

MANIFESTATION OF HETEROSIS IN CUCUMBER F₁ HYBRIDS ACCORDING TO YIELD INDICATORS IN THE FOREST-STEPPE CONDITIONS OF UKRAINE

Serhiienko Oksana*, <https://orcid.org/0000-0002-2754-306X>

Solodovnyk Lina, <https://orcid.org/0000-0002-1196-8709>

Harbovska Tetiana, <https://orcid.org/0000-0001-6434-0109>

Radchenko Larisa, <https://orcid.org/0000-0003-1389-8211>

*Institute of Vegetable and Melon Growing of National Academy of Agricultural Sciences of
Ukraine, Kharkiv region, Ukraine*

*e-mail: oksana.sergienko71@ukr.net, ovoch.iob@gmail.com

Summary. The conducted research evaluated the effect of heterosis and the degree of dominance of promising hybrid combinations of cucumber. Twenty-eight hybrid combinations were analyzed for four yield traits: total and marketable yield, yield in the first decade of fruiting, marketable percentage, and average fruit weight. It was established that the effect of heterosis varied depending on the combination of crossing and the investigated trait. The trend of a positive relationship between the values of heterosis and the degree of dominance was revealed: an increase in the degree of dominance was accompanied by an increase in the effect of heterosis. The highest heterosis effect was noted in F₁ hybrid combinations: RD 96 2-95 × Fen, Mag 62 × RD 96 2-95, Toma-18 × Fora, BD 96-18 × Fen, Ivol D 96 × Fen, Ivol D 96 × Toma-18, Kozyr. Card × Mag-62. These hybrid combinations are a valuable breeding material for increasing yield.

Keywords: cucumber, hybrid combinations, yield, heterosis, degree of dominance.

Introduction

Among the assortment of vegetables grown in Ukraine, a special place is occupied by the cucumber (*Cucumis sativus* L.). Its wide distribution is explained by its nutritional value, high dietary and medicinal properties, and its extensive use in the processing and cosmetic industries [1]. Cucumber contains many important vitamins and minerals, such as vitamin C, potassium, and magnesium, making it an important component of a healthy diet. In addition, cucumber has a low calorie content, which makes it popular among consumers.

For each vegetable crop, including cucumbers, it is necessary to have a variety of genetic material, thanks to which it will be possible to satisfy the needs of the population. The need for genetic diversity is also important for adapting to changing climate conditions and fighting new pests and diseases.

Heterosis, or hybrid vigor, plays an important role in the genetic and physiological aspects of controlling and increasing the adaptive and productive potential of agricultural plants. This phenomenon is characterized by the fact that hybrids obtained as a result of crossing different varieties or lines show higher productivity and stability compared to the parental forms. This diversity is the basis for adaptation to different environmental conditions and is key to resistance to diseases, pests and other stressors. F₁ heterozygous hybrids are widely grown in open and sheltered soil [2].

In Ukraine, the Institute of Vegetable and Melon Growing is the main institution that carries out the primary selection work with cucumbers. Researchers note that one of the priority directions in cucumber breeding is the creation of heterozygous hybrids, which, together with varieties, provide an increase in yield of 15–40% or more, and are characterized by increased yield and resistance to major diseases, as well as biotic and abiotic environmental factors [3].

The development of heterosis selection of cucumber, both in Ukraine and abroad, is an extremely relevant direction that contributes to increasing the productivity of agricultural production, ensuring the stability of crops, and meeting the needs of the population for high-quality and safe food products. Innovative approaches in cucumber breeding allow not only for an increase in yield and improvement in the quality of products, but also contribute to the economic development of the agricultural sector of the country.

The objective of the study is to determine the effect of heterosis in promising F₁ cucumber hybrids based on valuable economic traits for cultivation in the open grounds of the Forest-Steppe of Ukraine.

Materials and methods

The research was carried out at the Institute of Vegetable and Melon Growing of the National Agrarian Academy of Sciences of Ukraine, which is located in the Left Bank Forest Steppe in the central medium-humid area of the Kharkiv Region, at an altitude of 105 m above sea level, at 49°46'42" north latitude and 36°01'37" east longitude. The climate of the region is moderately continental.

The research was conducted during 2021-2023 in field conditions. The soil of the experimental plots is a typical low-humus heavy loamy chernozem. Breeding work was carried out using the method of synthetic selection with the use of intervarietal hybridization followed by individual selection. Twenty-eight collection varieties and lines of our own selection of cucumber served as material.

The assessment of plants according to the complex of signs was conducted in accordance with the "Methodology of the State Varietal Testing of Agricultural Crops" [4]. The fruits were collected at technical maturity according to the requirements of the DSTU 3247-95 [5]. The obtained experimental data were processed using the method of dispersion analysis of variance with the help of R. Fisher [5] and the "Statistica 6.0" program.

The magnitude of the heterosis effect (X) was calculated using the formula [7]:

$$X = (F_1 / [(P_1 + P_2) / 2]) * 100$$

where: F₁ is the value of the hybrid trait; P₁ is the value of the feature of the mother form; P₂ is the value of the characteristic of the parent form.

The degree of dominance was determined by the formula Beil G.M. i Atkins R.E. [8]:

$$h_p = (XF_1 - X_{MP}) / (X_P - X_{MP}),$$

where: XF₁ is the average value of the hybrid trait; X_{MR} is the average value of the indicator of both parental forms; X_R is the average value of the parental form with a higher rate.

Grouping of the received data was carried out according to the classification:

positive over dominance ($h_p > +1$) (positive heterosis); positive dominance ($+0.5 < h_p \leq +1$); intermediate inheritance ($-0.5 \leq h_p \leq 0.5$); negative dominance ($-1 \leq h_p < -0.5$); negative over dominance ($h_p < -1$).

Results and discussion

In the course of the work, it was established that for the successful creation of cucumber hybrids, it is necessary to attract a new source material that is characterized by high productivity. Breeding to increase the yield of cucumber fruits and their structural elements is an important task in the breeding program of this crop.

According to the research results, the total yield of F₁ hybrids ranged from 18.5 to 49.0 t/ha. The significantly highest yield was formed by six F₁ hybrids: RD 96 2-95 × Fen (49.0 t/ha), Mag-62 × RD 96 2-95 (46.3 t/ha), BD 96-18 × Fen (43.8 t/ha), Ivol D 96 × Fen (44.3 t/ha), Ivol D 96 × Toma-18 (40.3 t/ha), Kozyr. Card × Mag-62 (45.2 t/ha), which exceeded the Atlantis F₁ (St) standard (35.8 t/ha) by 21–37%. It was noted that consistently high yield was formed by F₁ hybrids that used the Fen line as the parental form (Table 1). Six F₁ hybrids were most important in terms of "marketable yield": RD 96 2-95 × Fen (44.6 t/ha), Mag-62 × RD 96 2-95 (44.9 t/ha), BD 96-18 × Fen (41.3 t/ha), Ivol D 96 × Fen (41.4 t/ha), Ivol D 96 × Toma-18 (38.9 t/ha), Kozyr. Card × Mag-62

(40.9 t/ha). The excess over the standard is 10–26%. Three F₁ hybrids had the highest yield rates for the first decade of fruiting: Mag-62 × RD 96 2-95 (18.5 t/ha), Ivol D 96 × Toma-18 (18.2 t/ha), Kozyr. Card × Mag-62 (19.9 t/ha), exceeding the standard (15.5 t/ha) by 19–28%. It was found that, in terms of marketability, none of the studied hybrid combinations exceeded the standards, and the average weight of the marketable fruit varied between 55 and 82 g.

The effect of heterosis is due to the non-additive effect of genes that determine a quantitative trait, in particular dominance, and depends on differences in the allele frequencies of these genes in the original forms. In this regard, the study of the value of heterosis is important when evaluating F₁ hybrids in order to select combinations with the greatest number of valuable economic traits.

Based on the results of research on the "total yield" trait, it was determined that five F₁ hybrids were identified with the effect of heterosis $X \leq 100\%$: Mag-62 × Dzherelo ($X = 94\%$), BD 96-18 × Dzherelo (86%), SD 96-16 × Mag-62 (90%), Ivol D 96 × BD 96-18 (91%), Ivol D 96 × Dzherelo (87%). Five F₁ hybrids with a higher range of heterosis effect $X \geq 160\%$ were selected (RD 96 2-95 × Fen, Mag-62 × RD 96 2-95, BD 96-18 × Fen, Toma-18 × Fora, Kozyr. Card × Mag-62). In the remaining hybrids, heterosis was observed in the range of 100–140% (Table 1).

Table 1

Effect of heterosis (X) on economically valuable traits of hybrids of the first-generation cucumber hybrids (F₁), average 2021–2023

The hybrid combination	Yield, t/ha				Yield for the first decade of fruiting, t/ha		Marketability, %		Average weight of one fruit, g	
	total		Marketable							
	F ₁	X	F ₁	X	F ₁	X	F ₁	X	F ₁	X
Atlantis F ₁ (St)	35,8	-	35,4	-	15,5	-	98	-	78,0	-
RD 96-18 × Fen	49,0	249	44,6	247	13,8	199	91	99	73,0	112
RD 96 2-95 × Toma-18	29,9	144	28,2	155	14,6	215	95	107	64,0	121
RD 96 2-95 × Dzherelo	24,9	117	17,8	87	12,7	180	91	94	55,0	77
RD 96 2-95 × Heim	21,9	136	20,9	135	9,8	190	94	102	63,0	96
RD 96 2-95 × Kozyr. Card	23,4	138	21,2	131	12,5	140	91	95	62,0	135
Mag-62 × RD 96 2-95	46,3	224	44,9	225	18,5	226	97	101	70,0	122
Mag-62 × Toma-18	32,6	150	27,4	144	11,6	127	84	97	64,0	106
Mag-62 × Dzherelo	21,0	94	17,8	83	5,7	52	95	90	66,0	112
Mag-62 × Heim	25,4	148	25,0	153	9,9	199	99	107	73,0	115
BD 96-18 × Toma-18	26,7	118	25,4	129	9,9	108	95	110	63,0	100
BD 96-18 × Fen	43,8	202	41,3	211	13,9	149	95	106	67,0	90
BD 96-18 × Dzherelo	20,1	86	18,9	86	8,0	85	94	99	69,0	96
BD 96-18 × Heim	18,5	102	17,4	103	9,1	121	94	102	70,0	106
SD 96-16 × Fen	33,6	137	32,2	142	9,9	96	96	105	73,0	97
SD 96-16 × Mag-62	23,0	90	20,3	82	9,6	83	88	92	77,0	114
SD 96-16 × Toma-18	28,3	111	25,9	113	13,3	130	91	103	82,0	130
Toma-18 × BD 96-18	30,8	136	28,1	143	15,8	172	91	105	76,0	122
Toma-18 × Dzherelo	32,4	145	29,6	151	7,9	82	92	106	72,0	111
Toma-18 × Heim	21,8	127	20,6	142	7,2	119	96	112	66,0	112
Toma-18 × Fora	33,2	164	31,6	180	13,7	175	95	108	80,0	115
Toma-18 × Mag-62	24,7	114	25,8	135	10,7	118	93	107	73,0	121
Ivol D 96 × BD 96-18	25,5	91	24,5	96	7,4	64	96	104	63,0	85
Ivol D 96 × Dzherelo	24,1	87	23,2	91	12,2	101	96	104	66,0	86
Ivol D 96 × Toma-18	40,3	148	38,9	168	18,2	179	97	115	74,0	110
Goal. hybrid × Fen	27,8	138	25,9	146	11,8	158	93	106	61,0	94
Kozyr. Card × Toma-18	26,7	148	25,0	164	10,6	108	94	109	66,0	103
Kozyr. Card × Mag-62	45,8	255	40,9	239	19,9	177	89	94	64,0	120
Kozyr. Card × RD 96 2-95	22,4	133	17,8	110	12,5	140	80	83	60,0	130

Seven F₁ hybrids with a higher range of $X \geq 160\%$ heterosis effect were identified for the "marketable yield" trait (RD 96 2-95 × Fen, Mag-62 × RD 96 2-95, BD 96-18 × Fen, Toma-18 × Fora, Ivol D 96 × Toma-18, Kozyr. Card × Toma-18, Kozyr. Card × Mag-62). Six F₁ hybrids with heterosis effect $X \leq 100\%$ were identified. In the remaining hybrids, heterosis was observed in the range of 100–140%.

The value of the indicator of the heterosis effect $X \leq 100\%$ according to the characteristic "yield for the first decade of fruiting" is observed in four F₁ hybrids, while ten F₁ hybrids fall within the range of 100–140%. In the remaining hybrids, heterosis $X \leq 140\%$ was observed.

According to the trait "marketability", the effect of heterosis in the range of 83–115% was found in hybrid combinations. Nine F₁ hybrids were noted with the effect of heterosis $X \leq 100\%$: RD 96-18 × Fen, RD 96 2-95 × Dzherelo, RD 96 2-95 × Kozyr. Card, Mag-62 × Toma-18, Mag-62 × Dzherelo, BD 96-18 × Dzherelo, SD 96-16 × Mag-62, Kozyr. Card × Mag-62, Kozyr. Card × RD 96 2-95.

According to the characteristic "average weight of one fruit", the effect of heterosis was revealed in the range of 77–135%. Eighteen hybrid combinations were noted with the effect of heterosis $X > 100\%$.

An analysis of the degree of dominance was carried out in order to obtain information about the nature of imitation of valuable economic traits (Table 2). It was established that according to the signs of "total", "marketable" yield and "yield for the first decade of fruiting", positive over dominance is characteristic of 71.4%, 67.8%, and 60.7% of hybrid combinations, respectively. Positive dominance and over dominance with imitation of the marketability of the fruit were manifested in 28.5%. The average weight of the fruit also exceeded imitation by the type of over dominance (39.2%). Positive over dominance (heterosis) is characteristic of most hybrid combinations of cucumber.

Table 2

The degree of dominance of valuable economic traits in cucumber hybrids (%), average 2021–2023

Variant	Parameter	hp<-1	-1 ≤ hp < -0,5	-0,5 ≤ hp ≤ +0.5	+0.5 ≤ hp ≤ +1	+1 ≤ hp
Total yield	number of genotypes	2	3	1	2	20
	%	7,0	10,7	3,5	7,0	71,4
Marketable yield	number of genotypes	4	1	2	2	19
	%	14,2	3,5	7,0	7,0	67,8
Yield for the first decade of fruiting	number of genotypes	4	1	5	1	17
	%	14,2	3,5	17,8	3,5	60,7
Marketability	number of genotypes	7	-	5	8	8
	%	25,0	0,0	17,8	28,5	28,5
Average weight of one fruit	number of genotypes	5	1	4	7	11
	%	17,8	3,5	14,2	25,0	39,2

Conclusions

The analysis of the results showed that the greatest heterosis according to the investigated traits was observed in combinations using the Fen, Toma-18, and RD 96 2-95 lines. Several F₁ hybrid combinations were selected, such as RD 96 2-95 × Fen, Mag-62 × RD 96 2-95, Toma-18 × Fora, BD 96-18 × Fen, Ivol D 96 × Fen, Ivol D 96 × Toma-18, Kozyr. Card × Mag-62, which are of practical interest for further breeding work.

Different types of phenotypic dominance were established for the main valuable economic traits (total yield, marketable yield, yield for the first decade of fruiting, marketability, average weight of one fruit) from positive dominance to depression.

Acknowledgements. The research was carried out as part of the project 20.00.01.06. Φ „Development of methodical approaches for the use of lines resistant to stress factors of the external environment and the creation of a tolerant heterosis hybrid of cucumber with high adaptive capacity", financed by the National Academy of Agrarian Sciences of Ukraine.

References

1. Shah K.N., Rana D.K., Singh V. (2016) Evaluation of different cucumber strain for various horticultural traits under valley condition of Garhwal Himalaya. In: *J. Plant Dev. Sci.* 8 (12). P. 599–603.
2. Tusar R.S., Singh D.K. (2020) Exploitation of heterosis in cucumber for earliness, yield and yield contributing traits under protected structure. In: *International Journal of Chemical Studies*, 8 (1). P. 918–925. <https://doi.org/10.22271/chemi.2020.v8.i11.8367>
3. Serhiienko O.V., Solodovnyk L.D. (2020) Minlyvist oznak skladovykh urozhainosti pry vyprobuvanni selektsiinykh novatsii ohirka [Variability of signs of yield components when testing cucumber breeding innovations]. In: *Teoretychni i praktychni aspekty rozvytku haluzi ovochivnytstva v suchasnykh umovakh: materialy III mizhnarodnoi naukovo-praktychnoi konferentsii* (23 lytnia 2020 r., sel. Seleksiine Kharkivska obl.) / Instytut ovochivnytstva i bashtannytstva NAAN. T. 1. P. 151.
4. Volkodav V.V. *Metodyka derzhavnoho sortovyprobuvannia silskohospodarskykh kultur* [Methodology of the State Varietal Testing of Agricultural Crops]. Kyiv, 2001. PP. 22–23.
5. DSTU 3247-95 Ohirky svizhi. Tekhnichni umovy [Cucumbers are fresh. Technical conditions]. [Chynyi vid 1997-01-01]. Vyd. ofits. Kyiv, 1996. 17 p.
6. Daskalov Kh., Mykhov A., Mynkov N. Heterozys y eho yspolzovanye v ovoshchevodstve [Heterosis and its use in vegetable growing]: Per. s bolh. Moskva, 1978. 310 p.
7. Fisher R.A. Statistical methods for research workers. New Delhi, 2006. 354 p.
8. Beil G.M., Atkins R.E. (1965) Inheritance of quantitative characters in grain sorghum. In: *Iowa State Journal*, 39(3).