

Fractal analysis as an element of intellectual expert system in plant selection

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The purpose. To form methodology and procedure of building system of accumulation and analytically verified use of information of matrixes of digital photo for formation of statistical fund of parametric states of selection samples in various conditions of vegetative period for its further complex unified assessment and analysis within the limits of intellectual expert system. **Methods.** Instrumental-cameral, matrix-digital, fractal, mathematical-statistical. **Results.** According to innovative scientific concept of the "third" form of variability of plants statistical fund is formed of parameters of ontogenetic states of selection samples of leading crops in the form of regression equations of fractal dimensions of quantity. **Conclusions.** Methodology is offered of expert assessment of dynamic system of formation of morpho-metric parameters of plants of selection samples of crops in the form of fractal dimensions of quantity of the most valuable productive elements in general plant stand. The verified technique of compression of data of matrix of digital photo of selection object (5-6 mbyte of information) up to the level of generalized analytic function of regression equation is developed. Principle of automation of cameral processing, built on mathematically correct algorithms of programs of segmentation of digital visualized images, and further compression of the gained segments up to the level of invariant fractal initial systems is realized in selection practice. Principles of formation of system of metadata in the form of phase-parametrical portraits, Liapunov's fractals, cubic splines for building supersystem of description of ontogenetic development of plants in conditions of definite vegetative period are offered as a prospect for further researches. In the given supersystem there is an opportunity of determination emergent-synergetic regularity of formation of productive phenotype under action of epigenetic-trigger mechanisms of VGS. That opens real prospects of long-term forecasting productivity.

Key words: *epigenetics, selection samples, digital matrix, self-affine transformations, fractal dimensions of quantity.*

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The radical changes in the climate and the introduction of the concept of 'Digital Economy of Ukraine' cause the transition to modern technologies in plant breeding. In the system of advanced technologies, it is necessary to apply an innovative scientific concept of the 'third' form of plant variability developed by academicians M. V. Roik, V.A. Dragavtsev and V. S. Maletsky. This concept implies application of the cybernetic principle of inverse communication in the ontogenetic formation of the phenotype on the platform of subsystems genotype – 'genotype-environment' interaction–environmentalfactors [1]. Given in Fig. 1 is proposed by the author the main methodological approaches to the modern representations of the emergent-synergetic principles of the complex nonlinear systems development.

Other important components of these technologies are the formation of large databases (big data) and the application of adequate nonlinear mathematical and statistical platforms for analysis of large arrays of these data in the form of neural networks, phase-parametric portraits, analytical geometric surfaces obtained by the method of topological mixing, fractal-percolation clusters, etc. (Fig. 2).

In order to predict the possibility of emergent-synergetic combinations of valuable breeding traits and the nature of their inheritance in further generations, in the Institute of Bioenergy Crops and Sugar Beet, a metadata base is being formed with the simultaneous involvement of the data into a large

information model of the cluster-hierarchical tree of the phenotype development on the time series of ontogenesis and phylogeny.

In particular, the principles of self-affined reformatting of digital photo matrices from an analog visual format into a mathematical-statistical information model are developed and actively used to form the database. To formulate a methodology and procedure for the development of a system of accumulation and analytically verified use of the digital picture matrices in the formation of the statistics library of the parametrical states of breeding samples under different conditions of growing season for further integrated assessment and analysis within the framework of the intelligence expert system.

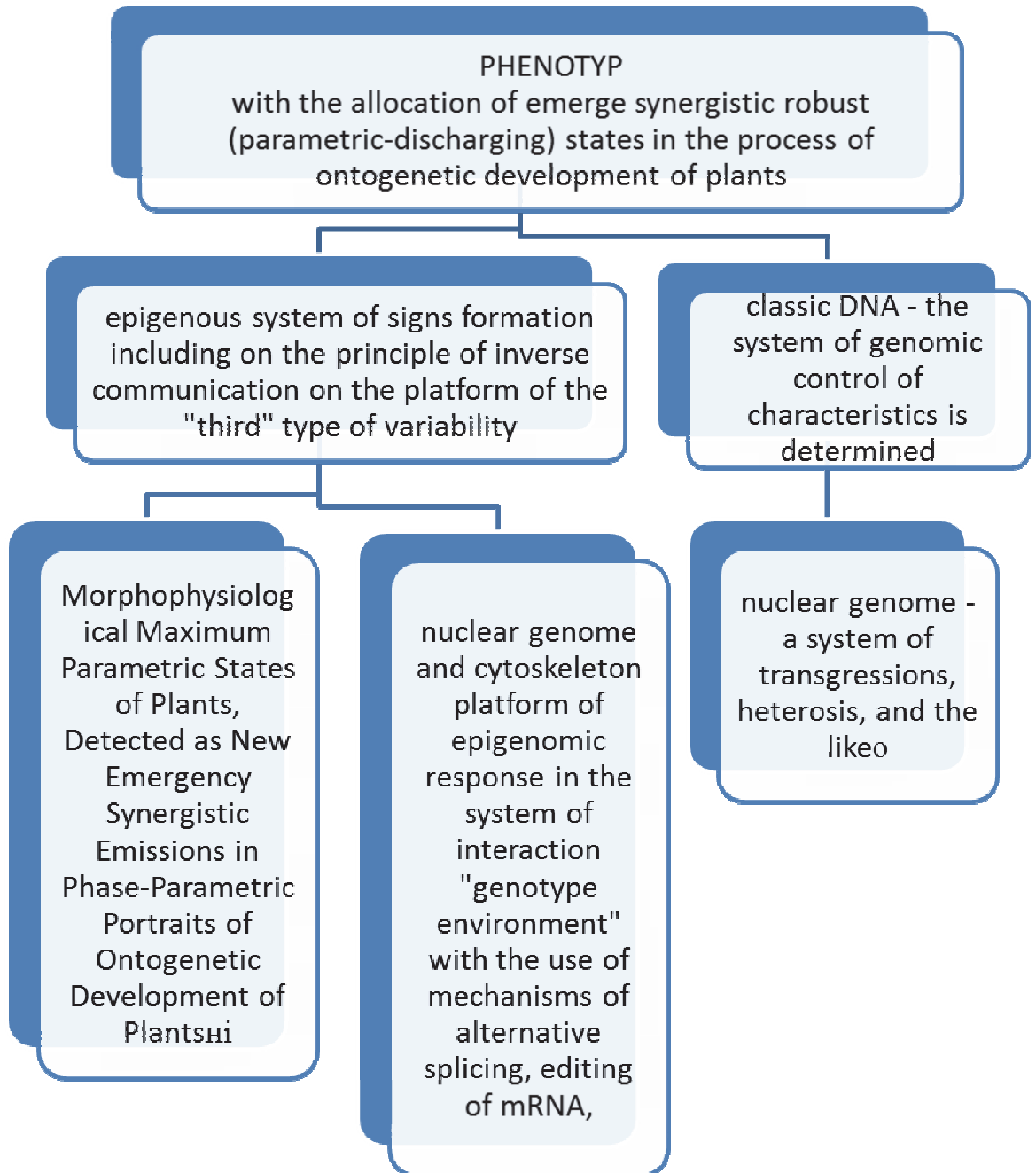


Fig. 1. Principal scheme of the phenotype formation according to modern ideas of the emergent-synergetic principles of the development of complex nonlinear systems based on the 'third variability' concept of Maletsky, Roik and Dragavtsev.

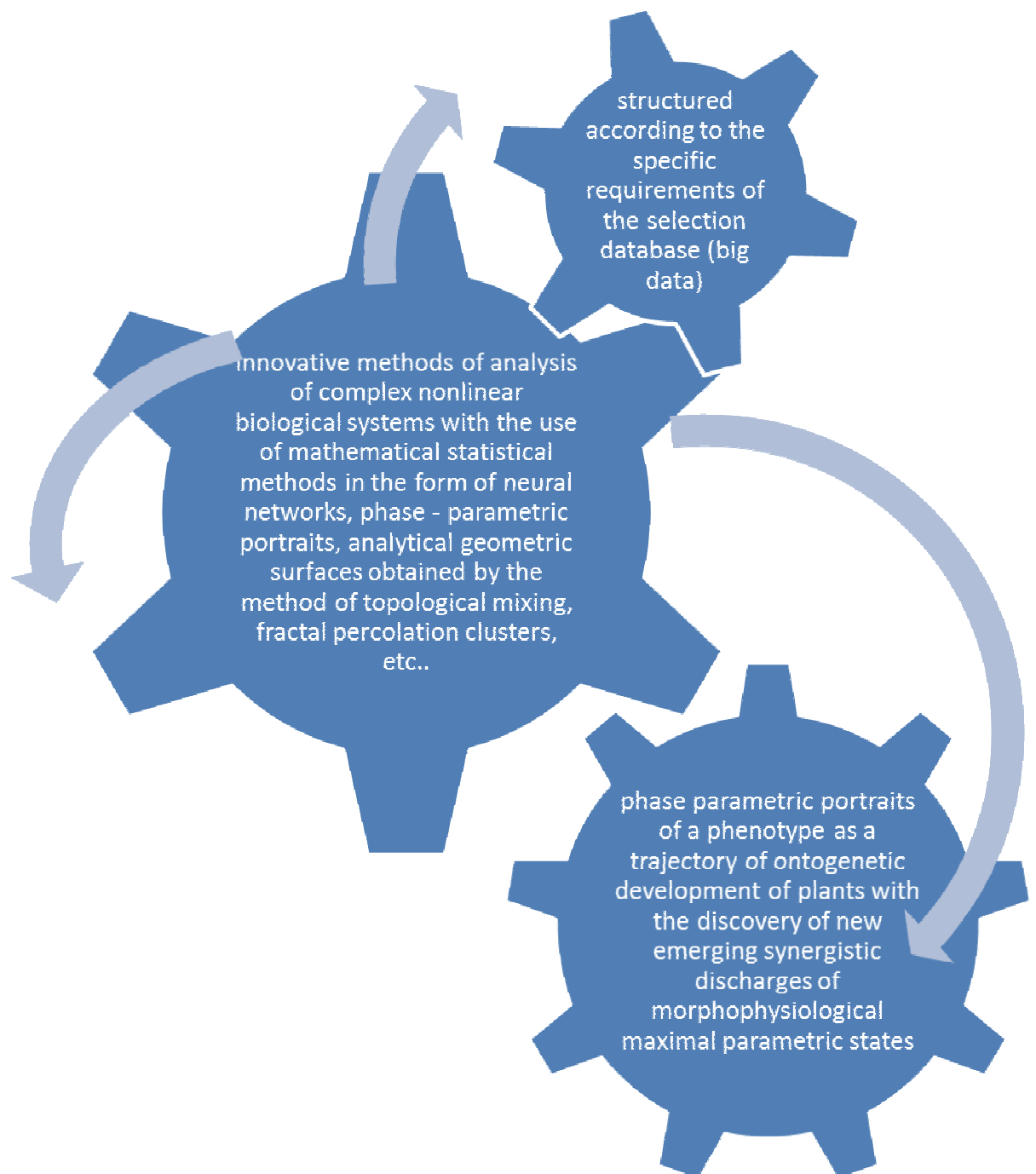


Fig. 2. Methodology and analytical platforms for detecting synergetic genomic-epigenomic states of plant phenotypes

One of the today's most effective and fastest analytical and hardware complexes for the intellectual classification of experimental objects is the method of comparing visual images of digital picture matrices (including those with benchmarks with known parametric characteristics of traits). The

method of fractal analysis has recently found a significant development in the classification of biological objects.

One of the most important characteristics of the fractal is large-scale invariance (similarity in a wide range of scales). The fractional value of the fractal dimension characterizes the degree of filling the space with the fractal structure [2].

There are computer programs for calculating the fractal dimension by methods of triangular prisms, box-counting, variations, variograms, isarithms, iterative coatings, Pentland and probabilistic method [3,4].

In the system for obtaining the matrix of fractal statistic images, an important element is the segmentation segment of the digital picture matrix itself [5,6]. A significant experience of using digital photography in the technological schemes of breeding various crops has been accumulated by the researchers of the Selection and Genetic Institute, in particular, to determine the degree of conformity of estimates of grain characteristics of different wheat genotypes in broad-row and continuous sowing schemes [7].

The certain practice of using the method of segmentation of visual images of breeding samples is also acquired by us on winter rye, field pea and blue lupine [8,9].

Research methods. Determination of the fractal dimension of the parameters of valuable agronomic characteristics highlighted with a colour in the system RGB was carried out in breeding nurseries of different hierarchical levels of different crops. The valuable generative and vegetative signs that are of economic interest were analysed. The colour characteristics of the traits differed both in a significant range on the RGB scale and in the narrow range.

The main methodological approaches were applied in accordance with general conceptual classical works on fractal geometry and modifications by various authors, taking into account the specifics of the industry (medicine, cytology, materials science, glaciology, GIS - systems of analysis of the earth's surface, etc.), in particular in the method proposed [10].

The general formula for all systems:

$$S \sim P^D$$

where S – area, P – perimeter a D fractal dimension of the figure (image element) selected by the isopixel characteristics.

In a linear fashion:

$$D = \ln S / \ln P$$

A verification of the hardware complex for the accuracy of the establishment of the levels of the fractal dimension of the standard fractal figures – the Sierpinski triangle and the Sierpinski carpet, which are characterized by theoretical levels of FR in accordance with the Hausdorff dimension, was carried out.

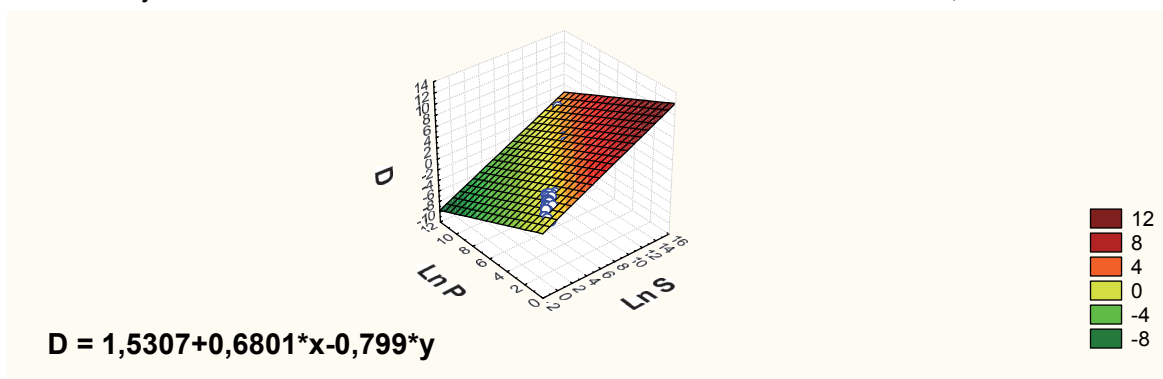


Fig. 3. The fractal dimension of the Sierpinski triangle

Results. A different degree of fractal dimension by spikelets and grains is found by us in breeding samples of winter rye with different sowing densities (continuous sowing and with the individual standing of plants), in particular with a continuous sowing method, the regression equation is $D = 1.4183 + 0.7705*x -$

$0.9259*y$. In the sowings with the individual placement of plants, the regression equation statistics reach significantly lower values of $D = 1.0978+0.6566*x-0.7017*y$, Fig.6,7.

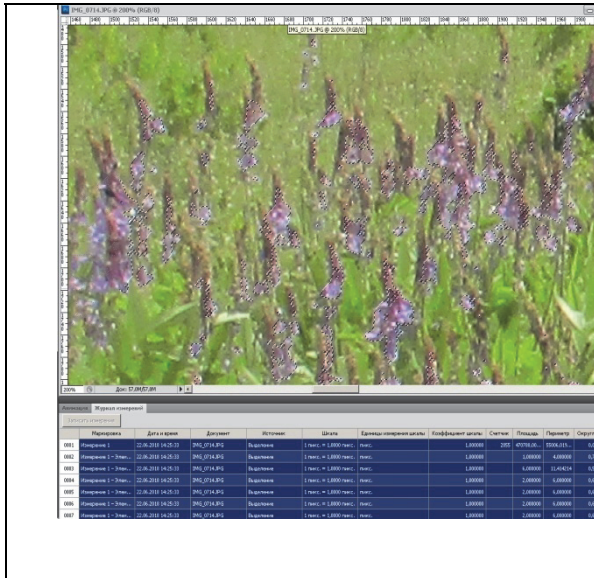


Fig. 4. Differentiation and fractalization (with the elements of the technique) of the generative organs of the Easterngalega (a visualanalog form of the digital matrix) 2018

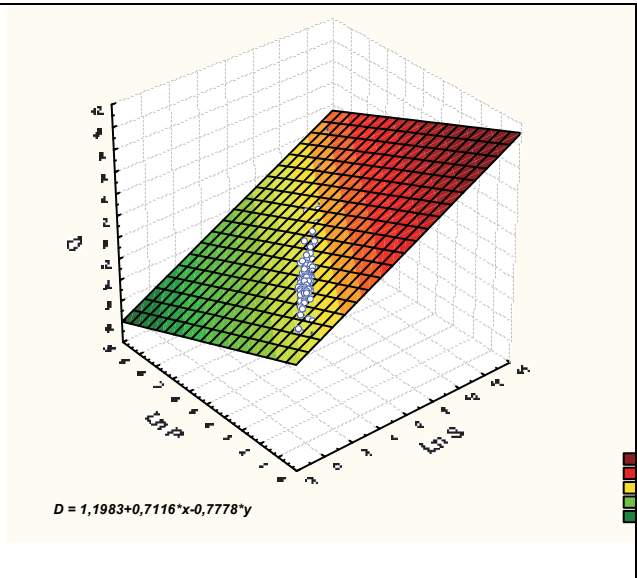


Fig. 5. The same matrix after the affine transformations and statistical transformations in the form of fractal filling by generative organs (2018)

The fractal dimension of spikelets, as generative fruit elements with corresponding colour characteristics in RGB, selected from ...

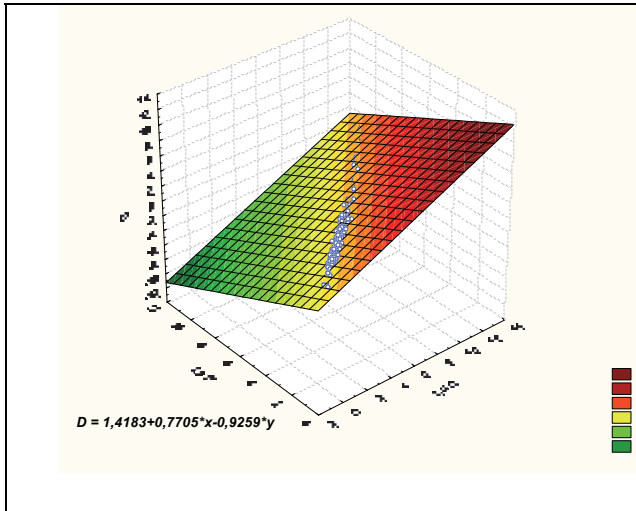


Fig. 6. ... a general selection sample of winter rye obtained at continuous sowing method (2016–2017).

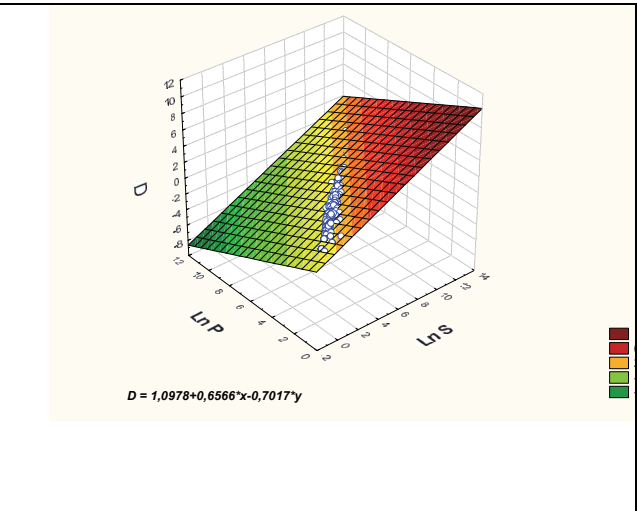
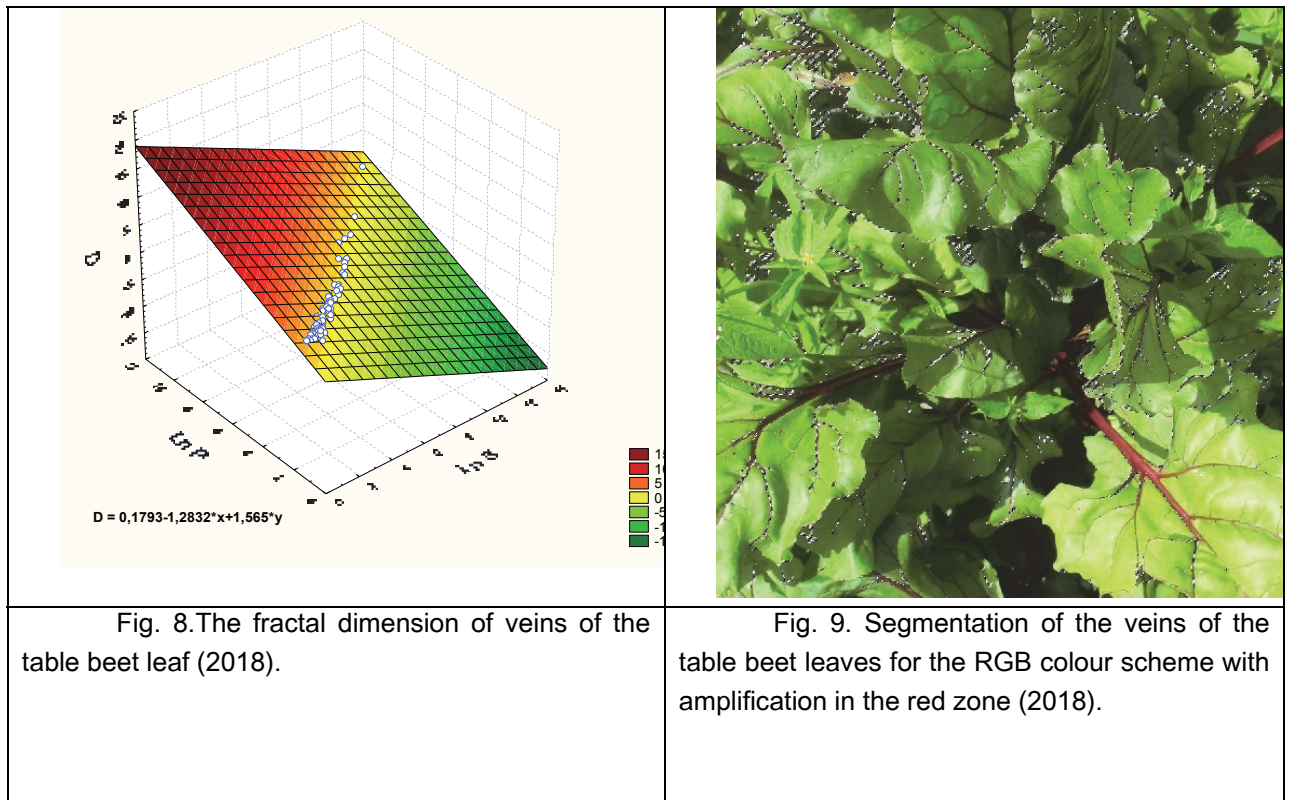


Fig. 7....sowings with the individual placement of plants (2016–2017).

The fractal surface of the leaves of table beet in the system of selection according to the colour scheme RGB has a complex nature of the interaction of the area, perimeter and fractal dimension, which is expressed in the complicated system of the regression equation $D = 0,1793-1.2832*x+1.565*y$. This scale of fractal dimension can serve as a reference when determining the degree of disease of the veins of sugar beet.

Prospects for further research. According to the results of experimental research on the basis of the created database, it becomes possible to deploy the first stage (linear) of the intelligence expert system as an approximated self-affined model of a real nonlinear system.



In accordance with [11], in the case of studying the diagnostic system, we consider three finite sets of parameters: input, output and structural. The latter manifests the properties of the elements from which the object of diagnostics is composed and their interconnections. For the vast majority of systems, the dependence of the diagnostic parameters on the parameters of the structure has the form of the linear regression equation and can be characterized by mathematical expectations:

$$M[y_i / x_1, x_2 \dots x_m] = \bar{y}_j(x_1, x_2 \dots x_m) = d_{j0} + \sum_{i=1}^m d_{ij} x_i, ;$$

The coefficients of the regression equation are determined by solving the system of equations obtained from the condition of a minimum of mean squared deviations from the regression plane:

$$\left. \begin{aligned} & \bar{y}_i(x_1, x_2 \dots x_m); \\ & \left. \begin{aligned} \gamma_{ji} + \gamma_{j2} r_{x_1 x_2} + \dots + \gamma_{jm} r_{x_1 x_m} &= r_{yi} x_1; \\ \gamma_{j1} + r_{x_1 x_2} + \gamma_{j2} + \dots + \gamma_{jm} r_{x_2 x_m} &= r_{yi} x_2; \\ \gamma_{j1} + r_{x_1 x_m} + \gamma_{j2} r_{x_2 x_m} + \dots + \gamma_{jm} &= r_{yi} x_m. \end{aligned} \right\} \cdot \end{aligned}$$

Conclusions

The system for the intellectual evaluation of digital picture matrices is a promising method of complex automated analysis in technological schemes of plant breeding.

When forming large arrays of metadata with the application of innovative principles of nonlinear analysis on the platforms of neural networks, phase-parametric spaces, etc., it is possible to construct the prognostic trends of development and inheritance of valuable economic and agronomic traits in generations of epigenetic systems (third type of variability) which opens significant prospects for the improvement of breeding technologies in line with radical climate change on the planet.

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