Peculiarities of heterosis manifested by yield and fruit quality traits in pepper F_1 hybrids developed using classical and MAS methods

O.G. Babak[1]*, T.V. Nikitinskaya[1], N.A. Nevestenko[2], I.G. Puhacheva[2], M.M. Dobrodkin[2], L.V. Khotyleva[1], A.V. Kilchevsky[1]

[1] *Institute of Genetics and Cytology, NASB, Minsk, Belarus*
[2] *Belarusian State Agricultural Academy, Gorki, Belarus*

DOI 10.18699/ICG-PlantGen2019-72

* e-mail: babak_olgal@mail.ru

Abstract: Results of a three-year-long assessment of heterosis manifestation peculiarities in F_1 *C. annum* hybrids based on fruit quality traits are presented. The selection of parental forms was carried out using forms with various alleles determining fruit quality (*Ccs, Cl, norc, APRR-2*) and disease resistance (*Me-1, pm*). Analysis of high heterosis in the hybrids revealed its diversified character for the majority of the signs studied, depending on the vegetation period conditions. According to the three-year average, the most frequent inheritance of yield was the dominance and overdominance followed by an increase in trait, whereas the inheritance of most biochemical characteristic have intermediate and overdominance types accompanied by a decrease in indicators. Based on the test results, we were able to identify hybrids that combine a high yielding capacity, a biological value of fruits and a high heterotic effect.

Key words: pepper; heterosis; yield and fruit quality.

1. Introduction

C. annuum fruits contain a large number of biologically active substances, so this culture is important as the functional foods of people. An important direction in the breeding and genetics of this culture is the development of varieties and hybrids with a high yielding capacity and better biochemical characteristics. Considering that yielding capacity is a quantitative trait, where a summing effect of alleles leads to a high heterotic effect and quality traits are determined by a small number of alleles, some aspects of heterosis manifested by yield and fruit quality traits in F_1 *C. annum* hybrids are given a brief overview in our research.

2. Materials and methods

As an experimental material, 9 parental forms and 16 F_1 hybrids of sweet pepper (crossing schemes 8 × 1 and 1 × 8) were studied in plastic unheated greenhouses (Table 1). Each line was selected using MAS methods with a specific set of genes for fruit quality and disease resistance: L 45-11 (1, *ccs/cl/norc427/pm*), 'Zholty buket' (2, ZB, *ccs*/*Cl/norc424/pm*), L 160-10 (3, Ccs/Cl*/norc427/Me1/pm*), 'Shokoladnaya krasavitsa' (4, SK, *cl/Ccs/Me1/pm/norc427*), 'Cherniy Krasavec' (5, CK, Cl/Ccs*/pm/norc427*), 'Oranzhevoe naslazhdenie' (6, ON, *ccs/Cl/norc427/Me1 /pm*), 'Sireneviy' (7, Si, *ccs/Cl/norc424/APRR-2-like*^{wh}*/pm),* L-80 (8, *Ccs/Cl/norc427/pm*), and L 140/10 (9, *Ccs/Cl /norc427/pm*). The *Ccs* allele provides for capsanthin and capsorubin accumulation in fruits, while *ccs* ensures their absence (Lang et al., 2004). The *cl* allele slows down the destruction of chlorophyll (Borovsky et al., 2008); *norc* affects ontogenetic stages (Babak et al., 2019). The *APRR-like* (*white*) allele is associated with the low accumulation of pigments in fruits (Pan et al., 2013). The *pm* allele provides for resistance to powdery mildew (Paran et al., 2009) and the *Me1* allele determines nematode resistance (Fazari et al., 2012). The features of the traits' manifestation in hybrids were evaluated during a three-year period (2016–2018) by the value of a dominance degree (Hp, Zhuchenko, 1980). As a standard, the pepper variety 'Troika' was used.

3. Results and discussion

Fruit yield value is shown in Table 1.

Based on the data presented, three hybrids surpassed the standard variety 'Troika' for their early yield and 10 hybrids, for their commercial and total yielding capacity. The fruit mass of all test forms was higher than that of the standard. Heterosis values in the hybrids varied depending on the conditions during the year. At the same time, according to average yield values, most hybrids showed dominance and overdominance towards the increased trait values, which is well illustrated by the peculiarities of the Hp value distribution in Figure 1.

Figure 2 shows the values of the measures reflecting the biochemical composition of the fruits.

By the content of dry matter, soluble carbohydrates and vitamin C, most hybrids were not comparable with the standard variety, but they were inferior to the standard by a carotenoid content. Based on the three-year test results, valuable F_1 hybrids were identified (L45-11 × 'Shokoladnaya krasavitsa', L45-11 × 'Zhelty buket', L45-11 × L140/0, L140/0 × L45-11), with a dry matter content of 8.18-8.77 %; carotene, 19.95-32.73 mg/kg; vitamin C, 112.49-144.4 mg/kg; and soluble carbohydrates, 4.36–4.77 %.

Figure 3 shows the inheritance of phenotypic manifestation of biochemical traits. According to the figures presented, heterosis effects in the hybrids studied are multidirectional, which is, in our opinion, determined by different compositions of fruit quality alleles. Furthermore, accumulation of dry matter and carotene in 50 % of the hybrids was inherited intermediately.

Table 1
Yield traits of pepper parental forms and their F_1 hybrids (the average for 2016-2018).

N	Sample designation	Fruit yield, kg/m^2			Fw*, g
		Y*	C*	G*	
1	L4511	0.15	2.93	3.01	113.7
2	ZB	0.41	3.76	3.93	120.3
3	L160/10	0.25	3.78	3.94	144.2
4	SK	0.11	4.69	4.77	155.1
5	CK	0.37	1.85	1.93	94.2
6	ON	0.53	3.61	3.72	118.6
7	Si	0.04	4.61	4.76	131.7
8	L80	0.24	3.50	3.64	157.3
9	L140/0	0.35	3.95	4.12	147.3
10	L4511 × L80	0.13	2.53	2.63	172.8
11	L4511 × ON	0.93	4.33	4.43	146.7
12	L4511 × Si	0.34	2.76	2.83	115.8
13	L4511 × SK	0.68	4.16	4.27	162.1
14	L4511 × L160/10	0.77	4.97	5.01	175.4
15	L4511 × CK	0.38	3.20	3.27	147.9
16	L4511 × ZB	0.69	3.63	3.79	127.8
17	L4511 × L140/0	0.29	3.55	3.71	154.9
18	L80 × L4511	0.60	4.11	4.22	164.9
19	L140/0 × L4511	0.74	4.23	4.40	136.6
20	ON × L4511	0.08	4.37	4.45	128.7
21	Si × L4511	0.23	3.43	3.49	136.9
22	SK × L4511	0.57	4.81	4.94	169.0
23	L160/10 × L4511	0.37	5.70	5.89	158.8
24	CK × L4511	0.91	4.21	4.23	122.4
25	ZB × L4511	0.91	3.76	3.92	136.5
26	Troika (st)	0.82	3.98	4.12	88.5

* Y: yearly' C: commercial' G: gross; Fw: fruit weight.

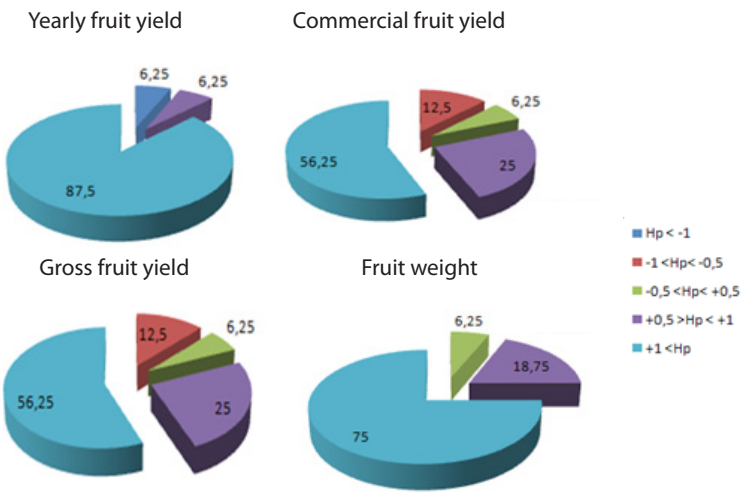

Figure 1. Peculiarities of dominance degree (Hp) manifestation in pepper hybrids by yield traits (average for 2016–2018 in %).

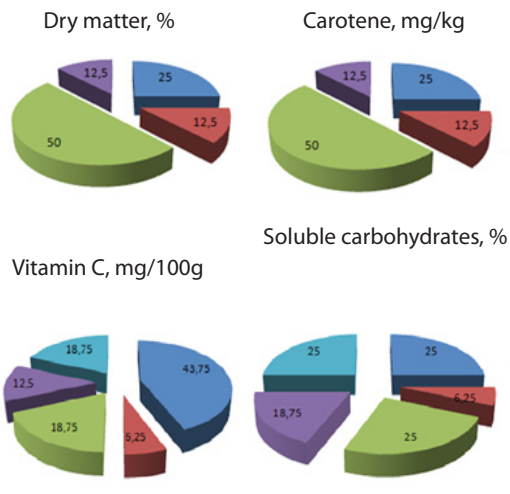

Figure 2. Manifestation of biochemical traits of the pepper parental forms and their F_1 hybrids (the average for 2016-2018). Numbering of samples as in Table 1.

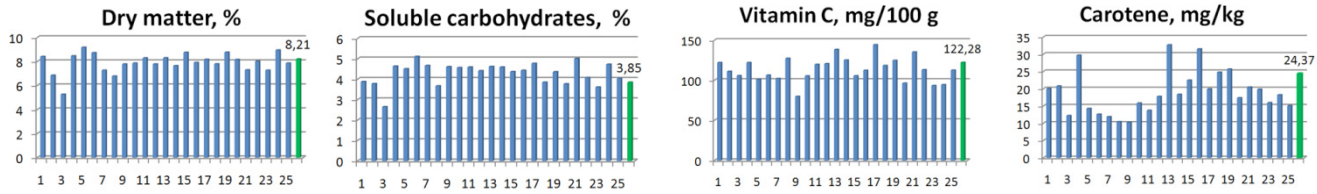

Figure 3. Level of dominance inheritance in manifestation of biochemical traits in pepper hybrids.

4. Conclusions

Our investigations generally show that, according to the three-year average, the most frequent inheritance of yield was the dominance and overdominance followed by an increase in yield traits, whereas the manifestation of the most biochemical traits have an intermediate type and overdominance accompanied by a decrease in indicators.

In this regard, we recommend to combine – in order to develop highly productive hybrids with improved biochemical qualities and resistant to diseases – the methods of classical heterotic breeding to increase yielding capacity and MAS methods to enhance disease resistance and improve the biochemical composition of fruits.

Based on the test results, we were able to identify hybrids that combine a high yielding capacity, a biochemical value of fruits and a high heterotic effect. Three best hybrid combinations with a complex of biometric features were selected and transferred to the State Inspection for Testing and Protection of Plant Varieties of the Republic of Belarus.

References

Babak O.G., Nikitinskaya T.V., Nekrashevich N.A., Yatsevich K.K., Kilchevsky A.V. Comparative analysis of gene homology of the NAC-NOR transcription factor in tomato and pepper and its polymorphism study. Molecular and Applied Genetics: Minsk. 2019;26: 7–18 (in Russian).

Borovsky Y., Paran I. Chlorophyll breakdown during pepper fruit ripening in the *chlorophyll retainer* mutation is impaired at the homolog of the senescence-inducible *stay-green* gene. Theor Appl Genet. 2008;117:235–240. DOI 10.1007/s00122-008-0768-5.

Fazari A., Palloix A., Wang L.H., Hua M.Y., Sage-Palloix A.M., Zhang B.X., Djian-Caporalino C. The root-knot nematode resistance N-gene co-localizes in the *Me*-genes cluster on the pepper (*Capsicum annuum* L.) P9 chromosome. Plant Breeding. 2012;131:665–673. DOI 10.1111/j.1439-0523.2012.01994.x.

Lang Y.-Q., Yanagawa S., Sasanuma T., Sasakuma T. Orange fruit color in *Capsicum* due to deletion of *capsanthin-capsorubin synthesis* gene. Breeding Science. 2004;54:33–39. DOI 10.1270/jsbbs.54.33.

Pan Y., Bradley G., Pyke K., Ball G., Lu C., Fray R., Marshall A., Jayasuta S., Baxter C., Wijk R., Boyden L., Cade R., Chapman N.H., Frase P.D., Hodgman C., Seymour G.B. Network inference analysis identifies an APRR2-like gene linked to pigment accumulation in tomato and pepper fruits. Plant Physiology. 2013;161:1476–1485. DOI 10.1104/pp.112.212654.

Paran I., Benarous S., Ashkenazi V. Disease resistant pepper plants. 2009. Patent WO2009098685 A2.

Zhuchenko A.A. Ekologicheskaya genetika kulturnyh rastenij. Kishinev: Shtiintsa, 1980, 586 pp (in Russian).

Conflict of interest. The authors declare no conflict of interest.