Biochemical and Physiological Properties of the Phenomenon of Heterosis in Cucumbers, Cucumis Sativus L.

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Doi: 10.23918/eajse.v7i1p114

Abstract: The research article is the study of hybrid vigor at different hybrid genotypes of cucumber plant (Cucumis sativus L.). Hybrid vigor is the most essential way for famers to improve their plant fertility. Cucumber quality as fertility, fruit color, shape, size and its nutritional quality are essential for breeders to improve their crop production. The results are about the relations between some physio-biochemical parameters as content of total proteins, catalase activity and content of nucleic acids with hybrid vigor. These biochemical and molecular parameters can forecast the heterosis at early stages of plants ontogenetic development. Implementation of heterosis is one of interests among researchers for their unique ontogenetic development. Established heterotic effect of many agricultural crops occurs in the first-generation hybrids on productivity, such as hybrids have substantial growth rate, strong development, intensity metabolic processes, fertility, and yield of a hybrid organism over those of its parents.

Keywords: Heterosis, Hybrid, Nucleic Acids, Cucumber

1. Introduction

Cucumber (Cucumis sativus L) is an important member of the family cucurbitaceous. The crop is of Asian origin, the progenitor may be closely related to the wild Cucumis sativus. Hardwicke, which was first found in the Himalayan foothills of Nepal (Hossain, Rabbani, Hakim, Amanullah & Ahsanullah, 2010). Heterosis or hybrid vigor is an important biological phenomenon refers to the manifested superiority of the F1 hybrid resulting from cross of genetically dissimilar homozygous parents over either of the parents. Heterosis or hybrid vigor can play a vital role in increasing the yield quality of cucumber. It refers to the phenomenon in which F1 hybrid obtained by crossing of two genetically dissimilar inbred lines or genotypes, shows increased or decreased vigor over the better parent or mid parent value (Poehlman, 1979). Heterosis is a useful tool for exploiting dominance and over dominance through the production of hybrids. In commercial production, hybrid seeds are usually heterozygous gynoecious with regard to gynoecious character and are termed predominantly female (Wien, 1997). In cucurbits, heterosis was first noted by Hays and Jones (Hays & Jones. 1961). Now, a heterosis breeding is one of the efficient tools to exploit the heterotic response for several traits (Simi et al., 2017). In order to get exact results, the physiological and biochemical approach is important at basis of molecular biology. Labeling of biological properties and economic signs of the plant - one of the main practical problems to address that should be pursued biochemical and molecular genetics as

Received: March 17, 2021
Accepted: June 3, 2021
Ozdemir, D. (2021). Biochemical and Physiological Properties of the Phenomenon of Heterosis in Cucumbers, Cucumis Sativus L. *Eurasian Journal of Science & Engineering*, 7(1), 114-121.

the theoretical basis of modern plant breeding. This should be especially valuable information about the structure and functional activity of the genome and plasma heterotic hybrids and their parental forms. There are several approaches to assess structural and functional state of the genome and its basic systems. It is known that heterosis manifested at all levels of metabolism and morphogenesis. Biochemistry and molecular biology make it possible to demonstrate this quite concretely and convincingly (Konarev, 1996).

Vavilov (1932) for the first time mentioned this fundamental issue. Konarev (1995) thought that the selection should be based not on individual fragments of the form, but in the form of overall as a complex system, in all its gene pool. To explain the mechanisms of heterosis and inbreeding depression a number of hypotheses were discussed in the past several decades (Dubinin, 1967; Kirpicnikov, 1974; Key, 1976). These studies are the most popular of these hypotheses about the combination of favorable dominant factors and genetic balance.

Diploid genome and protein formed the basis development principles and methods of labeling proteins of the genome as a system of the species category. Particular value is acquired using rapid and accurate identification of the genome and genome analysis source selection material. The crucial role here will belong to the protein and other markers (Konarev, 1983,1993), identification short fragments of the genome in the place of their location, which allows investigate such complex integrated traits like adaptability and productivity (Mitrofanova, Strelchenko, Konarev & Balfourier, 2009).

For protein markers Konarev performed genomic analysis of the main species of cultivated plants and their wild relatives and identified the nature and origin genomes of identified genomic composition in polyploidy complexes of wheat, potatoes, cereals herbs, cruciferous vegetables, fruit stone, etc. (Konarev,1995). A new stage in the further development of technology heterosis breeding would be the implementation methods based on the use of DNA markers (Konarev, 1983). In accordance with the foregoing, the purpose of study was to assess the quality of the overall protein, protein-enzyme catalase, and nucleic acids in hybrid combinations and parental forms of cucumber plants in relation to breeding for hybrid vigor for identifying markers of heterosis.

2. Methodology

Material for the studies were different parental lines (maternal and paternal) cucumber (Cucumis sativus L.) heterotic hybrids and their first generation, provided laboratories via breeding institute of irrigated farming and market gardening.

We studied five initial maternal forms of cucumber, three paternal lines (including zoning grade - Beregovoi and Favorit) and seven first-generation hybrids (F1), of which the first three (H 273, H 274 and H 275) had high productivity, and hybrids of H 6 and H 7 - low. Served as control zoned first generation hybrids F1 and F1 Vzglad and Epilog (Table 1).

Table 1: Genotypic structure of the investigated hybrids Cucumis sativus L.

Parental form	High productive hybrid			Homologated variant		Low productive hybrid	
	H 273	H 275	H 274	Vzglead	Epilog	H 6	H 7
♀	L 222	L 226	L 203	L 371	L 371	L 222	L 222
♂	L 203	L 203	L 216	Beregovoi	Favorit	Beregovoi	Favorit

Cucumber plants were analyzed in stage 3 true leaves. To determine total protein, catalase activity and nucleic acids were used known methods, tested at the department of plant biology (Duca & Savca, 1997), (Reva, Ciobanu, & Muller, 2001). Mathematical treatment experimental data was carried out by standard methods (Armor, 1985). The process was repeated three times.

3. Results and Discussion

Collected and processed experimental data, characterizing some hybrid combination, Cucumis sativus L. has different productivity from their parental forms on the effect of heterosis on some physiological and biochemical parameters. In order to establish patterns between the protein and the effect of heterosis, we determined content of total protein in the plants of cucumber Cucumis sativus L. stage 3 true leaves. For the convenience of identifying patterns of inheritance of traits, the studied data lines and hybrids were grouped by 3 combinations: maternal line, paternal line, a hybrid.

As seen from Table 2, the parental forms, and hybrids of cucumber on the content of total protein in the range of 119.17 to 210.83 mg / g (Table 2). First hybrids, lines which have a combination of high capacity, there exists actively superior to total protein content of the parent form and show a high percentage of heterosis as compared with an average initial parental form (from 13% up to 42%) and compared with the maximum level of one of the parental forms (from 7% to 36%). Maximum percentage heterosis effect - a hybrid F1 Epilogue: it is 42% compared with an average initial parental form.

Table 2: The total protein content for Cucumis sativus L., (mg/g of dry mass)

Genotypical index	$X \pm m_x$ (mg/g)	% Of hypothetical heterosis	% Of real heterosis
H 275	210,83±1,02	13,04	8,69
♀ L 226	174,17±2,84		
♂ L 203	192,5±2,92		
H 274	256,67±3,21	28,57	25,0
♀ L 203	192,5±2,92		
♂ L 216	174,17±2,84		
H 273	207,17±2,84	24,78	7,08
♀L 222	119,17±1,8		
♂L 203	192,5±2,92		
Vzglead	177,89 ± 2,01	23	12,40
♀ L 371	119,33±1,97		
♂ Beregovoi	155,83±2,59		
Epilog	229,17±1,54	42	36
♀ L 371	119,33±1,97		
♂ Favorit	146,67±2,01		
H 6	155,83±2,59	12	0
♀ L 222	119,17±1,8		
♂ Beregovoi	165,12 ± 2,71		
H 7	137,5±2,01	3.3	-6,67
♀ L 222	119,17±1,8		
♂ Favorit	146,67±2,56		

Hybrids, which lines have the combination of low power (H 6 and H 7), showed small positive heterotic effect in comparison with the average baseline parental forms and negative heterosis in comparison with the maximum level of one of parental forms. Patterns of inheritance of total protein content in cucumber plants show that some maternal lines when crossed with different paternal lines give positive heterotic effect, the magnitude of which depends, apparently, only from the maternal line. Thus, line 203, included in the hybrid and hybrid H 275 H 273 as the paternal line, provides H 275, H 274 and H 273 sight Epilogue H 6 and H 7 maternal forms paternal form F1 hybrids. Content of total protein from Cucumis sativus L., (mg / g) less influence on the percentage of heterosis than this same line, serving as the maternal form a hybrid H 274 (yields up to 30% heterosis effect).

Line 371, included as a parent in the control hybrids F1Vzglad and F1Epilog gives high percentage of heterosis - from 13% to 42%. Father's parental forms Favorit in F1 hybrids Epilog defines the high percentage of heterozygous, which, apparently, has had a significant influence maternal form L.371, because in hybrid H 7 - low and even negative heterosis percentage (from 3% to -6,7%). Analysis of data in the literature (Ali, Misur, Aliev, 1982) suggests that the activation of protein synthesis in the hybrids compared to the original parent forms - one of the mechanisms that provides molecular level expression of heterosis effect.

It was suggested that the observed superiority of high hybrids on the activity of the translational apparatus might seem a consequence of over dominance (Gilyazetdinov & Vakhitov, 1976). However, in reality, as the authors argue, it is complementary interaction of non-allelic genes. The ability of hybrids and their parental forms synthesize protein with a given speed should be considered, of course, as a complex process, as translational apparatus is a multi-component, and protein synthesis - a multistage (Ivanova, Kravchenko,1987). The direction and intensity of metabolic activity determined by enzyme systems. Biochemistry of heterosis in this plan is devoted to a lot of research. In studying activity of oxido reductases and transferases in plants heterotic hybrids was found that enzyme activity or they took an intermediate position between the pairs, or yield to them (Ali, Misur, & Aliev, 1982).

Enzymes as biological catalysts involved in all processes of living cells, so we can assume that the heterotic effect in hybrids due primarily all with the focus in the activities of enzymes and their activity. However, the existing literature data on the activity of enzymes in the heterotic hybrids and self-pollinating lines are contradictory. No correlation between the expression of heterosis and the catalase activity was found, but in the studies of Semenov it was found that lines with high combination the ability to have a higher restores the activity of tissues (Ali, Misur, & Aliev, 1982). We studied the activity of catalase in connection with the heterotic effect on stage 3 of these leaves in Cucumis sativus L. Heterotic effect of hybrids, lines which have a combination of high capacity on the catalase activity in cucumber plants varies slightly. Also, almost all hybrids (except H 273) showed positive heterosis.

Table 3: The catalysis activity for Cucumis Sativus L.

Genotypical	$X \pm m_x$	% Of hypothetical heterosis	% Of real heterosis
H 275	19,7±0,97	6,09	5,58
♀ L 226	18,6±0,76		
♂ L 203	18,4±0,86		
H 274	22,1±0,24	14,5	11
♀ L 203	18,4±0,86		
♂ L 216	19,4±0,86		
H 273	18,7±0,27	0	-1,02
♀L 222	19,0±0,75		
♂L 203	18,4±0,86		
Vzglad	20,6±0,18	16,7	6
♀ L 371	20,1±0,24		
♂ Beregovoi	19,4±0,86		
Epilog	21,3±0,09	10,56	8,92
♀ L 371	20,1±0,24		
♂ Favorit	18,7±0,71		
H 6	18,1±0,71	-5	-5
♀ L 222	19,0±0,75		
♂ Beregovoi	19,4±0,86		
H 7	18,3±0,09	3,01	-3,83
♀ L 222	19,0±0,75		
♂ Favorit	18,7±0,71		

A little allocated highly productive hybrid H 274 parental lines showed 14.5% heterosis effect compared with the average parent and 11% compared with the best indicator of one of the parental forms. Hybrids H 6 and H 7 with low productivity showed no heterosis effect (Table 3). About communication problems of nucleic acids with heterosis study, many researchers (Ali, Misur, Aliev, 1982) and some authors showed a direct relationship between the relative content of nucleic acids and manifestation of heterosis. In the experiment, it was found that there was a marked superiority of hybrid plants on the content of nucleic acids, particularly RNA, in the leaves of tomatoes. In seeds of hybrids cucumber and their parental forms to study the relative content of nucleic acids (Belin, Korner, 1968) it was found that hybrids whose seeds had a higher content of nucleic acids, showed heterosis and yield (Ali, Misur, & Aliev, 1982). Gilyazetdinov and Vakhitov (1976) found that parental forms heterotic hybrids differ the intensity of synthesis of ribosomal RNA (Shahbazov, 1972). Sahbazov and Sestopalova (1981) found increased activity of nucleolar apparatus in the cells of heterotic hybrids of plants.

The results in this study also suggest that the majority of hybrids, lines which possess the combination of high capacity, there is a heterotic effect. Thus, the data in Table 4 shows that the DNA content in cucumber plants at the stage 3, the studied true leaves hybrids detected a high percentage of heterosis (from 16,67% to 66,67%) compared with an average initial parental form (Table 4).

Table 4: Content of DNA and RNA from Cucumis sativus L.

Genotypical index	DNA $X \pm m_x$	% Of hypothetical	% Of real heterosis	RNA $X \pm m_x$	% Of hypothetical	% Of real heterosis
H	0,12 ± 0,008	66,67	58,33	0,87 ± 0,02	10,92	5,7
♀ L 226	0,03±0,007			0,83±0,01		
♂ L 203	0,05±0,001			0,72±0,08		
H 274	0,08 ± 0,001	25,0	12,5	1,00 ± 0,02	22,0	16,0
♀ L 203	0,05±0,001			0,72±0,08		
♂ L 216	0,07±0,002			0,84±0,12		
H	0,06 ± 0,002	16,67	16,67	1,01 ± 0,03	25,25	21,78
♀L 222	0,05±0,001			0,79±0,02		
♂L 203	0,05±0,001			0,72±0,08		
Vzglead	0,07 ± 0,002	50,0	28,57	0,86 ± 0,02	5,81	4,65
♀ L 371	0,05 ± 0,001			0,80 ± 0,06		
♂	0,02±0,001			0,82±0,07		
Epilog	0,06± 0,001	25,0	16,67	0,92± 0,03	24,46	13,04
♀ L 371	0,05 ± 0,001			0,80 ± 0,06		
♂ Favorit	0,04 ± 0,001			0,59 ± 0,01		
H 6	0,06 ± 0,002	41,67	16,67	0,86 ± 0,01	6,40	4,65
♀ L 222	0,05 ± 0,001			0,79 ± 0,02		
♂	0,02 ± 0,001			0,82 ± 0,07		
H 7	0,05±0,001	10,0	0	0,81±0,02	14,81	2,47
♀ L 222	0,05±0,001			0,79±0,02		
♂ Favorit	0,04±0,001			0,59±0,01		

A high heterotic effect was discovered and compared with the maximum level of the parental forms (from 12,5% to 58,3%). Maximum heterosis effect was observed for a hybrid H 275 and found as 66,7% and 58,3% respectively. On the content of RNA in cucumber plants at the stage 3, true leaves hybrids found a positive heterotic effect in all hybrid combinations, but higher effect was observed in the hybrids H 274, H 273 and F1 Epilog. It is noticeable that a high percentage of heterosis was observed in those combinations of hybrids, parental forms which differ significantly from each other on the content of nucleic acids.

No significant differences between the hybrids and the parental form of the content of RNA was detected. However, the total content of DNA and RNA in the majority of hybrid combinations are presented in Table 5 (Gilyazetdinov, Vakhitov, 1976). This is consistent with the literature data: hybrids surpass parental forms in rates of accumulation of RNA in vegetative organs.

Table 5: The nucleic acids content for Cucumis sativus L.

Genotypical index	$X \pm m_x$ (mg/g s. pr.)	% of hypothetical heterosis	% of real heterosis
H 275	0,99±0,08	17,17	13,13
♀ L 226	0,858±0,07		
♂ L 203	0,78±0,07		
H 274	1,082±0,09	22	14,81
♀ L 203	0,78±0,07		
♂ L 216	0,91±0,07		
H 273	1,07±0,09	24	20,56
♀L 222	0,85±0,08		
♂L 203	0,78±0,07		
Vzglad	0,925±0,09	8,11	8,60
♀ L 371	0,85±0,08		
♂ Beregovoi	0,845±0,07		
Epilog	0,98±0,09	24,49	13,27
♀ L 371	0,8±0,08		
♂ Favorit	0,63±0,07		
H 6	0,92±0,08	8,70	8,70
♀ L 222	0,84±0,08		
♂ Beregovoi	0,845±0,07		
H 7	0,86±0,06	14,53	2,33
♀ L 222	0,84±0,08		
♂ Favorit	0,63±0,07		

From the foregoing it can be assumed that the superiority of heterotic hybrids, lines which have a combination of high capacity, the content of DNA and RNA at stage 3 true leaves due to the high intensity of the processes of growth and development in the initial stages of ontogeny of plants. It should be noted that perhaps the phenomenon of heterosis in plants of cucumber caused by different links of the mechanisms of gene expression, and therefore features associated with certain content

nucleic acids in hybrid combinations, can only be seen as an important, but not the only causes of these phenomena.

4. Conclusion

Summarizing the results on the variability of some physiological and biochemical parameters in different genotypes of cucumber (Cucumis sativus L.), certain regularities can be highlighted between the studied traits and the phenomenon of heterosis, which will help further the rapid prediction of heterosis in plants in the early stages of ontogeny. Considerable variability for most of the physiological-biochemical aspects of cucumber observed among the studied genotypes. The crosses show us that hybrids surpass parental forms in rates of accumulation of nucleic acids and protein in vegetative organs.

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