

APPLICATION OF THE ECOLOGO-GENETIC MODEL
IN THE ESTIMATION OF BREEDING ACCESSIONS
OF *CICER ARIETINUM* L.

Natalia Georgieva[✉], Valentin Kosev

Received on March 13, 2026

Presented by H. Najdenski, Member of BAS, on April 28, 2026

Abstract

The use of traditional methods and analyses in breeding and genetic research should be combined with the application of new models for the estimation of quantitative traits. The present study aimed at ecologo-genetic evaluation of the main quantitative traits in 12 varieties and hybrid lines of *Cicer arietinum*. The ecological-genetic model is based on the understanding of genotype-environment interaction and is an alternative to classical methods of breeding. The highest seed yield was demonstrated by hybrid lines D (370.29 kg da⁻¹), XFKR (358.27 kg da⁻¹) and XFKW (343.96 kg da⁻¹). Garbanzo negro and line XD exhibited a good combination of genes for adaptability and attraction in terms of number of pods and seeds per plant. Regarding the module of seed yield, “strong” genes of the physiological system “attraction” were established in variety Balkan, and lines XFKA and XFKR retained good adaptation.

Key words: genotype, phenotype, module, ecologo-genetic model

Introduction. The use of plant genetic resources to develop improved varieties, hybrids, and populations adapted to specific conditions of particular agroecosystems is essential for ensuring food security and sustainable production. In this regard, legumes, which include the species *Cicer arietinum*, have enormous potential and are major crops in modern conventional and organic production. *C. arietinum* is considered one of the most drought-tolerant of the cool-season

legumes [1], making it suitable for changing climate conditions. It is characterized by high nutritional value, determined by its high content of protein, vitamins, essential amino acids, β -carotene, minerals, etc. [2]. Breeding in *C. arietinum* aims to create varieties with high productivity and tolerance to stress factors. In the early stages of the breeding process (2nd generation), it is crucial for a researcher to know the magnitude of genotypic variability of quantitative traits in a given population when selecting the best genotypes.

The fundamental issue of the interaction between heredity and environmental influence in the formation and expression of quantitative traits is relevant and discussed in common genetics and breeding. The use of traditional methods and analyses in selection- genetic research should be combined with the application of the ecologo-genetic model for an assessment of the quantitative traits. This model reveals a new perspective in plant breeding and makes it possible to measure phenotypic and genotypic variances in a two-dimensional system of trait coordinates without changing the offspring. In quantitative genetics, all existing principles for assessing variability require lengthy and laborious experiments, which are mandatorily associated with a change of generations. According to the ecologo-genetic model of the organization of complex quantitative traits, each complex characteristic is determined by a “nomadic” spectrum of genes. When the limiting environmental factor changes, the number and spectrum of genes that determine the genetic variability of the quantitative trait in the population also change. This knowledge reveals the real nature of genotype-environment interaction and allows the development of approaches to predict these effects [3].

The present study aimed to conduct an ecologo-genetic assessment regarding the main quantitative traits in *Cicer arietinum* accessions.

Material and methods. The research was conducted at the Institute of Forage Crops - Pleven. The objects of the study were 12 breeding accessions of *C. arietinum*: 6 varieties (Irenka, Progress, Balkan, Blanco Lechoso, Garbanzo negro, Plovdiv 8) and 6 hybrid lines (XB, XD, XFKA, XFKR, XFKW, XG). Depending on the seed morphology, four of the accessions belong to the “kabuli” type (Blanco Lechoso, XB, XFKA, XFKW), three to the “desi” type (Irenka, Garbanzo negro, XG), and five to the “pea grain” type (Progress, Balkan, Plovdiv 8, XD, XFKR). Biometric analysis of plants at the technical maturity phase included the following traits: number of pods and seeds per plant, weight of one grain, and seed productivity per plant (g). The seed yield (kg da^{-1}) was also determined. The biological manifestations of accessions were studied during two meteorologically contrasting years (2022 and 2023). With a total precipitation for the growing season of 252 mm, 2023 was characterized by optimal conditions for plant growth and development. 2022 can be defined as considerably unfavourable, as the amount of precipitation was 57% lower than in 2023, and plants developed in conditions of severely expressed water deficit.

The modular organization of the quantitative trait is presented according to the model of DRAGAVTSEV [4]. According to this model, the genetic formula of a trait consists of multiple discretely manifesting and functionally interconnected components within a single system. The module reflects all stages of the realization of genetic formulas depending on the level of environmental factors during ontogenesis. The orthogonal regression method for identifying phenotype by genotype, described by Dragavtsev [4], was applied. This method allows evaluation of genotypes in terms of genetic-physiological systems under different environmental limits at an early stage of the breeding process. In contrast to methods for genetic analysis of traits, Dragavtsev proposed studying genetic-physiological systems such as attraction (attr) (expression of genes for trait manifestation) and adaptability (ad) (genetic control under the action of limiting factors). The results were statistically processed using the Microsoft Office 2011.

Results and discussion. According to DRAGAVTSEV et al. [5], the ecologo-genetic model “invalidates” the idea of using marker genes, molecular markers, and RFLP markers for the purpose of selecting quantitative traits. The labile genetic formula of a complex trait cannot correlate with a rigid structure of markers, even if they densely cover the entire genome. GONCHAROVA et al. [6] indicated that the module is an elementary unit for describing the system of organization of the quantitative trait. It consists of three interconnected traits (one resulting and two component traits) and allows the elements of a plant organism to be studied as a system of an integrated whole. The environmental influence on the module determining seed productivity of the twelve genotypes is presented in Table 1. The formation of the module of seed weight/plant is a function of the mutual influence of seed number/plant and weight per one grain. The environmental limit directly reflects on the expression of both component traits. In terms of number of seeds/plant, the first two positions were occupied by hybrid lines XD and XFKR (> 105), which considerably exceeded the parental forms. In 2023, the situation changed significantly, with the varieties Garbanzo negro and Progress forming a substantial number of seeds per plant. In the hybrid lines, XG and XD can be distinguished. Regarding the component of weight per grain, the undisputed favourite was Blanco Lechoso, as well as XB line. With seed weight of 0.45 g, lines XFKA and XFKR also had good performance. When analyzing the two component traits, it can be concluded that there is a compensatory mechanism that is very well expressed in the resulting trait.

The data presented in Table 2 show that the line XD formed the highest average yield ($370.29 \text{ kg da}^{-1}$). The lines XFFR ($358.27 \text{ kg da}^{-1}$) and XFKW ($343.96 \text{ kg da}^{-1}$) were also of interest. These lines occupied the best positions in this indicator and were ranked 1–3. The lines XFKA and XB were ranked in fourth and fifth positions, but the difference between them and XFKW was statistically insignificant. DRAGAVTSEV and MALETSKY [7] believed that if, when environmental factors change, the spectrum of genes determining the genetic variability

T a b l e 1

Influence of environmental conditions on the module of seed productivity/plant in *C. arietinum* accessions

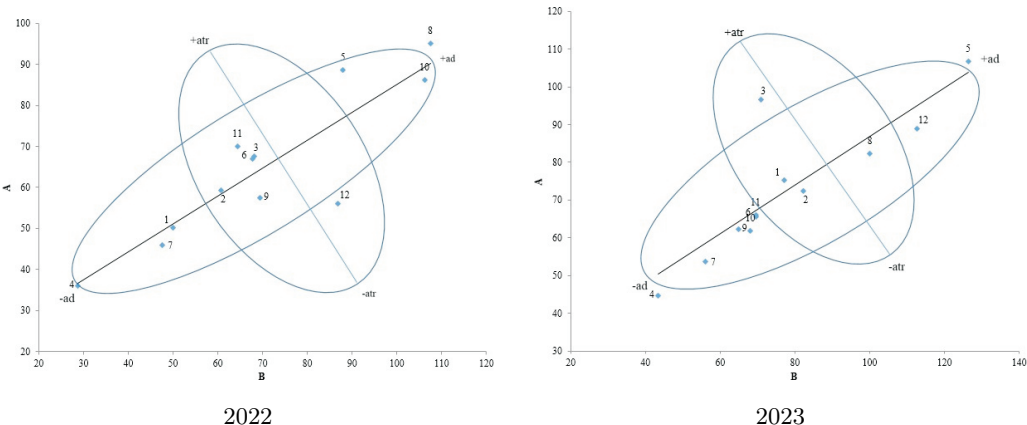
Accessions	Years					
	2022	2023	2022	2023	2022	2023
	Component trait 1		Component trait 2		Resulting trait	
	number of seeds/plant		weight per grain		seed weight/plant	
Irenka	50.0	94.8	0.179	0.204	8.952	19.38
Progress	60.7	105.6	0.301	0.295	18.273	31.14
Balkan	68.1	86.4	0.365	0.332	24.889	28.70
Blanco Lechoso	28.7	56.0	0.532	0.568	15.268	31.78
Garbanzo negro	88.0	157.3	0.217	0.203	19.081	31.91
Plovdiv 8	67.7	86.8	0.385	0.326	26.041	28.32
XB	47.6	56	0.484	0.491	23.05	27.50
XD	107.5	100.1	0.205	0.309	22	30.90
XFKA	69.5	64.9	0.375	0.450	26.06	29.20
XFKR	106.2	68.1	0.304	0.452	32.32	30.80
XFKW	64.4	69.5	0.328	0.403	21.1	28.00
XG	86.9	112.6	0.208	0.145	18.09	16.30

T a b l e 2

Influence of environmental conditions on the module of seed yield in *C. arietinum* accessions

Accessions	Module of seed yield (kg da ⁻¹)					
	2022	2023	Average	2022	2023	Average
	Limit (year)			Ranks		
Irenka	232.85	246.41	239.63a	12	11	12
Progress	267.31	285.25	276.28c	11	8	10
Balkan	303.09	275.36	289.22d	9	10	9
Blanco Lechoso	311.65	333.90	322.75f	6	6	6
Garbanzo negro	290.19	307.83	299.01e	10	7	8
Plovdiv 8	335.28	276.37	305.82e	2	9	7
XB	329.08	355.30	342.19g	3	5	5
XD	341.36	399.22	370.29i	1	1	1
XFKA	307.77	377.264	342.52g	7	3	4
XFKR	318.60	397.936	358.27h	5	2	2
XFKW	326.16	361.76	343.96g	4	4	3
XG	305.35	210.59	257.98b	8	12	11

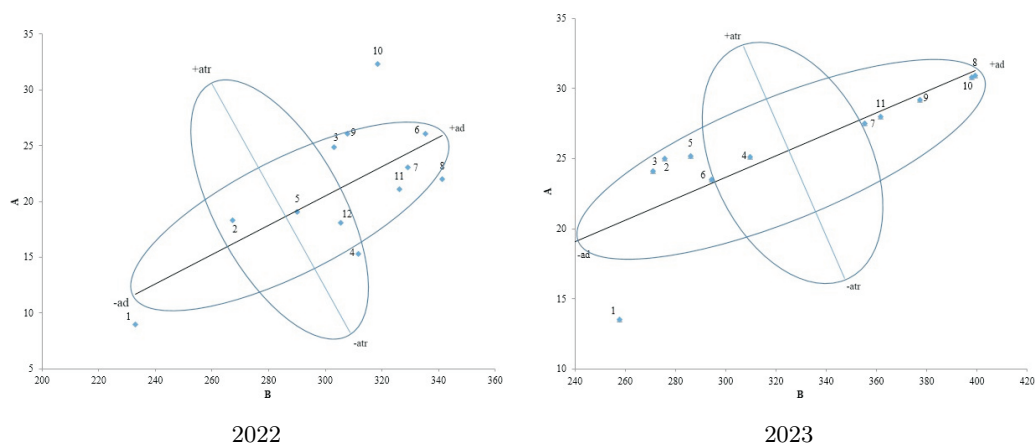
of a quantitative trait changes, this means that it is (in principle) impossible to obtain a rigid “passport” characteristic of the genetic “device” of each complex trait. In other words, the concept of “quantitative trait genetics” cannot exist at all in isolation from the specific dynamics of environmental factors.



1 – Irenka, 2 – Progress, 3 – Balkan, 4 – Blanco Lechoso, 5 – Garbanzo negro, 6 – Plovdiv 8, 7 – XB, 8 – XD, 9 – XFKA, 10 – XFKR, 11 – XFKW, 12 – XG
A – number of pods/plant; B – number of seeds/plant

Fig. 1. Distribution of mean values of quantitative traits along the orthogonal regression line in *C. arietinum* accessions

The abscissa of the coordinate system in Fig. 1 shows the number of seeds per plant for each accession. The ordinate shows the corresponding values for the number of pods. The regression and orthogonal lines, visualizing the impact of limiting environmental factors (drought) on the genetic-physiological systems of attraction and adaptability, respectively, form 4 new quadrants on the coordinate system. When plotting the average trait values on the graph, two main genetic causes of variability were taken into account: diversity of polygenes for adaptability (along the positive regression line through the ellipse) and diversity of polygenes for attraction (depicted by the perpendicular line). Under conditions of action of a limiting factor (water deficit), changes in the indicators of genotypes along the axis “number of seeds per plant” in the physiological system “adaptability” were more chaotic, and the trend line had a rather pronounced negative direction. Against this background, genotypes adapted to increased seed numbers emerge. Such are Garbanzo negro and XD, which are located in a quadrant with positive adaptability and attractiveness. Line XF also had a relatively good position due to its high adaptability and very weak negative attractiveness. A significant part of the genotypes exhibited negative adaptability, and Irenka, Blanco Lechoso, XB, and XFKA had similar attractiveness.



1 – Irenka, 2 – Progress, 3 – Balkan, 4 – Blanco Lechoso, 5 – Garbanzo negro, 6 – Plovdiv 8, 7 – XB, 8 – XD, 9 – XFKA, 10 – XFKR, 11 – XFKW, 12 – XG
A – seed weight per plant (g), B – seed yield (kg da^{-1})

Fig. 2. Distribution of mean values of seed weight/plant and seed yield along the orthogonal regression line in *C. arietinum* accessions

Under favourable environmental conditions (2023), the manifestation of genotypes was demonstrated by a closer location to the regression line. Garbanzo negro was distinguished from the others by maintaining its place in the same quadrant, although its projection was displaced to the far right. Line XD moved to the quadrant of XG and fell into the group of genotypes with negative attractiveness. In the opposite quadrant, only some of the parental forms (Progress, Balkan, and Irenka) were characterized by positive attractiveness. The improvement of environmental conditions did not affect the expression of the studied traits in Blanco Lechoso and XB.

Figure 2 presents the behaviour of *C. arietinum* accessions depending on individual productivity (g plant^{-1}) and seed yield (kg da^{-1}). Varieties Balkan and Plovdiv 8, and lines XFKA and XFKR, were identified with positive projections on both axes (adaptability and attractiveness). When crossing them, new genotypes can be obtained with a better combination of favourable genes. When environmental conditions are relatively more favourable, lines XFKA and XFKR retained their degree of adaptation. In contrast, Balkan and Plovdiv 8 were characterized by negative changes in adaptability.

By analogy with Fig. 1, the location of genotypes in 2023 was relatively close to the regression line. Two main groups were formed: one, with positive adaptation, included lines XB, XD, XFKA, XFKR and XFKW), and the other (Irenka, Progress, Balkan, Blanco Lechoso, Garbanzo negro, Plovdiv 8, and XG) had negative values in both genetic- physiological systems. The elongated ellipse, obtained on the graph, suggests that genotypic variability in the varietal adaptability was

greater than phenotypic variability. On the other hand, the ellipse in attractiveness was more extended, indicating that the variability in attraction systems is greater than in adaptability systems. The conclusion confirms that the plant genotype is a self-regulating system of interconnected traits. In this system, each change in one of the parameters causes a self-regulating change in other traits and properties that are related to it. Due to the self-regulation of the productivity structure system, there are close interactions of different nature and strength.

Conclusions. The ecological-genetic model is based on the understanding of genotype-environment interaction and is an alternative to classical methods of breeding. It allows the development of genotypes that are stress-tolerant and have improved productivity under specific environmental conditions.

In terms of the module of seed productivity per plant, no essential difference was found between most of the accessions of “kabuli” and “pea grain” types. Varieties Progress, Blanco Lechoso, and Garbanzo negro were selectively valuable, with productivity over 31 g/plant. The highest seed yield was demonstrated by hybrid lines D ($370.29 \text{ kg da}^{-1}$), XFKR ($358.27 \text{ kg da}^{-1}$) and XFKW ($343.96 \text{ kg da}^{-1}$), occupying the best positions in rank (1–3).

Garbanzo negro and line XD exhibited a good combination of genes for adaptability and attraction in terms of number of pods and seeds per plant.

Regarding the module of seed yield, “strong” genes of the physiological system “attraction” were established in variety Balkan, and lines XFKA and XFKR retained good adaptation.

REFERENCES

- [1] NEGUSSU M., E. KARALIJA, C. VERGATA et al. (2023) Drought tolerance mechanisms in chickpea (*Cicer arietinum* L.) investigated by physiological and transcriptomic analysis, *Environ. Exp. Bot.*, **215**, 105488.
- [2] SAHU V. K., S. TIWARI, N. GUPTA et al. (2020) Evaluation of physiological and biochemical contents in Desi and Kabuli chickpea, *Legume Res.*, **45**(10), 1197–1208.
- [3] DRAGAVTSEV V. A. (2019) Solutions to technological problems in breeding for higher yields, based on the theory of the ecological-genetic organization of quantitative traits, *Bull. of the State Nikitsky Botan. Gard.*, **132**, 17–28, (in Russian).
- [4] DRAGAVTSEV V. A. (2002) Algorithms of an ecologo-genetical survey of the genofond and methods of creating the varieties of crop plants for yield, resistance and quality, *St. Petersburg: VIR*, 41 pp.
- [5] DRAGAVTSEV V. A., I. M. MIKHAILENKO, M. A. PROSKURYAKOV (2017) On how we can non-canonically increase hereditary drought resistance in plants (by an example of cereals), *Agric. Biol.*, **52**(3), 487–500.
- [6] GONCHAROVA E. A., N. V. SHUMLYANSKAYA, Z. A. SCHEDRINA (2013) Methodology of analysis of quantitative traits for development of initial plant breeding material, *Veg. Crops Russ.*, **3**(20), 30–31.

- [7] DRAGAVTSEV V. A., S. I. MALETSKY (2016) Inscrutable are genes-to-traits pathways, Biosph., 8(2), 143–150, (in Russian).

*Agricultural Academy, Institute of Forage Crops - Pleven,
89 General Vladimir Vazov St, 5800 Pleven, Bulgaria
e-mails: immatalia@abv.bg, valkosev@abv.bg*