



## Heterosis and heterobeltiosis for morpho-physical, phenolics, flavonoids and antioxidants in grape (*Vitis vinifera*) hybrids

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### ABSTRACT

Eleven coloured hybrids and their 9 parental genotypes were evaluated for bunch weight, berry weight, juice recovery, total soluble solids (TSS), total monomeric anthocyanins (TMA), total phenolics (TP), total flavonoids (TF) and antioxidant activities (AOX) in terms of CUPRAC, FRAP and DPPH. Data analysis indicated significant differences in the traits under study. The substantial positive mid-parent and better-parent heterosis was found for TSS, TMA, total flavonoids, CUPRAC and FRAP. The negative mid-parent heterosis and heterobeltiosis was exhibited for bunch weight, berry weight, juice recovery, total phenolics, and DPPH activity. The results suggest that hybrid ER-R<sub>2</sub>P<sub>36</sub> and hybrid 16/2A-R<sub>1</sub>P<sub>8</sub> can be considered as good source of natural antioxidants and having higher TSS content.

**Key words:** Antioxidants, Biochemical traits, Grape, Heterobeltiosis, Heterosis

Worldwide, grape (*Vitis vinifera* L.) is widely cultivated for its delicious and nutritive berries. It holds a unique position among the fruits and grown in large scale. According to FAO (2013) estimates 67.2 million tonnes of grapes being produced from an area of around 6.9 million ha in world. India ranks ninth in grape production, with an annual production of 2.43 million tonnes from an acreage of 0.12 million ha with very high (21.10 t/ha) productivity (NHB 2014).

Now a days, there is need to develop hybrids with higher yield potential along with better nutritive value (Ibanez *et al.* 2015). The scope for exploitation of hybrid vigour largely depends on the direction and magnitude of the heterosis and ease with which hybrid can be produced. The reproductive biology and production of appreciable quantity of F<sub>1</sub> hybrids in with seeded parents provide ample opportunity for manifestation of heterosis in grapevines. The heterosis in positive side of the quantitative traits in grapevines has always been of interest to grape breeders for greater economic importance. The use of heterosis for getting higher yield and improved quality has been largely used in cross-pollinated crops (Inamullah *et al.* 2006). These

breeding programs are essential to maintain heterozygosity with improved quality traits (Alleweldt and Possingham 1988). Grape breeding has contributed significantly towards improvements in yield and quality.

In majority of grape growing countries, breeding objectives focused towards large size, easily breakable and firm flesh, high soluble solids concentration, and low acidity, in addition to high nutritive value, good appearance, seedlessness and early maturity (Ban *et al.* 2016, Yamada and Sato 2016, Yamamoto 2016). So far, hybridization has been based on parental phenotypes; cultivars with superior performance for a given traits (Seedlessness, berry size and bioactive compounds) are crossed. This approach has produced many promising cultivars (Yamada and Sato 2016). This investigation was undertaken to ascertain the nature and extent of heterosis for morpho-physical berry and bunch traits and the biochemical components of berry juice.

### MATERIALS AND METHODS

All the investigations were carried out on the seedling population, obtained by hybridization. The vineyard of seedling progenies is situated at the experimental farm of Division of Fruits and Horticultural Technology, ICAR-Indian Agricultural Research Institute, New Delhi. A total of 20 grape genotypes including eleven hybrids and 9 parents were evaluated (Table 1). Berries were harvested from the mature vines at full maturity. The berries of uniform size, shape, colour, free from injuries were sorted out and used for this experiment. Five uniform bunches from the selected vines were used for taking morpho-physical parameters. Randomly selected 100 berries from each genotype were

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Table 1 List of grape hybrids and their parents.

Hybrid	Female parent	Male parent
	♀	♂
Hy.16/2A-R <sub>1</sub> P <sub>2</sub>	Madeleine Angevine	Ruby Red
Hy.16/2A-R <sub>1</sub> P <sub>7</sub>	Madeleine Angevine	Ruby Red
Hy.16/2A-R <sub>1</sub> P <sub>8</sub>	Banqui Abyad	Beauty seedless
Hy.16/2A-R <sub>1</sub> P <sub>14</sub>	Banqui Abyad	Beauty seedless
Hy.16/2A-R <sub>1</sub> P <sub>18</sub>	Banqui Abyad	Beauty seedless
Hy.16/2A-R <sub>1</sub> P <sub>19</sub>	Black Muscat	Beauty seedless
Hy.16/2A-R <sub>3</sub> P <sub>12</sub>	Pearl of csaba	Beauty seedless
Hy.16/2A-R <sub>4</sub> P <sub>13</sub>	Pearl of Csaba	Beauty seedless
Hy.ER-R <sub>1</sub> P <sub>19</sub>	Pearl of Csaba	Beauty seedless
Hy.ER-R <sub>2</sub> P <sub>19</sub>	Cardinal	Beauty seedless
Hy.ER-R <sub>2</sub> P <sub>36</sub>	Hur	A-5

chosen for evaluating the biochemical parameters. Four replicates for each cultivar were used for analytical work. Physical parameters were analyzed from whole intact fruit. The total phenolic content was determined, using Folin-Ciocalteu reagent method (Singleton *et al.* 1999). The total flavonoid content was measured as per method described by Zhishen *et al.* (1999). The quantity of the total monomeric anthocyanin was measured by UV-VIS Spectrophotometer using the pH-differential method (Wrolstad *et al.* 2005). The antiradical capacity of the sample extract was measured as DPPH as suggested by Brand-Williams *et al.* (1995) and modified by Sanchez-Moreno *et al.* (1998). The ferric reducing antioxidant power assay was done according to Benzie and Strain (1996) method. The Cupric reducing antioxidant capacity was used for measurement of antioxidant capacity of grape (Apak *et al.* 2008). The data were averaged and the mean values obtained were used for statistical analysis.

The data sets were analyzed through statistical tool univariate analysis of variance. The statistical analysis software SPSS 12 was used. The values of mid parent heterosis and better parent heterosis (heterobeltiosis) were calculated according to the method given by Matzingar *et al.* (1962) as given the formulae:

$$\text{Heterosis (\%)} = \frac{F1-MP \times 100}{MP}$$

$$\text{Heterobeltiosis (\%)} = \frac{F1-BP \times 100}{BP}$$

F1, MP and BP in the formulae denote the performance of hybrid, average performance of parents and performance of better parent, respectively.

## RESULTS AND DISCUSSIONS

The analysis of variance, means for the parents and hybrids are given in Table 2 and 3. The data indicates highly significant differences among the hybrids and parents for all the traits studied. Character-wise discussion of the results is summarized below.

Table 2 Analysis of variance for the characters studied.

Characters	Mean squares			LSD
	Replications df (3)	Genotypes (hybrids + parents) df (19)	Error df (57)	
Bunch weight	8676.83	22976.32	674.99**	36.79
Berry weight	0.64	5.38	0.06**	0.34
Juice %	2.77	166.00	1.48**	1.72
TSS	8.29	16.02	0.43**	0.93
Total monomeric anthocyanins	283.42	145192.71	28.13**	7.53
Total phenolics	0.23	10744.91	1.63**	1.81
Total flavonoids	1.25	5716.91	1.78**	1.89
FRAP	0.00004	26.58	0.0002**	0.16
CUPRAC	00017	344.27	0.002**	0.45
DPPH	0.015	6.322	0.01**	0.18

### Bunch weight

The large bunch size is a desirable trait contributing in the higher productivity of grapevines. In majority of the hybrids, the negative heterosis over mid parent was recorded. However, it was recorded positive in hybrid ER-R<sub>2</sub>P<sub>36</sub> (Table 4). The maximum mid parent and better parent heterosis values were +61.14% and +13.74%, respectively (Table 4 and 5) for the hybrid ER-R<sub>2</sub>P<sub>36</sub> alone. Roytchev (2000) reported that the bunch weight is inherited by incomplete dominance over smaller bunches and it has variable response due to genotypes towards heterosis for berry weight.

### Berry weight

Berry size per bunch determines the bunch weight and positively attribute towards the productivity. Analysis of the data revealed that 3 out of 11 hybrids were showed positive mid parent heterosis as well as better parent heterosis. The maximum positive mid parent heterosis was recorded for hybrid 16/2A-R<sub>1</sub>P<sub>14</sub> (+49.42%) followed by 16/2A-R<sub>4</sub>P<sub>13</sub> (+35.59%) and ER-R<sub>2</sub>P<sub>19</sub> (+34.67%); whereas, positive better parent heterosis was found significantly higher in hybrid ER-R<sub>2</sub>P<sub>19</sub> (+28.85%). The high heterosis values for berry weight confirming the higher variability for this trait in the population. This variable heterosis is mainly due to genetic inheritance pattern of the trait which is governed by polygenes and larger berry size is partial dominant over small (Milutinovic *et al.* 2000).

### Juice recovery

The highest mean value for juice recovery was recorded (Table 3) for hybrid 16/2A-R<sub>4</sub>P<sub>13</sub> (77.20%). Heterotic studies revealed that the 8 out of 11 hybrids were positive by heterotic over mid parent value (Table 4). The maximum positive heterosis for juice recovery over mid parent was displayed by hybrid 16/2A-R<sub>4</sub>P<sub>13</sub> (+19.48%) followed by 16/2A-R<sub>1</sub>P<sub>14</sub> (+18.40%) and 16/2A-R<sub>3</sub>P<sub>12</sub> (+17.72%).

Table 3 Means of hybrids, parental means, mid parent value observed for various morpho-physical, nutraceutical and antioxidant traits of grape

Hybrid No.	Hybrid/parent	Bunch weight (g)	Berry weight (g)	Juice (%)	TSS ( <sup>o</sup> Brix)	TMA (mg/kg)	Total phenolics (mg/100g)	Total flavonoids (mg/100)	FRAP (μmol/g)	CUPRAC (μmol/g)	DPPH (μmol/g)
Hy.1	Hy.16/2A-R1P2	129.35	2.10	72.40	16.28	196.11	304.22	128.03	6.62	15.92	8.82
	MA (P1)	144.25	2.05	69.33	16.70	181.69	172.44	73.08	5.69	14.67	9.25
	RR(P2)	127.50	2.50	69.35	17.08	91.88	201.02	68.66	6.02	10.38	8.62
Hy.2	Hy.16/2A R1P7	120.35	1.13	62.28	19.70	250.59	227.15	109.61	7.36	27.26	7.24
	MA (P1)	144.25	2.05	69.33	16.70	181.69	172.44	73.08	5.69	14.67	9.25
	RR(P2)	127.50	2.40	69.35	17.08	91.88	201.02	68.66	6.02	10.38	8.62
Hy-3	Hy. 16/2AR1P8	149.20	1.45	66.43	18.68	258.94	276.05	135.17	5.94	24.58	5.37
	Hur(P1)	289.85	3.65	72.65	17.65	0.00	194.92	74.10	0.46	6.21	7.54
	A-5(P2)	134.55	2.38	65.48	17.08	51.80	101.36	41.02	2.02	5.60	6.66
Hy-4	Hy.16/2A R1P14	185.25	4.80	76.15	19.05	386.06	181.08	129.71	7.73	27.72	6.47
	Card(P1)	165.30	4.05	69.48	17.50	67.08	180.11	66.50	7.24	12.47	10.38
	BS(P2)	278.23	2.38	59.15	16.28	217.80	208.43	99.88	6.33	18.90	8.46
Hy-5	Hy.16/2A-R1P18	118.35	0.85	73.00	18.40	640.72	197.31	110.82	5.53	17.05	8.21
	BA(P1)	292.93	3.53	70.08	17.10	0.00	128.81	41.47	3.53	6.58	9.74
	BS(P2)	278.23	2.38	59.15	16.28	217.80	208.43	99.88	6.33	18.90	8.46
Hy-6	Hy.16/2A R1P19	135.08	1.40	56.21	18.00	438.79	217.80	97.02	12.07	31.94	9.36
	BA(P1)	292.93	3.53	70.08	17.10	0.00	128.81	41.47	3.53	6.58	9.74
	BS(P2)	278.23	2.38	59.15	16.28	217.80	208.43	99.88	6.33	18.90	8.46
Hy-7	Hy.16/2A R3P12	130.03	2.03	72.40	17.83	324.06	189.70	175.29	8.48	25.84	7.86
	BM(P1)	325.23	4.48	63.85	17.43	65.92	268.47	44.49	6.71	11.58	6.80
	BS(P2)	278.23	2.38	59.15	16.28	217.80	208.43	99.88	6.33	18.90	8.46
Hy-8	Hy.16/2A R4P13	189.18	4.00	77.20	17.90	553.63	172.34	115.00	8.53	31.78	8.31
	BA(P1)	292.93	3.53	70.08	17.10	0.00	128.81	41.47	3.53	6.58	9.74
	BS(P2)	278.23	2.38	59.15	16.28	217.80	208.43	99.88	6.33	18.90	8.46
Hy-9	Hy. ER-R1P19	118.18	1.38	63.87	19.98	438.79	246.19	126.64	4.24	5.41	7.54
	PoC(P1)	114.55	2.60	70.86	17.03	0.00	140.54	47.05	3.22	6.34	7.75
	BS(P2)	278.23	2.38	59.15	16.28	217.80	208.43	99.88	6.33	18.90	8.46
Hy-10	Hy. ER-R2P19	108.75	3.35	69.68	19.45	392.13	190.16	116.37	4.03	5.18	7.37
	PoC(P1)	114.55	2.60	70.86	17.03	0.00	140.54	47.05	3.22	6.34	7.75
	BS(P2)	278.23	2.38	59.15	16.28	217.80	208.43	99.88	6.33	18.90	8.46
Hy-11	Hy. ER-R2P36	316.45	2.33	70.38	23.55	179.13	123.13	133.09	4.39	13.26	9.63
	PoC(P1)	114.55	2.60	70.86	17.03	0.00	140.54	47.05	3.22	6.34	7.75
	BS(P2)	278.23	2.38	59.15	16.28	217.80	208.43	99.88	6.33	18.90	8.46
	Max.	325.23	4.80	77.20	23.55	640.72	304.22	175.29	12.07	31.94	10.38
	Min	108.75	0.85	56.21	16.28	0.00	101.36	41.02	0.46	5.18	5.37
	Mean	205.91	2.64	66.53	17.35	176.60	188.09	84.96	5.48	14.54	8.34

P1= Parent1; P2= Parent2; Hy= hybrid; MA= Madeline Angevine; RR= Ruby Red; Card= Cardinal; BS= Beauty Seedless; BA= Banqui Abyad; BM= Black Muscat; PoC= Pearl of Csaba.

Table 4 Heterotic values (%) for important traits of grape in the 11 hybrids

Hybrid	Bunch weight	Berry weight	Juice	TSS	TMA	Total phenolics	Total flavonoids	FRAP	CUPRAC	DPPH
Hy.16/2A-R <sub>1</sub> P <sub>2</sub>	-4.80	-7.69	4.42	-3.60	43.37	62.92	80.66	13.13	27.12	-1.31
Hy.16/2A-R <sub>1</sub> P <sub>7</sub>	-11.43	-49.44	-10.19	16.65	83.20	21.65	54.67	25.80	117.69	-19.01
Hy.16/2A-R <sub>1</sub> P <sub>8</sub>	-29.69	-51.87	-3.82	7.56	899.72	86.34	134.82	379.57	316.20	-24.35
Hy.16/2A-R <sub>1</sub> P <sub>14</sub>	-16.46	49.42	18.40	12.79	171.03	-6.79	55.93	13.90	76.74	-31.31
Hy.16/2A-R <sub>1</sub> P <sub>18</sub>	-58.56	-71.19	12.98	10.25	488.35	17.01	56.80	12.18	33.85	-9.75
Hy.16/2A-R <sub>1</sub> P <sub>19</sub>	-52.70	-52.54	-13.01	7.85	302.93	29.17	37.28	144.95	150.75	2.88
Hy.16/2A-R <sub>3</sub> P <sub>12</sub>	-56.91	-40.88	17.72	5.80	128.44	-20.44	142.83	29.99	69.55	3.08
Hy.16/2A-R <sub>4</sub> P <sub>13</sub>	-33.76	35.59	19.48	7.25	408.38	2.21	62.72	72.96	149.46	-8.69
Hy.ER-R <sub>1</sub> P <sub>19</sub>	-39.83	-44.72	-1.75	19.98	302.93	41.10	72.38	-11.27	-57.16	-7.04
Hy.ER-R <sub>2</sub> P <sub>19</sub>	-44.62	34.67	7.18	16.80	260.08	8.99	58.40	-15.62	-58.91	-9.13
Hy.ER-R <sub>2</sub> P <sub>36</sub>	61.14	-6.53	8.26	41.42	64.49	-29.43	81.15	-8.07	5.13	18.77

Table 5 Heterobeltiotic values (%) for important traits of grape in 11 hybrids

Hybrid	Bunch weight	Berry weight	Juice	TSS	TMA	Total phenolics	Total flavonoids	FRAP	CUPRAC	DPPH
Hy.16/2A-R <sub>1</sub> P <sub>2</sub>	-10.33	-16.00	4.40	-4.66	7.93	51.33	75.19	10.03	8.54	-4.64
Hy.16/2A-R <sub>1</sub> P <sub>7</sub>	-16.57	-53.13	-10.20	15.37	37.92	13.00	49.99	22.35	85.87	-21.74
Hy.16/2A-R <sub>1</sub> P <sub>8</sub>	-48.53	-60.27	-8.57	5.81	399.86	41.62	82.41	193.80	295.73	-28.76
Hy.16/2A-R <sub>1</sub> P <sub>14</sub>	-33.42	18.52	9.60	8.86	77.25	-13.12	29.87	6.74	46.70	-37.66
Hy.16/2A-R <sub>1</sub> P <sub>18</sub>	-59.60	-75.89	4.17	7.60	194.18	-5.34	10.95	-12.63	-9.76	-15.67
Hy.16/2A-R <sub>1</sub> P <sub>19</sub>	-53.89	-60.28	-19.79	5.26	101.47	4.50	-2.86	90.78	69.05	-3.87
Hy.16/2A-R <sub>3</sub> P <sub>12</sub>	-60.02	-54.75	13.39	2.32	48.79	-29.34	75.50	26.28	36.74	-7.06
Hy.16/2A-R <sub>4</sub> P <sub>13</sub>	-54.84	13.48	10.17	4.68	154.19	-17.31	15.14	34.71	68.18	-14.67
Hy.ER-R <sub>1</sub> P <sub>19</sub>	-57.53	-47.12	-9.86	17.36	101.47	18.12	26.79	-33.04	-71.40	-10.92
Hy.ER-R <sub>2</sub> P <sub>19</sub>	-155.84	28.85	-1.67	14.24	80.04	-8.76	16.51	-36.32	-72.56	-12.93
Hy.ER-R <sub>2</sub> P <sub>36</sub>	13.74	-11.83	-0.68	38.33	-17.75	-40.93	33.25	-30.63	-29.81	13.81

However, positive heterobeltiosis (Table 5) was recorded in 5 hybrids out of 11 and maximum was in hybrid 16/2A-R<sub>3</sub>P<sub>12</sub> (+13.39%)

#### Total soluble solids

The data on means for total soluble solids (TSS) revealed that it was varied highly and in most of the hybrids a positive heterosis as well as heterobeltiosis was recorded except in hybrid 16/2A-R<sub>1</sub>P<sub>2</sub> where it was found negative (-) 3.60% and (-) 4.66%, respectively (Table 4 and 5). The maximum positive mid parent heterosis revealed by the hybrid 'ER-R<sub>2</sub>P<sub>36</sub>' (+41.42%) followed by ER-R<sub>1</sub>P<sub>19</sub> (+19.98%) and ER-R<sub>2</sub>P<sub>19</sub> (+16.80%); whereas, positive better parent heterosis was recorded for the hybrid ER-R<sub>2</sub>P<sub>36</sub> (+38.33%) followed by ER-R<sub>1</sub>P<sub>19</sub> (+7.36%) and 16/2A-R<sub>1</sub>P<sub>7</sub> (+15.37%). Positive heterosis for TSS/sugars has also been reported by Milutinovic *et al.* (2000). Liang *et al.* (2011) also reported that sugar contents is polymeric characteristic and inheritance transgression is observed in hybrid progeny and it appear additive.

#### Total monomeric anthocyanins

Anthocyanin content of the grape berry determines the colour of grape berry and their juice. This trait has been extensively studied due to its importance in terms of antioxidant properties of anthocyanins. Therefore a positive heterosis for anthocyanin content is desirable (Liang *et al.* 2009, Fournier-Level *et al.* 2009). Heterotic values for total monomeric anthocyanin content revealed that in all the hybrids positive heterosis was observed (Table 4). The maximum mid parent heterosis was recorded in hybrid 16/2A-R<sub>1</sub>P<sub>8</sub> (+899.72%) followed by 16/2A-R<sub>1</sub>P<sub>18</sub> (+488.35%) and 16/2A-R<sub>4</sub>P<sub>13</sub> (+408.38%). However, heterobeltiosis (Table 5) was recorded in 10 hybrids out of 11 hybrids and the maximum positive better parent heterosis was recorded in hybrid 16/2A-R<sub>1</sub>P<sub>8</sub> (+399.86%) followed by 16/2A-R<sub>1</sub>P<sub>18</sub> (+194.18%) and 16/2A-R<sub>4</sub>P<sub>13</sub> (+154.19%). Gomez-Plaza *et al.* (2008) also reported that *Vitis vinifera* varieties inherit anthocyanin content significantly to their hybrids.

### Total phenolics

There were significant differences in total phenolic content recorded among parent-hybrids (Table 3). Grape phenolics are powerful antioxidants and thus have great potential in the development of antioxidant rich grape hybrids that is protective against certain chronic diseases. Therefore, phenolic rich grapes are preferred and positive heterosis is desirable (Connor *et al.* 2005). Heterotic studies for total phenolics revealed that 8 out of 11 hybrids showed positive heterosis (Table 4). The maximum positive mid parent heterosis was recorded in hybrid 16/2A-R<sub>1</sub>P<sub>8</sub> (+86.34%); whereas, the maximum positive better parent heterosis (Table 5) was recorded for 16/2A-R<sub>1</sub>P<sub>2</sub> (+51.33%) followed by 16/2A-R<sub>1</sub>P<sub>8</sub> (+41.62%). The positive heterosis for total phenolics was also reported by Singh *et al.* (2011).

### Total flavonoids

Flavonoids are the most common and widely distributed group of phenolic compounds present in the grapes. These compounds possess a broad spectrum of chemical and biological activities including radical scavenging properties. Based on the results, it was noticed that the total flavonoids content were found markedly higher in hybrids over both the parents (Table 3). The higher heterosis is also desirable for transferring the trait. Heterotic studies revealed that in all the hybrids positive heterotic effect over their respective mid parent was observed (Table 4). The maximum positive mid parent heterosis (Table 4) was exhibited by the hybrid 16/2A-R<sub>3</sub>P<sub>12</sub> (+142.83%) followed by 16/2A-R<sub>1</sub>P<sub>8</sub> (+134.82%) and ER-R<sub>2</sub>P<sub>36</sub> (81.15%). The maximum heterobeltiosis values were recorded in hybrids 16/2A-R<sub>1</sub>P<sub>8</sub> (+82.41%) followed by 16/2A-R<sub>3</sub>P<sub>12</sub> (+75.50%) and 16/2A-R<sub>1</sub>P<sub>2</sub> (+75.19%) (Table 5). Singh *et al.* (2011) and Kraptchev *et al.* (2014) also opined that mid parent and better parent heterosis for total flavonoids could be obtained in fruit crops. Hence, the hybrids confirming the maximum heterosis could further be employed for getting improved bioactive compound rich grapes.

### Antioxidant activities

Now-a-days grape vine breeders are giving due consideration for the improvement of nutritional parameters along with yield. Like yield, nutritional improvement in grape also requires sufficient genetic variation for antioxidant properties present in the gene pool. The mean squares due to parents and hybrids were found highly significant (Table 2 and 3) for all the antioxidant activities recorded (DPPH, FRAP and CUPRAC). The data indicate the existence of sufficient amount of variability, which is a pre-requisite for the genetic improvement of the grape. The DPPH, CUPRAC and FRAP activity of parents and hybrids is shown in the Table 3. Where the antioxidant activities varied from 5.37 to 10.38 Trolox equivalent,  $\mu\text{mol/g}$ ; 5.18 to 31.94 Trolox equivalent,  $\mu\text{mol/g}$  and 0.46 to 12.07 Trolox equivalent,  $\mu\text{mol/g}$ , respectively, for DPPH, CUPRAC and FRAP. The data revealed that the mid parent heterosis (Table 4) was found positive in 3 hybrids for DPPH, 9 hybrids

for CUPRAC and 8 hybrids for FRAP activity. However, the better parent heterosis (Table 5) was found positive in only one hybrid for DPPH, 7 hybrids for CUPRAC and 7 also for FRAP activities out of 11 hybrids. The maximum mid parent heterosis as well as heterobeltiosis was recorded was in hybrids 'ER-R<sub>2</sub>P<sub>36</sub>', '16/2A-R<sub>1</sub>P<sub>8</sub>' and '16/2A-R<sub>1</sub>P<sub>8</sub>' respectively for DPPH, CUPRAC and FRAP. Kraptchev *et al.* (2014, 2016) are also in agreement that mid parent and better parent heterosis for antioxidant activities could be obtained in fruit crops and better genotypes could further be employed for getting improved antioxidant rich grapes.

It was concluded that the hybrids, which were found to have the maximum significant heterosis and heterobeltiosis economic traits may be exploited for commercial use. The results suggest that the hybrid 'ER-R<sub>2</sub>P<sub>36</sub>' and hybrid '16/2A-R<sub>1</sub>P<sub>8</sub>' can be considered as a good source of natural antioxidants as well as other quality traits. This information may have a significant impact on evaluation of nutritional value of grape and could increase interests among consumers regarding fruit selection for increased consumption of coloured grapes. Hence, these aforesaid hybrids of grape have a high potential for commercial cultivation with respect to morpho-physical and biochemical traits.

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