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INHERITANCE OF BERRY SKIN COLOUR IN VINE SEEDLINGS FROM COMPLEX INTERSPECIES HYBRID COMBINATIONS

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Abstract

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Research has been carried out into the characteristics of the inheritance of the trait berry colouring in vine seedlings from F_1 progeny of complex interspecies hybrid combinations. It has been found that the cultivars used in the separate crosses are characterized by different genotypes in terms of the studied trait, which leads to the observed great phenotypic diversity. The inheritance of berry colour takes place by monohybrid - dominant and incompletely dominant and dihybrid – epistatic scheme. The genetic analysis and determination of the individual genotype of parent cultivars related to that qualitative trait, present a theoretical possibility for increasing the efficiency of the selection process in vine in accordance with the concrete objective.

Key words: interspecies hybrid combinations, berry skin colour, variability, inheritance, probable genotypes

Introduction

The inheritance of berry colouring in vine has been a subject of numerous investigations dating back to the beginning of the previous century. The obtained experimental results have been reported in a number of scientific publications (Reimer and Detjen, 1914; Hedrick and Antony 1915; Stuckcy 1919; Muller-Thurgau and Kobel, 1924; Seeliger, 1925; Snyder, 1931; Pirovano, 1933; Negrul, 1936; Valchev, 1990). They indicate that the black colour of berry skin is manifested as a dominant and incompletely dominant trait and it dominates over the red and white colouring, which are considered as recessive traits. In hybrid combinations between cultivars with black and white berries, progenies are obtained with phenotypic decomposition 3 (black): 1 (white), black: red and black-red: white. According to Rasmuson (1916), berry colour is determined by two complementary genes – *C* – red and *D* – which does not form colour separately, and with *C* – gives blue colouring, with the following possible combinations: black – *CCDD* – progeny only with dark coloured berries, *CCDd* – decomposition of 3 (blue): 1 (red), *CcDD* – 3 blue: 1 white, *CcDd* – 9 blue: 3 red and 4 white; red – *CCdd* – only red coloured berries, *CcDd* – 3 red: 1 white; white – *ccDD* – only white, *ccDd* – only white, *ccdd* – only white. According to this trait, researchers divide the cultivars into three main cultivar groups – white, red and black, and a middle one – pink with different shades. Most experiments confirm the monohybrid-dominant or incompletely dominant inheritance of this trait. Golodriga et al. (1975) establish that in crosses between cultivars with white colour of berry skin – *aa*, 100% white are obtained; in black (*AA*) x black (*AA*) – 100% black; black (*Aa*) x black (*Aa*) – 3 black: 1 white; black (*Aa*) x white (*aa*) – 1 black: 1 white. The crosses between cultivars with black (*AA*) and red (*Aa*) berry skin decompose to 2 black: 1 red: 1 white. The hypothesis of Barritt and Einset (1969) is also of special interest – according to it two genes with dominant-epistatic interaction participate in the formation of berry colour. The white colour is determined by two recessive genes (bbrr), the red colour in the presence of R (bbRr) or (bbRR), and the

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black in the presence of one or two alleles of B, gene B being epistatic in regard to gene R. The inheritance of this trait corresponds both to the monohybrid-dominant or incompletely dominant model, and to the dihybrid one with complementary or epistatic gene interaction. The purpose of the current research is to determine the inheritance of berry colouring in complex interspecies hybrid combinations, where more studies are needed.

Materials and Methods

The investigation includes seedlings from F_1 progeny of 16 interspecies hybrid combinations with red (R), white (W) and pink (P) berry colour, which has been visually determined through multiannual observations of grapes during the physiological maturity of each plant from the separate crosses. The seedlings with red to dark red and blue-black colour of berry skin are united in a single group – red ones, due to the possibility for subjective determination of the nuances of red colour. In order to establish the genotype of the different cultivars according to the studied trait, a table is developed, showing the theoretically possible crosses between the genotypes and their decomposition depending on the main discussed hypotheses – monohybrid-dominant and incompletely dominant and dihybrid with gene interaction (epistatic and complementary). The criterion χ^2 has been used for verification of the zero hypothesis, in which, if the value of χ^2 is lower than the table value (χ^2 = 3.84 and $P_{0.05}$), the zero hypothesis is confirmed, meaning that the experimental and the theoretical ratios correspond to each other ($\chi^2_{experimental} > \chi^2_{theoretical}$ and $P_{experimental} > P_{0,05}$) (Genchev et al., 1975; Troshin and Frolova, 1976).

Results and Discussion

In crosses between cultivars with red berry colour and cultivars with white colour, in F_1 progeny only white coloured berries are observed, or red and white in the ratio 1R : 1W, 1W : 1P and 2R : 1W : 1P (Table 1). In the hybrid combinations between cultivars with red (R) and pink (P) berries, 100% seedlings with red berries have been obtained, and in cultivars with white (W) and pink (P) berries – 1W: 1P. This data shows that the used cultivars have different genotypes in terms of the studied trait, which leads to the reported phenotypic diversity. In the cross of the rootstock (R) Kober 5BB x (P) Pamid, 100% of the seedlings have red berries, as well as in (R) Kober 5BB x (W) Rkatsiteli, (W) Danube lazur, (W) Srebrostrui, (W) Pomoriiski biser, (W) Druzhba (cultivars with white berries) – again 100% of the seedlings possess red coloured berries. According to the scale of monohybrid

Table 1
Inheritance of the trait berry colour in interspecies hybrid combinations

Hybrid combinations	Total	Red		White		Pink		Theoretical ratio				
	number	number	%	number	%	number	%	R	W	P	χ^2	*P*
(R) Kober 5 BB x (P) Pamid	88	88	100	–	–	–	–	–	–	–	–	–
(R) Kober 5 BB x (W) Rkatsiteli	120	120	100	–	–	–	–	–	–	–	–	–
(R) Kober 5 BB x (W) Danube lazur	142	142	100	–	–	–	–	–	–	–	–	–
(R) Kober 5 BB x (W) Srebrostrui	129	129	100	–	–	–	–	–	–	–	–	–
(R) Kober 5 BB x (W) Pomoriiski biser	116	116	100	–	–	–	–	–	–	–	–	–
(R) Kober 5 BB x (W) Druzhba	196	196	100	–	–	–	–	–	–	–	–	–
(R) Kober 5 BB x (R) Danube gamza	259	259	100	–	–	–	–	–	–	–	–	–
(W) Seyve Villard 12375 x (W) Pleven	23	–	–	23	100	–	–	–	–	–	–	–
(W) Naslada x (W) Plevenski favorit	28	–	–	28	100	–	–	–	–	–	–	–
(W) Augustin x (W) Nedelchev VI–4	28	–	–	28	100	–	–	–	–	–	–	–
(W) Naslada x (R) Jubilee moldovskii	23	11	47.8	12	52.2	–	–	1	1	–	$0.04 > P_{0.50}$	
(W) Naslada x (R) Strashinski	26	12	46.1	14	53.9	–	–	1	1	–	$0.04 > P_{0.50}$	
(W) Seyve Villard 12375 x (R) Muscat plevenski	27	14	51.8	13	48.2	–	–	1	1	–	$0.04 > P_{0.50}$	
(W) Augustin x (P) Kishmish luchistii	25	–	–	8	32.0	17	68.0	–	1	1	$3.14 > P_{0.05}$	
(W) Plevenski favorit x (P) Kishmish luchistii	27	–	–	17	63.0	10	37.0	–	1	1	$1.81 > P_{0.22}$	
(W) Augustin x (R) Kishmish moldovskii	28	15	53.6	6	21.4	7	25.0	2	1	1	$0.57 > P_{0.75}$	

Legend: Berry colouring – (R) – red; (W) – white; (P) – pink

Table 2
Probable genotypes of the parent cultivars participating in the studied hybrid combinations

№	Colour	CULTIVAR	Monohybrid inheritance		Dihybrid inheritance	
			Dominant	Incompletely dominant	Epistatic	Complementary
			I. Hybrid combinations with the rootstock Kober 5 BB			
1	R	Kober	AA	–	–	–
2	P	Pamid	–	Aa	–	–
3	W	Rkatsiteli	aa	aa	–	–
4	W	Danube lazur	aa	aa	–	–
5	W	Srebrostrui	aa	aa	–	–
6	W	Pomoriiski biser	aa	aa	–	–
7	W	Druzhba	aa	aa	–	–
8	R	Danube gamza	AA	–	–	–
			II. Hybrid combinations between the separate cultivars			
1	W	Seyve Villard 12375	aa	–	ccdd	ccdd, ccDD, ccDd
	W	Pleven	aa	–	ccdd	ccdd, ccDD, ccDd
2	W	Naslada	aa	–	ccdd	ccdd, ccDD, ccDd
	W	Plevenski favorit	aa	–	ccdd	ccdd, ccDD, ccDd
3	W	Augustin	aa	–	ccdd, ccDd	ccdd, ccDD, ccDd
	W	Nedelchev VI–4	aa	–	ccdd	ccdd, ccDD, ccDd
4	W	Naslada	aa	–	ccdd	–
	R	Jubilee moldovskii	Aa	–	Ccdd	–
5	W	Naslada	aa	–	ccdd	–
	R	Strashinski	Aa	–	Ccdd	–
6	W	Seyve Villard 12375	–	–	ccDD	–
	R	Muscat plevenski	–	–	Ccdd	–
7	W	Augustin	aa	aa	ccDD, ccDd	ccDD
	P	Kishmish luchistii	–	Aa	CcDD, CcDd	CCDD
8	W	Plevenski favorit	–	Aa	ccDD, ccdd	ccDD
	P	Kishmish luchistii	–	Aa	CcDD, CcDd	CCDD
9	W	Augustin	–	–	ccDd, CcDD	–
	R	Kishmish moldovskii	–	–	Ccdd	–

Legend: Berry colouring – (R) – red; (W) – white; (P) – pink.

decomposition, the inheritance of this trait completely corresponds to the monohybrid-dominant model (Table 2). This means that the rootstock Kober 5BB has genotype AA, and the remaining cultivars Rkatsiteli, Danube lazur, Srebrostrui, Pomoriiski biser and Druzhba – aa (Table 3). The rootstock (R) Kober 5BB and (R) Danube gamza have genotype AA, since 100% of the seedlings in their cross are with red coloured berries.

In the hybrid combinations (W) Seyve Villard 12375 x (W) Pleven, (W) Naslada x (W) Plevenski favorit and (W) Augustin x (W) Nedelchev VI-4, seedlings with 100% white berry colouring have been obtained, corresponding to genotype aa by the monohybrid scheme, ccdd by the epistatic one; in Augustin ccDd is also possible and for complementariness – ccdd, ccDD and ccDd.

In the hybrid combinations (W) Naslada x (R) Jubilee moldovskii and (W) Naslada x (R) Strashinski, the decomposition in F_1 progeny is 1 W : 1 R, which corresponds to the monohybrid-dominant and the epistatic model, Naslada having genotype aa or ccdd, Jubilee moldovskii and Strashinski – Aa or Ccdd. In (W) Seyve Villard 12375 x (R) Muscat plevenski the ratio is 1 W : 1 R, corresponding to the epistatic model with genotype of Seyve Villard 12375 – ccDD and of Muscat plevenski – Ccdd. For (W) Augustin x (P) Kishmish luchistii and (W) Plevenski favorit x (P) Kishmish luchistii, this ratio is 1 W : 1 P, corresponding to the monohy-

Table 3
Comparability of the results obtained from the inheritance of berry colour in the studied interspecies hybrid combinations

№	Hybrid combinations	Monohybrid inheritance							
		Dominant				Incompletely dominant			
		Colour	R	P	W	Colour	R	P	W
1	AA homozygous x AA homozygous	R x R	1	–	–	R x R	1	–	–
2	AA homozygous x aa homozygous	R x W	1	–	–	R x W	–	1	–
3	AA homozygous x Aa heterozygous	R x R	1	–	–	R x P	2	1	1
4	Aa heterozygous x aa homozygous	R x W	1	–	1	P x W	–	1	1
5	Aa heterozygous x Aa heterozygous	R x R	3	–	1	P x P	1	2	1
6	Aa homozygous x aa homozygous	W x W	–	–	1	W x W	–	–	1
	Hybrid combinations	Dihybrid inheritance							
		Epistatic				Complementary			
		Colour	R	P	W	Colour	R	P	W
1	Ccdd x ccdd	R x W	1	–	1	W x W	–	–	1
2	ccDD x Ccdd	W x R	–	1	1	W x W	–	1	1
3	ccDD x CcDd	W x P	–	1	1	W x P	–	1	1
4	ccDD x CcDD	W x P	–	1	1	W x P	–	1	1
5	CCDD x ccDD	P x W	–	1	1	W x W	–	1	1
6	CcDD x ccdd	P x W	–	1	1	P x W	–	1	1
7	CCDd x ccdd	P x W	1	1	–	P x W	–	1	1
8	CcDD x ccDd	P x W	1	1	–	P x W	–	1	1
9	CCdd x CCdd	R x R	1	–	–	W x W	–	–	1
10	CCdd x Ccdd	R x R	1	–	–	W x W	–	–	1
11	CCdd x ccdd	R x W	–	1	–	W x W	–	1	–
12	ccdd x ccdd	W x W	–	–	1	–	–	–	–

LEGEND: Berry colouring – (R) – red; (W) – white; (P) – pink

brid-incompletely dominant, with genotype aa for the parent with white berries and Aa with pink, epistatic – ccDD, ccDd – white and CcDD, CcDd – pink and complementary – ccDD – white and CCDD – pink. In (W) Augustin x (R) Kishmish moldovskii the decomposition is in a ratio 2 R : 1 W : 1 P and it corresponds to the epistatic model with genotype for Augustin – ccDd, CcDD and Kishmish moldovskii – Ccdd.

The genetic analysis of the hybrid combinations between (R) Kober 5BB and the cultivars with white berry skin indicates that in F_1 progeny the red colour is manifested as dominant and it completely coincides with the experimental data of other authors included in the References section. In (W) Naslada x (R) Jubilee moldovskii, (W) Naslada x (R) Strashinski and (W) Seyve Villard 12375 x (R) Muscat plevenski, decomposition of 1 R : 1 W has been obtained, which also confirms the dominant character of the red colour. In (W) Augustin x (P) Kishmish luchistii and (W) Plevenski favorit x (P) Kishmish luchistii, the decomposition is 1 W : 1 P. This means that Kishmish luchistii is heterozygous, and a cultivar participates in its genotype with red coloured berries, with incomplete dominance, which, when crossed with a cultivar with white colour in F_1 progeny gives pink colour to the berries. That is the reason why the pink colouring of berries is considered heterozygous, corresponding to the monohybrid-incompletely dominant and epistatic model. In (W) Augustin x (R) Kishmish moldovskii the ratios between the different berry colours are 2 R : 1 W : 1 P, which means that the red colour in Muscat plevenski and Kishmish moldovskii is inherited incompletely dominantly or complementarily, according to Rasmuson's hypothesis (1916).

Conclusions

The genetic analysis related to inheritance in F_1 progeny in interspecies hybrid combinations between vine cultivars with red, white and pink berry colouring, as well as the determination of the individual genotype of parent cultivars, offer a theoretical possibility for increasing the efficiency of the selection process aimed at the development of new cultivars, in accordance with the purpose of the selection programme.

The inheritance of this trait occurs by monohybrid – dominant and incompletely dominant and dihybrid – epistatic scheme.

In F_1 progeny of hybrid combinations between cultivars with red and white colour of berry skins, seedlings are observed only with white berry colour, or with red, white and pink colour in the ratios 1 R : 1 W, 1 W : 1 P and 2 R : 1 W : 1 P. In crosses between cultivars with red and pink berries – 100% of the plants have red berries, and in cultivars with white and pink berries, the ratio is 1 W : 1 P. As a result of crossing the rootstock Kober 5BB with Pamid and cultivars with white berries – Rkatsiteli, Danube lazur, Srebrostrui, Pomoriiski biser, Druzhba, 100% seedlings with red coloured berries are obtained. The inheritance of this trait entirely corresponds to the monohybrid – dominant model, and the rootstock Kober 5BB has genotype AA, while the remaining cultivars are with aa.

In the crosses Seyve Villard 12375 x Pleven, Naslada x Plevenski favorit and Augustin x Nedelchev VI-4, in F_1 progeny 100% seedlings with white berry colour have been obtained, which corresponds to genotype aa by the monohybrid scheme and ccdd by the epistatic one; in Augustin ccDd is also possible, and for complementariness – ccdd, ccDD and ccDd. In Naslada x Jubilee moldovskii, Naslada x Strashinski, the decomposition is 1 W : 1 R, which corresponds to the monohybrid-dominant and the epistatic model. The cultivar Naslada has genotype aa or ccdd, and Jubilee moldovskii and Strashinski – Aa or Ccdd. In Seyve Villard 12375 x Muscat plevenski the ratio is 1 W : 1 R, corresponding to the epistatic model with genotype of Seyve Villard 12375 – ccDD and of Muscat plevenski – Ccdd.

The decomposition in F_1 progeny for the crosses Augustin x Kishmish luchistii and Plevenski favorit x Kishmish luchistii is 1 W : 1 P, corresponding to the monohybrid-incompletely dominant, with genotype aa – for the parent with white berries and Aa – with pink, and epistatic – ccDD, with white ccDd and CcDD, CcDd – pink, and for complementary – ccDD for white and CCDD for pink. In Augustin x Kishmish moldovskii the decomposition is in a ratio 2 R : 1 W : 1 P and it corresponds to the epistatic model with genotype ccDd, CcDD for Augustin and Ccdd – Kishmish moldovskii.

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