have been mainly two philosophies behind the breeding programs designed to improve production of new varieties. They were defined by DONALD (1968) and MOCK and PEARCE (1975) as "selection for yield" and "defect elimination".

Plant breeding programs based on "selection for yield" focus mainly on improvement of yield per se. Little consideration is usually given to understanding

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the morphological or physiological traits contributing to increased yield in a particular environment, or to selection for those specific characters that may have helped to improve yield. Such programs usually involve hybridization among promising parents (high yielding elite varieties with good combining ability for yield), the production of segregating populations and the selection of high yielding individuals from the segregates. This type of breeding has been successful over the years, probably because final yield is an integration of several desired traits. The amount of success has depended on several factors such as the availability of a wide range of improved materials in the program, the choice of the crosses to be made, and the skillful evaluation of the emergent genotypes. Since in many cases the breeders do not know exactly why the new variety yields better than its predecessors, the methodology has also been called by DONALD (1968) and HAMBLIN (1993) as "the empirical approach".

Defects can be eliminated genetically by removing or overcoming biotic or abiotic constraints on crop production. "Defect elimination" is adopted, for instance, when disease resistance is bred into a susceptible genotype or when earliness is incorporated into a variety prone to water stress late in the season, or to correct physical imperfections such as a weak stem. Breeding programs based on "defect elimination" have also contributed to substantial increases in crop yield and quality in a great array of circumstances.

An alternative approach for improving grain yield was proposed by DONALD (1968). According to his philosophy, instead of breeding only for grain yield per se, breeders should try to define an ideal plant type for a specific environment and then breed for this "ideotype". The basis of this philosophy is that, from known principles of physiology, morphology, anatomy and agronomy, it should be possible to design a plant that is capable of greater production than the existing types in a community environment Such a model plant is likely to involve a combination of traits that will rarely, if ever, occur by any chance in breeder's plots.

According to the ideotype approach, it is more efficient to define a plant type which is theoretically efficient and then breed toward this profile. Breeders would select directly for the ideotype, rather than use the empirical approach of breeding only for yield. They would, of course, continue to test ideotype material for yield potential. Therefore, inherent in the ideotype approach is the aim to reduce the amount of empiricism in plant breeding by using a more deliberate analytical method and thus increase efficiency in the use of resources and time in selection of improved materials.

The purpose of this review is to present the main concepts related to ideotype breeding and to discuss the major advantages and constraints of this breeding philosophy as an alternative to improve the agronomic performance of current crop varieties.

DEVELOPMENT

1. Ideotype definitions:

Literally speaking, the word ideotype means " a form denoting an idea". Since it was originally proposed for biological models, it has been defined in different ways. In its broader sense, DONALD (1968) characterized an ideotype as " a biological model which is expected to perform or behave in a predictable manner within a defined environment". LOOMIS (1979), LOOMIS and COONOR (1992), characterized an ideotype as a model of an ideal phenotype where the word ideal embraces both morphological and physiological features of the phenotype that would suit a particular cropping system. Alternatively, RASMUSSON (1991) defined ideotype breeding as a method of breeding designed to enhance genetic yield potential based on modifying individual traits where the breeding goal for each trait is specified. Therefore, it is the goal-setting and description of a model plant for traits of interest that separates ideotype from traditional breeding. A traditional breeder seeks to enhance genetic yield potential by selecting for yield per se, and by modifying individual traits such as plant height, maturity and kernel number. Yield selection has always been a part of traditional yield breeding. However, in ideotype breeding, goals are specified for each trait, resulting in a description of a model plant for the traits of interest (RASMUSSON, 1987).

2. Basic premises and steps to observe in ideotype breeding:

A basic premise of the ideotype breeding approach is that yield potential can be enhanced by genetically altering morphological, physiological and phenological traits (RASMUSSON, 1991). In other words, it is assumed that single yield traits can be manipulated genetically and ultimately assembled in a single genotype. Once this is accepted, the challenge is to find the traits to modify and to specify the optimum phenotypic expression for these traits.

According to MOCK and PEARCE (1975), ideotype breeding involves three fundamental points: defining a crop production environment; designing a plant model from morphological and physiological traits known to influence crop growth in that environment; and combining the traits into one plant type.

In analyzing the first essential aspect of ideotype breeding, DONALD (1968) suggested that the designer of any model phenotype should initially seek the simplest environmental situation, and, further, one that can be readily defined. Generally speaking, this would be the situation where the factors needed for growth and development, particularly water and nutrients, approach maximal needs. The idea would be to first define a basic ideotype designed to give maximum production in a highly favorable or idealized environment. After such an ideotype is developed, then the effect of any restriction of resources, like a decrease in nutrient and water supply, could be further examined in terms of progressive modifications of the basic ideotype. Sometimes, the production of a crop ideotype may call for the creation of a new environment. Therefore, model building do not need to be associated exclusively with existing environments. Indeed, they may involve the concurrent design of a new environment, including man-made components such as crop density, planting arrangement and nutrient level.

According to RASMUSSON (1987), at least three steps should be observed in order to address the other two essential issues pointed out by MOCK and PEARCE (1975):

- First, decisions should be made about traits that should be part of the ideotype breeding effort and a phenotypic goal for each trait should be specified. During this step, one should gather information about the role of the individual trait in determining yield; develop a hypothesis about the role and importance of the trait, and then make the decision about whether to proceed with a breeding effort toward its incorporation into a segregating population. Identifying worthy traits for an ideotype is a major challenge. It is important to take into account the physiological and morphological basis for expecting the trait to influence yield, as well as genetic aspects such as heritability and inheritance of the character (RASMUSSON, 1991).
- Secondly, there should be sufficient genetic variability to justify a breeding effort. It is also important that diversity be available in improved germplasm. However, sometimes the desired genes exist only in genetically inferior stocks. In those cases, yield gains may be precluded , unless a sizable breeding effort to introgress the genes into an acceptable genetic background is carried out.
- thirdly, the plant breeder should be willing to conduct several cycles of breeding as well as to try the trait in question in different genetic backgrounds and possibly under different cultural practices. This attitude is crucial to increase the likelihood that the trait will contribute to higher yield.

3. Potential benefits of using the ideotype approach to breed new varieties:

DONALD'S (1968) paper has stimulated a lot of discussion among breeders about the utility of his ideas, and among physiologists, agronomists and breeders about what characters might be important to production. Since it was introduced, the ideotype concept has had variable impact in plant breeding. It has received great support from several researchers, such as JENNINGS (1964), MOCK and PEARCE (1975), ADAMS (1982), KELLY and ADAMS (1987), RICHARDS (1991), RASMUSSON (1991), THURLING (1991) and others. Some of the arguments that have been used to encourage the adoption of an ideotype breeding approach are:

a) yield has been improved over the years by selecting for yield related traits. Probably the best known examples of that are provided by the development of semi-dwarf varieties of wheat (REITZ and SALMON, 1968) and short stature, erect leaf cultivars of rice (JENNINGS, 1964). Increases in yield components, harvest index and biomass production have also been reported by AUSTIN et al. (1980), HAMID et al. (1978), TAKEDA and FRY (1985) and SHARMA (1993) as being the underlying basis for the increase in yield of several crops. Also, altered maturity in soybean and reduced height in *sorghum* have influenced significantly the range of adoption and productivity of these crops in the United States (RASMUSSON, 1987).

b) grain yield is the product , directly or indirectly, of single traits. The ideotype breeder obtains genetic diversity for traits that are hypothesized to be important to yield. Without a substantial effort to obtain diversity and to assemble the traits in one plant, the ideal combination of characters for maximum yield could be precluded altogether. DONALD (1968) pointed out that "selection for yield is unlikely ever to approach the asymptote of yield, since the appropriate combination of characters, never being sought, can be attained only by attrition or chance". According to Donald's ideas, selection for yield has all the immediate advantages and the longer term limitations of a wholly pragmatic procedure. Therefore, seeking and incorporating genetic diversity for traits the breeder thinks are potentially yield enhancing may be an investment in the present as well as in the future.

c) 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 materials, because this decreases the amount of time, money and effort necessary to produce a new variety. The improved pools are usually the product of decades of effort and numerous cycles of breeding. In many cases, the genes controlling specific traits desired in the ideotype may not be present in elite cultivars. Therefore, introgression of genes controlling single-yield related traits from one pool to the other is a way of bridging the gap between improved and unimproved germplasm collections. In summary, the idea is that ideotype breeding can complement traditional breeding for yield providing genetic diversity obtained from little-used gene pools.

d) the ideotype approach may encourage generation of hypotheses regarding how yield is achieved. It can stimulate thinking about goals in the breeding program that should ultimately lead to a more effective breeding strategy. Even though ideotype models do not produce immediately useful commercial materials, they can provide new basis for the understanding of crop ecology and for the design of progressively more efficient models.

4. Potential constraints to the use of the ideotype approach as a breeding tool to develop new cultivars:

Despite of theoretical advantages and considerable interest and debate generated amongst crop agronomists, physiologists and breeders, the development of model plants and ideotypes has not been adopted as a major breeding philosophy in most commercial programs (CROSBIE, 1982). Indeed, the approach has been criticized by several authors, such as Mc DONALD (1990), MARSHALL (1991), and SIMMONDS (1991). There are a number of practical difficulties and disadvantages which may have contributed to prevent a greater acceptance and use of the concept of breeding model plants. These limitations may be separated in two main classes: (a) conceptual or philosophical problems associated with the approach, which lead breeders to question the validity of the ideotype concepts; (b) practical difficulties associated with the implementation of this breeding philosophy.

4.1 *Conceptual problems:*

4.1.1 The definition of a single optimum genotype/phenotype:

DONALD (1968,1979), when describing the basic ideas surrounding ideotype breeding, implied that there would be a single optimal phenotype, and, in the case of self-pollinated species, a single genotype, for a given climatic or agricultural region. This concept has been criticized by MARSHALL (1991) on the basis of results coming from population genetic studies of natural populations, showing that they are highly variable genetically, regardless of the breeding system or life-form of the species under consideration (ALLARD, 1988). Marshall's hypothesis is that if a single optimal genotype almost never emerges in natural populations after thousands of years of evolution, it would be unlikely that such individuals exist. Furthermore, since different genotypes will be maintained in equilibrium populations only if they are equally fit, the genetic diversity found in natural population suggests that highly fit individuals may take many forms, according to the fluctuations of the environment.

On the other hand, HAMBLIN (1993) argued that the idea of a single optimal phenotype requirement is a misreading of Donald's original proposition. The real suggestion was that "for a defined environment there is likely to be a single optimal phenotype", which will involve plants that fit well within a community. The fact that Donald specified a single optimum environment did not mean he was unaware of the problems of fluctuating, variable environments. In reality, ideotypes should not be considered as fixed. Even in one location, in non stress environments, they may vary with farming systems or market needs (SEDGELY, 1991; BELFORD and SEDGELY, 1991). Ideotypes should change as the increase in understanding of how plant characters relate to crop yield. Breeders should not expect that simple models will be the final word on a topic or that one model will serve all the purposes in different environments. Models should be seen as hypothesis generating, as they allow the rational development and testing of ideas on how to improve varieties in a fluctuating environment.

4.1.2 Identification of yield enhancing traits:

Identifying individual traits that enhance yield universally, or even in a limited range of environments, is a difficult task. The frustrations expressed by SIMMONDS (1991) and MARSHALL (1991) with crop physiology for failing to identify yield enhancing traits are not entirely without merit. Several reasons for that can be pointed out, such as : poorly conceived fads (e.g. proline for osmotic adjustment and NO_3 reductase for enhanced N assimilation), overemphasis of reductive research relative to integrative research, too little progress with bad models, and failure to turn physiological knowledge into simple screens.

Even for the simple, well studied, qualitative traits, such as the presence or absence of awns in winter cereals, it has been difficult to establish that the particular character is unambiguously advantageous to improve grain yield. This difficulty is greatly enhanced for quantitatively varying traits such as: leaf-length, width, thickness, specific weight and angle. An integration between physiologists and breeders is important to circumvent this barrier and to search new plant traits which can be used to improve grain yield.

4.1.3 Quantification of self-competition:

The measurement or assessment of the degree of self competition among individual plants in genetically homogeneous populations has been considered a third conceptual difficulty with ideotype breeding. DONALD (1968) reasoned that for a monotypic community to be high yielding under high plant population production environments the individual plants making it up should be weak competitors, meaning that they should interfere with each other to a minimum degree. In other words, these plants should be able to adjust themselves to a competition environment without altering substantially their pattern of growth and development. However, DONALD (1968) provided no clear evidence about how genotypes with low competitive abilities against themselves were to be identified or selected from segregating populations (MARSHALL, 1991). An additional criticism is that there appears to have been little effort by physiologists and agronomists to develop procedures for the evaluation of self-competition effects on monotypic monocultures that could be used to select among a range of genotypes, all of them meeting the requirements of being low self-competitive ideotypes.

Alternatively, HAMBLIN (1993) suggested two ways to measure low competitive ability within a variety. The breeder could either identify characteristics that are universally related to low competitive ability, such as the uniculm habit in wheat and barley, or he could measure a genotype's competitive ability against other genotypes and assume that low competitive ability against other genotypes equates to relatively low competition within the genotype itself. An index to estimate interplant competiton was presented by MOOT and McNEIL (1995). It compared the plant of highest dry weight from a crop with the mean dry weight for plants of the same genotype sown at an specific plant population. However, HAMBLIN (1993) and MOOT and McNEIL (1995) also recognized that it is more difficult to measure the yield/competitive ability relationships for large numbers of random lines derived from segregating populations. The lack of practical quantifiable methods to select genotypes based on competitive ability explains partially the general reluctance of breeders to utilise this idea.

4.2 *Practical problems:*

4.2.1 Lack of suitable genetic diversity and pleiotropy:

One of the primary potential practical problems in developing ideotypes is a lack of the appropriate genetic diversity for the trait the breeder is interested in incorporating to his model plant. An example of that kind of situation was the effort to develop uniculm cultivars in the small-grained cereals. Naturally occurring uniculm mutants have been identified and isolated in barley and wheat (ATSMAN and JACOBS, 1977). Chemically induced uniculm variants have also been generated (KIRBY, 1973). Nonetheless, in all cases, the uniculm mutants showed deleterious pleiotropic effects which limited their utility in practice.

Enthusiasm of plant breeders tends to be great when they select for a trait that they believe enhances yield and that is controlled by a single gene. Unfortunately, there are several examples of traits in winter cereals that fit this description (e.g. uniculm, multiple awn, erect leaf angle) that have associated negative effects, likely the result of pleiotropy. An example of this situation was reported by TUNGLAND (1987) who found that an erect leaf angle gene in barley affected several traits, some of them in an undesirable way. For instance, erect leaf lines had erect spikes and less culm flex than horizontal counterparts. They were also later in maturity and had reduced head number. The expression of all these traits was probably influenced by pleiotropic effects of the gene which influenced developmental processes leading to the erect leaf trait.

The above example serves to emphasize the notion that potential yield promoting traits should be examined carefully for associated debilitating characters before beginning a breeding effort. Some seemingly attractive characters may be precluded from increasing productivity due to pleiotropy. In summary, breeders are unlikely to consider the development of ideotypes, regardless of the potential benefits they may offer, in the absence of adequate genetic variability. On the other hand, the development of molecular biology and particularly the utilization of molecular markers may be instrumental in helping breeders and physiologists to put together yield enhancing genes, to break undesirable linkages and to minimize negative pleiotropic effects.

4.2.2 Symmetry in size of plant parts:

An implicit assumption in the ideotype approach is that yield enhancing traits can be manipulated genetically and assembled into a single genotype. With that assumption in mind, some ideotypes have been proposed presenting a package of traits that may be very difficult to obtain or to combine in a single plant. A good example of that can be analyzed in the wheat ideotype presented by DONALD (1968). He proposed to develop a plant having small, narrow erect leaves and a large erect spike. Plants tend to have a high degree of proportionality of size among different organs which means that there are constraints on the form that a plant can take (GRAFIUS, 1978). Therefore, obtaining a large spike and small narrow leaves on a wheat plant may be difficult. That happens because this combination requires that the plant meristem, which produces both leaves and spike, switch from production of small leaves to production of a large spike.

The plasticity or ability to manipulate traits independently is inversely proportional to ontogenetic proximity. Consequently, traits arising nearly simultaneously from the same meristem tend to be more difficult to manipulate independently than characters arising at different times and from other meristems. Therefore, breeding efforts will be more likely to succeed where selection is in harmony with symmetry requirements than where there is a conflict or symmetry is neglected.

4.2.3 Compensation among plant parts:

Trait interrelationships including intraplant competition for a plant's growth resources often results in compensation among plant parts that may hinder breeding progress. In the beginning, breeders have thought primarily in terms of compensation at a higher organizational level, involving traits such as kernel number and kernel weight. However, MISLIN and RASMUSSON (1970) and JONES (1977) demonstrated that compensatory mechanisms are common even at the cellular or tissue level.

The most common situation of compensation is observed when an increase in one yield component is accompanied by a reduction in other components. For instance, in barley RASMUSSON and CROOKSTON (1977) observed that increase in head number did not result in enhanced yield because it was offset by reductions in both kernel number and kernel weight. Sometimes, compensation involves inter-related aspects of a single trait. An example of this was reported by JONES (1977) who found that low stomatal frequency did not reduce water use in barley presumably because of offsetting changes in stomatal size.

Knowledge of compensatory relationships may reduce expectations of gain with the ideotype approach.This could either limit the utilization of this breeding philosophy or lead to wiser decisions by the breeder when deciding whether or not to breed for a trait during selection (RASMUSSON, 1987). HAMBLIN (1993) has a more optimistic view about constraints to the ideotype breeding represented by inter-relationships among traits. He argues that they are caused by linkages among genes that control related traits, an area where breeders have been most successful in breaking unfavorable relationships between characters. So, except in the case of pleiotropic effects, HAMBLIN (1993) believes that if breeders have sufficient reason to break an unfavorable linkage between related traits they will do that.

4.2.4 Genetic background

The performance of a breeding line depends on the value of genes for traits that are selected and on genetic background that may contain unwanted genes. The negative impact of an unimproved genetic background is not limited to one specific breeding procedure but it may be particularly important in ideotype breeding because genetic diversity is often sought in unimproved gene pools. Genetic background will tend to be a growing problem as the performance level widens between the elite gene pool , with which the breeder works, and the unimproved germplasm of a particular crop.

Whenever the desired level of a trait is obtained from a poor genetic background, a great breeding effort will be necessary to free potentially useful genes so that the traits they control can contribute to yield. Concrete evidence of this problem was experienced by RASMUSSON (1984) when he tried to transfer erect leaf angle, an important trait for his barley ideotype, using as the donor parent an inferior genetic stock that yielded only 59% of the check. Five backcross cycles were required to obtain erect leaf angle lines that were similar in yield to the check cultivar. Therefore, some traits may be judged to be yield-negative, when they could be yield positive if placed in a genetic background free of deleterious associations.

4.2.5 The tyranny of numbers:

Another practical difficulty that can be associated with ideotype breeding is the substantial increase in the number of traits that must be selected by the breeder (MARSHALL, 1991). The need to select simultaneously for many characters can make plant breeding a difficult "numbers game" because for each additional trait controlled by a single gene difference, the size of the selected population must be substantially increased if the same progress for other criteria is to be maintained.

MARSHALL (1991) provided an interesting example to emphasize this point where two parental varieties differed by 20 loci governing traits of interest to the breeder were crossed. Assuming that all loci were independent, then less than one plant in a million will carry the desirable allele at each one of the 20 loci in the F2 of a cross between such parents. Marshall's take-home message is that breeders can select for only a very limited number of traits in any segregating population. Therefore, replacing one trait, yield, by 10-15 ideotype characteristics would simply make the breeder's task impossible.

Marshall's view that the ideotype approach would lead to a tyranny of numbers has not been a common sense in the scientific community. According to HAMBLIN (1993), regardless of the approach used, plant breeders have not been trying to get all the desired traits at once. Continued development toward a desired objective is the breeding norm. Breeders have built on current success, and improve upon it. An improvement in one character affecting production over an adapted, high yielding parent, is all that is needed for advance. In other words, the tyranny of numbers can be avoided or minimized in ideotype breeding by using parental material that includes high yielding, locally adapted cultivars. Obviously, the chances of producing high yielding genotypes, using only exotic sources, are small, even with the traditional breeding approaches. Still, in support of Hamblin's argument, LOOMIS (1993) stated that progress with quantitative traits in ideotype breeding need not lead to a tyranny of numbers because it depends more on understanding mechanisms and on clarity of goals than on simultaneous success with all criteria. In many cases, traits can be examined sequentially, providing the system is understood. Furthermore, sometimes multivariate analysis of subjective rankings may also help to reduce the tyranny of numbers as well as the number of physiological and morphological measurements required, as was observed by JOHNSON et al. (1988).

CONCLUSION

Considering all the effort verified in the 60's and 70's to utilize individual traits to increase grain yield of the main crops, very little has been done to incorporate ideotype principles in breeding programs during the last twenty years. According to many breeders, the ideotype approach has not been used in their programs because it offers no advantage over the available alternatives in terms of yield improvement in their crops.

Despite the potential problems presented to breed crop ideotypes, both plant breeders interested in developing cultivars with greater yield potential and plant physiologists doing research on yield enhancement may receive advantages from describing a model plant or ideotype. The adoption of this procedure may result in sorting out what is known from what is not. It may also call attention to germplasm resources and needs, and promote goal-setting for individual traits and for a research program.

The ideotype approach tries to integrate principles of three important areas in crop production which very often have not followed the same direction: crop physiology, crop ecology and plant breeeding. It stimulates researches to think in a holistic way , trying to put all the pieces of the puzzle called grain yield together and develop a strategy to solve it. Sometimes, the solution presented are viable conceptually but not practically. Perhaps the major benefits of this breeding philosophy are conceptual and analytical rather than in direct yield improvements. At any rate, it is always important to understand the system as whole, to generate hypothesis and to try to prove them. This is the way science has been evolving over the years.

To design and breed a plant from the material available, which is theoretically capable of greater production than the genotype it is to replace, in any defined environmental situation, the availability of three resources is required: sufficient knowledge, adequate genetic diversity and suitable techniques. During the last 10 years great improvements have been done, particularly in the techinques available to manipulate genetic variability through molecular biology. However, most of the effort carried out to transform and improve crop plants have been concentrating on supressing stresses (increase tolerance to herbicides, insects and diseases). QTLs, RFLPs, RAPDs, AFLPs and other techniques may have a broader use in the future. In order to accomplish this goal, it is important that breeders and physiologists work togheter to develop model plants suitable to improve yield potential of our main crops under different cropping systems. This objective will be easier to pursue if ideotype breeding is seen by breeders and physiologists as a complement instead of a substitute of traditional breeding methods to improve grain yield.

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