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Journal of Clinical and Laboratory Research
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Research Article

Increase In DNA Content in Agricultural Crops Hybrids in Connection with Yield

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Received Date: 25 October 2024 | **Accepted Date:** 12 November 2024 | **Published Date:** 16 December 2024

Citation: Afet D. Mammadova, Ramiz T. Aliyev, (2024), Increase in DNA Content in Agricultural Crops Hybrids in Connection with Yield, *Journal of Clinical and Laboratory Research*, 7(9); **DOI:10.31579/2768-0487/158**

Abstract

Aim of study: Study of DNA content in agricultural crops during heterosis to clarify the general biological pattern of activity of synthesis of the genetic apparatus of plant cells of various taxonomic groups.

Area of study: The studies were conducted at the experimental base and in the physiological genetics department of the Institute of Genetic Resources of Azerbaijan.

Material and methods: Object of study: Solanum lycopersicum L., Cucumis sativus L., Solanum melongena L., Triticum L., Gossypium L. The content of total DNA was determined spectrophotometrically, the amount of which was recalculated per cell, cytophotometry of DNA in nuclei – by the Feulgen reaction.

Main results: All hybrids, regardless of their type and degree of heterotic effect, surpassed the parental forms in DNA content per nucleus and leaf cell. The increase in DNA content corresponds to the heterosis value. Thus, in the wheat hybrid k-47091 x k-53215, the grain weight exceeded the average values of the parents by 16.7%, the DNA content in the nucleus increased by 21.6%. In the hybrid 47091 x k-51549, these indicators were 14.6% and 19.5%, respectively. In tomato varieties, classes of nuclei with DNA content of 2c and 4c were noted, in hybrids – 4c-8c. The average DNA content in wheat hybrids increased due to cells with DNA content of 2c-4c.

Research highlights: The obtained results allow us to recommend determining the DNA content in the somatic cell of plants and cytophotometric studies, which allow us to identify nuclei with an increased degree of ploidy, for predicting heterosis.

Key words: cell; core; dna; productivity; genetics and genetic resources

Introduction

The problem of productivity is closely related to the phenomenon of hybrid vigor, which manifests itself in an increase in the degree of development of certain traits (Begna, 2021; Chandel et al.,2008; Kumar & Sharma, 2008). The use of heterotic seeds allows you to increase productivity by an average of 20-50% compared to the original varieties or lines, improves product quality, and increases plant resistance to adverse environmental factors.

Heterosis manifests itself already in the early stages of development of a hybrid organism (Goncharova, 2010; Meyer et al., 2004). The meristematic tissue of hybrids has the ability to actively divide, which ensures more powerful vegetative development of hybrid plants. In hybrids, there is an increase in the degree of development of individual characteristics: plant height, root mass, leaf surface, etc. Thus, heterosis in corn manifests itself already during the development of primary roots in the form of increased growth of both primary and lateral roots (Paschold et al., 2010; Rehman et al., 2021). Barley hybrids exhibit heterosis by total weight, while a positive relationship was revealed between yield and dry biomass (Nikitina & Bakhtin, 2011).

Numerous studies have been devoted to identifying the molecular mechanisms underlying the heterosis effect. The activity of a number of

enzymes was studied in the tissues of hybrid organisms at different stages of development (Kamalkumar et al., 2007; Singh et al., 2010), activity of biosynthetic processes (Blein-Nicolas, 2015), content of biologically active compounds (Meena et al., 2019), functional activity of chloroplasts (Tongkun et al., 2020) and mitochondria Sen, 1981).

Much attention is paid to assessing the state of the hereditary apparatus during heterosis (Ozdemir, 2021).

There is not yet enough experimental data to develop a unified theory of heterosis, so any research in this area has not lost its relevance. Analyzing the literature data, we can conclude that with heterosis, new characteristics do not appear in hybrids, but a change in certain characteristics of the parental lines occurs. In this regard, it is generally accepted that the leading role in the phenomenon of hybrid vigor is played by genes of quantitative traits – GTL, many of which are identified by molecular genetic methods (Asins, 2002; Gepts, 2002).

The purpose of this work was to study the DNA content in heterotic hybrids of various agricultural plants and their parental forms.

Material and methods

Economically valuable crops were chosen as the object of research cucumber (Cucumis sativus L.), eggplant Solanum melongena L., tomato (Solanum lycopersicum L), wheat Triticum L. and cotton Gossypium L.) and their parent forms.

Samples for analysis of wheat plants were taken in the heading phase, for other crops - in the mass flowering phase (2nd leaf from top).

The total DNA content in plant material was determined by spectrophotometry. The DNA content was recalculated per dry or wet weight of plant material, as well as per one cell, the number of which was determined using Brown's method modified by M.A. Ali-zade et al. (1979).

For cytophotometric studies, the material was fixed in Carnoy's mixture. In contrast to the generally accepted object for cytophotometry – the root tip – we conducted experiments on leaves. To determine the optimal period of hydrolysis based on the intensity of the Feulgen reaction, special methodological work was carried out. It was found that the optimal hydrolysis time for the intense reaction of Feulgen in wheat leaves is 12 minutes (1N HCI, t=60o C), tomato leaf kernels – 1 hour (5N HCI, t=22o C).

The analysis data were processed statistically (Dospehov, 1985).

Results

The first series of studies examined the relative DNA content in the leaves of heterotic hybrids and their parental forms. As research results have shown, the relative amount of DNA does not always allow us to assess the real processes occurring in a living cell. At the same time, the study of DNA content per cell revealed a clear pattern: in all studied hybrid combinations, regardless of what species they belong to, the DNA content in leaf tissues per cell is higher than in the parental varieties. For example, in the highly heterotic cucumber hybrid Din-zo-sn x Iva, it was approximately 63% of the form recorded for this indicator – the variety Din-zo-sn, and in two other hybrids (Iva x Din-zo-sn and Iva x Anshansky) with a lesser effect of heterosis – approximately 50% of the value of the best parental form for this indicator for each crossing combination. At the same time, in hybrids the number of cells per unit leaf area decreased, and the size of the cells themselves increased (table 1).

Determination of DNA content per cell in wheat and cotton confirmed the results of studies on vegetable crops. The studied hybrids of these cultures also differed significantly from their parents in DNA content per cell, being characterized by a high DNA content.

In the second series of studies, the amount of fuchsin DNA in the leaf nuclei of parental forms and F1 hybrids of wheat and tomato was studied, after which the distribution frequencies of interphase nuclei were calculated. The cytophotometric method we used to determine the DNA content in the interphase nuclei of hybrids and their parental forms is of interest for quickly predicting the heterotic effect, as well as for identifying the mechanism for increasing the DNA content in the cell of hybrids of various cultures.

Discussion

As a result of our studies, it was established that heterotic hybrids, regardless of their species and the degree of heterotic effect, surpassed the parental forms in DNA content in one cell. The fact of an increase in DNA content in one cell can be considered a general biological pattern that characterizes the phenomenon of heterosis. These data are consistent with a number of hypotheses about heterosis. Thus, James [1961] believes that one of the reasons for heterosis is the redundancy of the genetic code. Heterosis, according to Severin [218], depends on the completeness of the genetic complex in combination with the favorable influence of additional genes, that is, heterosis is manifested as a result of the formation of a positive excess of information in hybrids in the form of copies of structural genes. Spaffort [487] also explains heterosis by the redundancy of gene repetitions.

In our studies, the increase in the average DNA content in nuclei of heterotic tomato hybrids occurs mainly due to the formation of new polyploid cells with a DNA content of 4c-8c, in wheat hybrids - 2c-4c. On this basis, it can be assumed that the increase in DNA content in the nuclei of tomato leaf cells, which have a relatively small genome size and a tendency to polyploidization, occurs mainly due to endopolyploidy, in wheat - due to the amplification of individual fractions of the genome.

An increase in DNA content in one somatic cell of hybrids compared to the original parental forms, especially at the early stages of ontogenesis, is recommended as a method for predicting the heterotic effect. For the same purpose, it is recommended to use the cytophotometric method for determining the degree of endopolyploidy in hybrids.

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DOI:10.31579/2768-0487/158