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THE WHEAT PLANT IDEOTYPE AND ITS SPECIFIC MORPHOLOGICAL AND PHYSIOLOGICAL TRAITS - A BRIEF OVERVIEW

Elena Daniela DIHORU[1], Elena BONCIU[2], Gabriela PĂUNESCU[3], Cătălin Aurelian ROȘCULETE[2], Ramona Aida PĂUNESCU[4], Elena ROȘCULETE[2]

(1) University of Craiova, Doctoral School of Animal and Plant Resources Engineering (IRAV), 13 A.I. Cuza Street, Craiova, Romania; elena.dihoru@yahoo.com
(2) University of Craiova, Faculty of Agronomy, 19 Libertății Street, Craiova, Romania; elena.agro@gmail.com; catalin_rosculete@yahoo.com; rosculeta2000@yahoo.com
(3) University of Craiova, SCDA Caracal, 106 Vasile Alecsandri Street, Caracal, Romania; paunescucraiova@yahoo.com
(4)Syngenta Agro Romania, 73-81 Bucuresti-Ploiesti Street, 013685 Bucharest, Romania; aida.paunescu@yahoo.com

Corresponding author email: elena.agro@gmail.com

Abstract

In cereals breeding, alongside selection for yield and other features, a valuable additional approach is the breeding of crop ideotypes, plants with certain model characteristics which influence photosynthesis, growth and grain production. In literature, the ideotype concept generally refers to the breeding process, but this does not have to be an exhaustive notion, because is important to seeking the best crop phenotype to grow in specific environments, with defined cropping systems and for intended end uses.

These brief overviews present some recent results regarding the wheat plant ideotype and its specific morphological and physiological characteristics. The variability of growing conditions and climate changes trend require the development of wheat cultivars that can adapt efficiently to the available water, withstand increased temperatures and maintain a relatively high yield at the same time. Ideotype breeding is a continuous process because ideotypes are developed to meet the changing needs. Integrating of plant ideotype approach within wheat breeding strategies can lead to create more productive and resilient cultivars that are well adapted to specific pedoclimatic conditions.

***Key words**: wheat, ideotype, traits, cultivars, yield*

INTRODUCTION

Wheat is the most important staple crop in temperate zones and is in increasing demand in countries undergoing urbanization and industrialization (Shewry et al., 2015).

Increasing global demand for wheat is based on the ability to make unique food products and the increasing consumption of these with industrialization and westernization. There is an on-going debate about how best to feed the growing world population in the long run and associated implications for research and development (Grote et al., 2021).

Wheat is a cheap source of essential amino acids (which are not synthesized in the body), good quality minerals, vitamins, and vital dietary fibres to the human diet. (Paunescu et al., 2021). The economic importance of wheat and its contribution to the diets of humans (Gracia-Romero et al., 2023; Paunescu et al., 2021; Shewry et al., 2015) and livestock (Cola and Cola, 2020, 2019 a, 2019 b) cannot be disputed.

Understanding the complex interactions between the genotype, the environmental conditions, and the specific agronomic and management conditions is crucial for the success of wheat crop improvement programs. Because crop performance, understood as grain yield response to the environment, is a complex trait, breeding selection has to include a wide range of environmental growing conditions (Gracia-Romero et al., 2023). However, the development of genomic and biotechnological technologies is one of the ways that can bring an extensive wave of innovation and represents the key to effective solutions for solving of the main current global challenges like food security (De Souza and Bonciu, 2022).

Wheat production is highly sensitive to environmental conditions. One of the negative effects of climate change on cereal crops are changes in landscape features and exacerbating the attack of pathogens and pests with impact on environment and yields (Paraschivu et al., 2015; Cotuna et al., 2021; Sărățeanu et al., 2023). Also, climate change may affect the multi-disease resistance in wheat and grains quality (Cotuna et al., 2022 a, b; Păunescu et al., 2022).

One of the most important goals of plant breeding is to produce new wheat cultivars with a high degree of drought tolerance Păunescu, 2023). The ideotype notion defines the combination of morphological and physiological traits that theoretically optimize crop performance under particular environmental conditions (Gracia-Romero et al., 2023).

Crop ideotype refers to model plants or ideal plant type for a specific environment (Ahmed et al., 2019; Anten and Vermeulen, 2016; Araus et al., 2022).

In broad sense an ideotype is a biological model which is expected to perform or behave in a predictable manner within a defined environment. More specifically, crop ideotype is a plant model which is expected to yield greater quantity of grains, fibre, oil or other useful product when developed as a cultivar. The term ideotype was first proposed by Donald in 1968 working on wheat (https://courseware). It is postulated that a successful crop ideotype will be a weak competitor, relative to its mass (Donald, 1968). Thus the like plants in the crop community will compete with each other to a minimum degree. This relationship of plant form to the exploitation of the environment may lead to two negative relationships among genotypes, namely: between the performance of cultivars at low density and at high density respectively, and between the competitive ability of cultivars against other genotypes on the one hand, and their capacity for yield in pure culture on the other.

Global warming is characterized by shifts in weather patterns and increases in climatic variability and extreme events (Anten and Vermeulen, 2016). New wheat cultivars will be required for a rapidly changing environment, putting severe pressure on breeders who must select for climate conditions which can only be predicted with a great degree of uncertainty (Semenov and Stratonovitch, 2013).

In order to develop high-yielding wheat ideotypes, several traits were identified as a key for improvement of wheat yield potential (Gracia-Romero et al., 2023; Semenov and Stratonovitch, 2013).

MATERIALS AND METHODS

In this brief overview, the main objective was the presentation of some recent results regarding the wheat plant ideotype and its specific morphological and physiological characteristics.

The used methods included searching of the various databases with the latest publications in the field and identification of some relevant results. The main databases were Web of Science and Google Scholar but also some short online communications.

RESULTS AND DISCUSSIONS

In the second half of the 20th century, growing conditions were controlled by an increasing use of synthetic fertilizers, regulators and pesticides, resulting in a homogenization of the environment towards an optimum for plant growth (Brancourt-Hulmel et al., 2003). This control of potential limiting factors resulted in an increase in sowing density and a simplification of the cropping system by shortening the rotation and increasing the field area.

Consistent with this control of culture environments, breeders have selected cultivar types capable of maximizing yield and quality under non-limiting conditions and therefore over large areas of culture (Ahmed et al., 2019). These trends in both cropping practices and plant breeding have led to an unprecedented increase in agricultural productivity. For example, wheat yield increased in France by 1.26 q/ha/year between 1960 and 1990, half of which was attributed to genetic progress (Brancourt-Hulmel et al., 2003).

Donald (1968) first defined an ideotype as a “*biological pattern that is expected to behave or behave in a predictable way in a defined environment*”. This plant model consists of a combination of physiological and morphological traits known to positively influence a plant's performance in its target environment. Including downstream chain demand and the genetic basis of the traits considered. Debaeke and Quilot-Turion (2014) defined an ideotype as "*an optimal combination of morphological and physiological traits or their underlying genetic basis that results in an effective match of the plant material to its environment, its cropping system and consumer demand*".

This concept of ideotype was originally proposed as an interesting tool to renew classical empirical approaches to reproduction (Donald, 1968), based mainly on: removal of defects, such as susceptibility to disease or physical imperfection; selection for yield without considering the whys and wherefores of that higher yield.

Donald (1968) proposed ideotype reproduction as a third interesting mode of selection. It consists in using existing knowledge mainly in eco-physiology to identify traits of interest under defined culture conditions, combining these traits into an ideotype and selecting varieties according to this ideotype. Although rare in the scientific literature, some ideotype breeding experiments have been successful.

The most popular success of breeding ideotypes is probably on rice. Peng et al. (2008) showed yields obtained by an ideotype selection 8 to 15% higher than those obtained by classical selection. In this case, the ideotype consisted of a plant with moderate cutting capacity, heavy and drooping panicles and some morphological features of the top three leaves, and a panicle position that optimizes source-sink relationships.

Optimal flowering is one of the most important factors to maximize yield in dry environments; on the other hand, past increases in wheat yield have been associated with shortening of the duration of vegetative development phases (Semenov and Stratonovitch, 2013).

Ideotype breeding has the potential to increase selection efficiency. Donald (1968) argued that the success of classical selection for yield rests in part on luck that could be reduced by integrating into the selection process mechanisms and related traits responsible for higher yield. Apart from this assumption, it is clear that the yield (in grains or biomass) is not possible to estimate properly in the first years of selection due to the limited amount of material available and the growing conditions which can be very different from those encountered in a culture field. Therefore, by identifying traits responsible for high yield under real culture conditions that can be measured accurately and early in the selection process, the breeder is able to select earlier for yield and therefore be more effective in improving it (Teixeira et al., 2017).

Donald (1968) proposed ideotype of wheat with following main features:

1. A short strong stem. It imparts lodging resistance and reduces the losses due to lodging;
2. Erect leaves. Such leaves provide better arrangement for proper light distribution resulting in high photosynthesis or CO_2 fixation;
3. Few small leaves. Leaves are the important sites of photosynthesis, respiration and transpiration. Few and small leaves reduce water loss due to transpiration;
4. Larger ear. It will produce more grains per ear;
5. An erect ear. It will get light from all sides resulting in proper grain development;
6. Presence of awns. Awns contribute towards photosynthesis;
7. A single culm.

This breeding approach is all the more useful in today's breeding context with an increasing number of breeding goals that may be loosely related and sometimes antagonistic. Identifying traits and mechanisms that influence different breeding objectives and integrating them into a single model make it possible to disentangle the existing correlation (negative or positive) between those objectives and to identify combinations of traits, sometimes weakly related, that provide an acceptable trade-off between the objectives targeted (Teixeira et al., 2017).

Cruz (2006) proposed a selection index based on the definition of an ideotype called the genotype-ideotype distance index, which proved interesting in multi-criteria selection.

Another advantage of this ideotyping approach lies in the formalization of traits and mechanisms into plant models that can be reused for different species and production contexts. It is clear that the wheat ideotype and the underlying physiological mechanisms and morphological traits proposed by Donald (1968) inspired those proposed for other cereals such as maize (Mock and Pearce, 1975) or rice (Peng et al., 2008).

Schmidt et Gaudin (2017) illustrated the possibility of designing generic ideotypes. They developed and compared root ideotypes for irrigated and rainfed systems that may be of interest to several annual crops. Finally, the ideotyping approach provides a framework to facilitate the interspecific sharing of new concepts and knowledge, and thus the possibility of accelerating genetic progress in a more collective way.

Donald (1968) seeks to define an ideotype capable of high grain yield when grown as a crop community and under high seeding density. Growing environments are those of intensive agriculture, favourably endowed for water and nutrient supply and well controlled against weeds and pests (https://courseware.cutm.ac.in/wpcontent/uploads/2020/05/Ideotype-concept.pdf).

Ideotype improvement offers the opportunity to accelerate the selection of innovative cultivars by first defining a plant model that may differ greatly from current cultivar profiles. The design of new ideotypes (Figure 1) is a creative process that first consists of defining a conceptual representation (Gauffreteau, 2018).

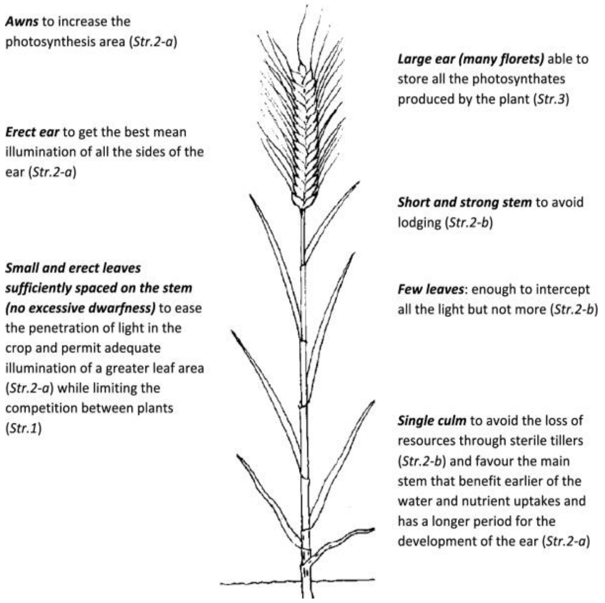

Figure 1. The design of new wheat ideotype (Gauffreteau, 2018, based on Donald, 1968)

The conceptual representation may be based on strategies whose feasibility has not been properly assessed. Wheat varieties capable of fixing nitrogen as legumes or inhibiting nitrification are, for example, innovative strategies under study to improve wheat's resistance to nitrogen stress. This creative step of ideotype design can involve stakeholders from various backgrounds (scientists in genetics, agronomy, physiology, pathology and professionals such as breeders, examination offices, advisors or farmers) sharing and discussing different forms of knowledge (Gauffreteau, 2018; (https://courseware.cutm.ac.in/wpcontent/uploads/2020/05/Ideotype-concept.pdf).

What methods to support such a design process is a key question. Agronomists working on the design of new agricultural systems mobilized, proposed and compared several participatory approaches (Prost et al., 2018; Berthet et al., 2015) that could be adapted to the case of ideotypes. Those participatory approaches are also good ways to identify knowledge gaps that might warrant further research. Once the ideotype is defined, its evaluation will be based on the varieties selected according to this ideotype. Therefore, the challenge is to select those varieties in an efficient way. This will be all the easier when selection traits are easily and precisely measurable, that some genetic markers are available (https://courseware.cutm.ac.in/wpcontent/uploads/2020/05/Ideotype-concept.pdf).

Breeding is classically a step-by-step process, improving existing varieties by crossing with parents carrying interesting attributes (Gauffreteau, 2018). This breeding process may not be adapted to rapid changes in growing conditions and a diversification of consumer demand and growing practices that must renew the supply of cultivars with sometimes very different profiles from the selected one. This requirement is already observed in some organic farming systems with an important use of foreign varieties and the development of local participatory breeding programs (Gauffreteau, 2018).

Selected cultivars should be evaluated under culture conditions representative of the target population of media and according to the specifications listed above. This assessment is classically implemented in a multi-environment study. It is based on a precise characterization of environmental conditions that can be partially experimentally controlled and an analysis of genotype x environment interactions aimed at delimiting the optimal culture conditions for the varieties studied. This multi-criteria analysis helps to identify critical default values of varieties that could lead to changes in the underlying ideotype.

The improved genetic transformation efficiency (Bonciu, 2023; Bonciu et al., 2021a); the knowledge about the genetic basis of yield-related traits (Bonciu et al., 2021b) and the connection between genotype and phenotype is required for ideotype breeding as a complement to conventional breeding. New agricultural solutions must be developed, including more sustainable agronomic practices and acceleration of crop genetic advances (Araus et al., 2022).

CONCLUSIONS

The changing climate demands the crop varieties with desirable traits for higher adaptability and yield. The ideotype defines the combination of morphological and physiological traits that optimize crop performance under particular environmental conditions.

Concept of wheat ideotype provides the idea of best performing plant in a given environment and provides a picture of important and desirable traits in plant. Wheat ideotype improvement offers the opportunity to accelerate the selection of innovative cultivars. There is no conflict between current reproduction methods and ideotype reproduction.

The greater number of desired characteristics for the current state of the culture and diversification leads to an increase in the number of improvement objectives impossible to achieve simultaneously and efficiently. Furthermore, this ideotype-based approach provides an intriguing framework to support a collective design involving stakeholders from different technical and scientific fields.

Designing ideotypes is a valuable way to pool and share different forms of knowledge by specifying underlying strategies, mechanisms, and features. In addition, it facilitates the transfer of ideas from one species to another. This is demonstrated by the wheat model proposed by Donald (1968), which has served as a clear model for the design of ideotypes for a variety of different species. As a result, it is a useful procedure for some minor species whose range is generally limited. Evaluation can also provide innovative knowledge, or at least an innovative avenue for research.

REFERENCES

Ahmed, H.G.M.D., Khan, A.S., Li, M.J., Khan, S.H., Kashif, M. (2019). Early selection of bread wheat genotypes using morphological and photosynthetic attributes conferring drought tolerance. *J. Integr. Agric.,* 18, 2483-2491.

Anten, N.P., Vermeulen, P.J. (2016). Tragedies and crops: understanding natural selection to improve cropping systems. *Trends Ecol. Evol*., 31: 429–439.

Araus, J.L., Kefauver, S.C., Vergara-Díaz, O., Gracia-Romero, A., Rezzouk, F.Z., Segarra, J., et al. (2022). Crop phenotyping in a context of global change: What to measure and how to do it. *J. Integr. Plant Biol*., 64, 592–618.

Berthet, E., Barnaud, C., Girard N., Labatut, J., Martin, G. (2015). How to foster agroecological innovations? A comparison of participatory design methods. J. Environ. Plan. Manag. 59(2): 280–301.

Bonciu, E. (2023). Genetic transformation in agriculture: the real chance for ensuring worldwide sustainable food security. *Scientific Papers Series Management, Economic Engineering in Agriculture & Rural Development*, Vol. 23(1): 73-80.

Bonciu, E., Liman, R., Cigerci, I.H. (2021a). Genetic bioengineering in agriculture-a model system for study of the mechanism of programmed cell death. *Scientific Papers: Management, Economic Engineering in Agriculture & Rural Development*, Vol. 21(4): 65-70.

Bonciu, E., Păunescu, R.A., Roșculete, E., Florea, D. (2021b). The variability of some characters and their correlations with the yield of an extensive assortment of autumn wheat varieties, tested on the chernozem from ARDS Caracal. *Annals of the University of Craiova - Agriculture, Montanology, Cadastre Series*, 51(1), 244-260.

Brancourt-Hulmel, M., Doussinault, G., Lecomte, C., Bérard, P., Le Buanec, B., Trottet, M. (2003). Genetic Improvement of Agronomic Traits of Winter Wheat Cultivars Released in France from 1946 to 1992. *Crop Breeding, Genetics & Cytology*, 43:37-45.

Braun, H.J., Rajaram, S., van Ginkel, M. (1996). CIMMYT's approach to breeding for wide adaptation. *Euphytica*, 92: 175-183.

Cola, M., Cola, F. (2020). Experiments on a Holstein-Friesian line on the effect of selection for robustness on feeding behaviour. *Scientific Papers. Series A. Agronomy, Bucharest*, Vol. LXII, No. 1, 264-269.

Cola, M., Cola, F. (2019 a). Study on breeding a Holstein-friesian line of cows to improve milk quality.*19th International Multidisciplinary Scientific GeoConf. SGEM* , Vol 19, 913-922.

Cola, M., Cola, F. (2019 b). Study on the breeding of a Holstein-Friesian line of cows to improve the reproduction indices. *19th International Multidisciplinary Scientific GeoConference SGEM* , Vol 19, 923-932.

Cotuna, O., Paraschivu, M., Sărăţeanu, V., Partal, E., Durău, C.C. (2022a). Impact of *Fusarium head blight* epidemics on the mycotoxins' accumulation in winter wheat grains. *Emirates Journal of Food & Agriculture*, Vol. 34(11):949-962.

Cotuna, O., Paraschivu, M., Sărăţeanu, V., Horablaga, M.N., Durău, C.C. (2022b). Research regarding the contamination with *Fusarium spp*. of the wheat grains from the variety *Triticum aestivum* ssp. spelta before and after the treatment with bio-fungicide - case study. *Scientific Papers. Series A. Agronomy*, Vol. LXV, No. 1: 266-273.

Cotuna, O., Paraschivu, M., Bulai, A., Toma, I., Sărăţeanu, V., Horablaga, N.M., Buzna, C. (2021). Behaviour of some oat lines to the attack of the fungus *Blumeria graminis* (D.C.) *f. sp. avenae* EM. Marchal. *Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development*, Vol. 21(4): 161-170.

Cruz, C.D., (2006). Program Genes: A Software in the Area of Genetics and Experimental Statistics. Available at: http://www.ufv.br/dbg/genes/Genes_EUA.htm

Debaeke, P., Gauffreteau, A., Durel, C.E., Jeuffroy, M.H. (2014). Conception d'idéotypes variétaux en réponse aux nouveaux contextes agricoles et environnementaux. *AE&S*, 4 (2): 9.

De Souza, C.P., Bonciu, E. (2022). Progress in genomics and biotechnology, the key to ensuring food security. *Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development*, 22(1), 149-157.

Donald, C.M. (1968). Improvement of culture ideotype. *Euphytica*, 17: 385-403.

Fontaine, L., Rolland, B., Bernicot, M.H., Poiret, L. (2009). Des variétés rustiques concurrentes des adventices pour l'agriculture durable en particulier l'agriculture biologique. Innovations Agronomiques, 4: 115-124.

Gauffreteau, A. (2018). Using ideotypes to support cultivar selection and recommendation. *OCL,* 25.6: D602.

Gracia-Romero, A., Vatter, T., Kefauver, S.C., Rezzouk, F.Z., Segarra, J., Nieto-Taladriz, M.T. et al. (2023). Defining durum wheat ideotypes adapted to Mediterranean environments through remote sensing traits. *Front. Plant Sci*., 14:1254301.

Grote, U., Fasse, A., Nguyen, T.T., Erenstein, O. (2021). Food Security and the Dynamics of Wheat and Maize Value Chains in Africa and Asia. *Front. Sustain. Food Syst*., 4:617009.

Ideotype breeding (2020). Available at: https://courseware.cutm.ac.in/wpcontent/uploads/2020/05/Lec-15.Ideotype-concept.pdf

Mock, J.J., Pearce, R.B. (1975). An ideotype of maize. *Euphytica,* 24: 613-623.

Paraschivu, M., Cotuna, O., Paraschivu, M., Durau, C.C., Damianov, S. (2015). Assesement of *Drechslera tritici repentis* (Died.) Shoemaker attack on winter wheat in different soil and climate conditions in Romania. *European Biotecnology Congress* Bucharest, *Journal of Biotechnology*, Vol. 208: S113.

Paunescu, R.A., Bonciu, E. Rosculete, E., Paunescu, G., Rosculete, C.A., Babeanu, C. (2021). The Variability for the Biochemical Indicators at the Winter Wheat Assortment and Identifying the Sources with a High Antioxidant Activity. *Plants*, 10(11), 2443.

Păunescu, G., Paraschivu, M., Păunescu, R.A., Roșculete, C.A. (2022). The relationship between yield and pathogens attack on the advanced breeding winter wheat lines assessed for adult plant resistance. *Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development*, Vol. 22(1): 493-501.

Păunescu, R.A. (2023). *Metode de identificare a fenotipurilor de grâu rezistente le stresul hidric (Methods for identifying water stress resistant wheat phenotypes)*. Ed. Sitech, Craiova.

Peng, S., Khush, G.S., Virk, P., Tang, Q., Zou, Y. (2008). Progress in ideotype breeding to increase rice yield potential. *Field Crop. Res.,* 108: 32–38.

Prost, L., Reau, R., Paravano, L., Cerf, M., Jeuffroy, M.H. (2018). Designing agricultural systems from invention to implementation: the contribution of agronomy. Lessons from a case study. *Agricult. Syst.* 164: 122–132.

Sărățeanu, V., Cotuna, O., Paraschivu, M., Cojocariu, L.L., Horablaga, M.N., Rechițean, D., Mircov, V.D., Sălceanu, C., Urlică, A.A., Copăcean, L. (2023). Features of natural succession of ex-arable forest-steppe grass-land (from western Romania) under the influence of climate. *Plants*, 12(6):1204.

Schmidt, J., Gaudin, A. (2017). Toward an integrated root ideotype for irrigate systems. *Trends Plant Sci*., 22(5): 433-443.

Semenov, M.A., Stratonovitch, P. (2013). Designing high-yielding wheat ideotypes for achanging climate. *Food and Energy Security*, 2(3): 185–196.

Shewry, P.R., Hey, S.J. (2015). The contribution of wheat to human diet and health. *Food Energy Secur*., 4(3):178-202.

Teixeira, F.G., Hamawaki, O.T., Nogueira, A.P.O., Hamawaki, R.L. et al. (2017). Genetic parameters and selection of soybean lines based on selection indexes. *Genet. Mol. Res*., 16(3).