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Morphological and biochemical characterization of newly evolved grape (*Vitis vinifera*) hybrids

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ABSTRACT

In current investigation, morphological and biochemical characteristics of grape (*Vitis vinifera* L.) hybrids were evaluated at ICAR-IARI, New Delhi. Hybrids of Pearl of Csaba × Beauty Seedless came earliest in full bloom, maturity and harvest with largest size of bunch, while hybrids of Banqui Abyad × Beauty Seedless harvested last and produced smaller size of bunch. Larger berry size and maximum juice recovery was measured in hybrids Hy.16/2A-R_1P_{14} (Cardinal × Beauty Seedless) and Hy.16/2A-R_4P_{13} (Banqui Abyad × Beauty Seedless). The maximum total soluble solids, TSS/acid ratio with least total titratable acidity was estimated in Pearl of Csaba × Beauty Seedless hybrids. Based on morphological and biochemical evaluation, two hybrids, i.e. Hy.ER-R_2P_{36} and Hy.16/2A-R_1P_{14} were found promising especially under subtropical conditions of North India.

Key words: Biochemical, GDD, Grape, Morphological, TSS

Grape is one of the most remunerative fruit crop owing to its very high productivity and market value. It is a well known fact that the grape has tremendous potential for manufacture into several industrial products due to its nutritional properties (Vislocky *et al*. 2010, Folts 2002). India annually produces 2.43 million tonnes of grapes from an acreage of 0.12 million ha with very high (21.10 t/ha) productivity (NHB 2015). The maximum cultivated area lies in the tropical (Southern states) and small acreage in subtropical areas (Northern and North-eastern states). In subtropical parts of India, early maturing grape cultivars holds promise for commercial cultivation. Because the late maturing cultivars get affected with the premonsoon showers and causes berry cracking, berry rot and yield and quality loss. Keeping in view the specific requirements of the region, the grape breeding programme was initiated at ICAR-Indian Agriculture Research Institute, New Delhi envisage aiming to bred an early maturing variety with better quality traits like seedlessness, high TSS content and bold berry. Therefore, to overcome such problems, attempts were made from time to time at IARI to evolve superior hybrids using conventional breeding methods. The explanation of results obtained on horticultural traits and bio-chemical constituents of newly developed grape hybrids and parental genotypes are discussed below in the light of available literatures and scientific knowledge.

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MATERIALS AND METHODS

The experimental was conducted during 2015-16 at the Experimental Grape Breeding Block, Main Garden, ICAR-Indian Agricultural Research, New Delhi, India. Eleven grape hybrids and nine parental genotypes were included in the study. The hybrids are under field evaluation for their possible release. The details are given in Table 1.

The date of full bloom was recorded at >50% anthesis. The days to maturity was calculated from full bloom to harvesting period. The growing degree days was calculated by using the following formula.

$$GDD = (T_{MAX} + T_{MIN}/2) - T_{BASE} \text{ (Where, } T_{BASE}=10^{\circ}C)$$

Fully ripened bunches were randomly harvested from vineyard. Five uniform bunches were selected from each replicated genotypes. Bunches were sorted and packed in polythene bag and subsequently transported to laboratory for recording observation on horticultural traits (morpho-physical). Grape bunches were immediately kept under ambient conditions for further biochemical analysis.

Table 1 Newly developed grape hybrids and parents used for the study.

Parents	Hybrids	No. of Hybrids
Madeleine Angevine × Ruby Red	16/2A R_1P_2, 16/2A R_1P_7	2
Banqui Abyad × Beauty Seedless	16/2A R_1P_{18}, 16/2A R_1P_{19}, 16/2A R_4P_{13}	3
Black Muscat × Beauty Seedless	16/2A R_3P_{12}	1
Pearl of Csaba × Beauty Seedless	ER-R_1P_{19}, ER-R_2P_{36}, ER-R_2P_{19}	3
Cardinal × Beauty Seedless	16/2A R_1P_{14}	1
Hur × A-5	16/2A-R_1P_8	1

One hundred berries were randomly collected from all bunches. The fresh homogeneous suspension was used for TSS, acidity and ascorbic acid content estimation. Physical parameters were analyzed from whole intact fruit.

The sampled bunch and berries from each replication were weighed and average bunch and berry weight were calculated on each sample. Bunch and berry weight was determined using the electronic balance in gram (g). Bunch length and width with pedicel was determined by using measuring scale in centimeter (cm). Bunch compactness was recorded on visual observations considering the descriptor code #204 for *Vitis* cultivars proposed by OIV (2001) and Albuquerque (1999): loose (rachis visible), medium loose (separated berries, well distributed and non-visible pedicels), and dense bunches (compact berries). Berry diameter and length was determined by using Digimatic caliper in millimeter (mm). Seed number was determined by counting of seed number per berry. The juice recovery was measured and expressed in percent.

The total soluble solids (TSS) of grape juice were measured with the help of digital refractometer. Data were expressed as equivalent degree brix (^{0}B). The digital pH

Table 2 Flowering period, growing degree days (GDD), harvesting time and bunch characteristics of new grape hybrids and their parents.

Genotype	Date of 50% bloom	Harvesting period	Days to maturity	Number of GDD	Bunch weight (g)	Bunch length (cm)	Bunch width (cm)
Hy.16/2A R_1P_2	21st March	8th-12th June	81	1579.32	129.35±6.18^{efg}	14.50±0.50^{defg}	9.25±0.48^{cdef}
Hy.16/2A R_1P_7	17th March	1st-4th June	78	1456.42	120.35±9.74^{fg}	10.75±0.48^{jk}	7.75±0.48^{fg}
Hy.16/2A R_1P_8	19th March	4th-8th June	79	1497.27	149.2±13.49^{def}	12.50±0.50^{hi}	8.75±0.25^{def}
Hy.16/2A R_1P_{14}	20th March	1st-4th June	75	1428.62	185.25±5.79^{cd}	11.00±0.41^{j}	7.75±0.25^{fg}
Hy.16/2A R_1P_{18}	21st March	15th-20th June	89	1760.17	118.35±3.26^{fg}	14.75±0.25^{cdef}	8.25±0.72^{efg}
Hy.16/2A R_1P_{19}	22nd March	9th-11th June	80	1568.07	135.08±18.91^{efg}	16.00±1.35^{bc}	10.75±1.25^{abc}
Hy.16/2A R_3P_{12}	20th March	1st-5th June	75	1428.62	130.03±12.83^{efg}	13.25±0.48^{gh}	10.25±0.48^{bcd}
Hy.16/2A R_4P_{13}	22nd March	14th-20th June	87	1725.62	189.18±6.78^{c}	15.50±0.29^{bcde}	11.25±0.75^{ab}
Hy.ER-R_1P_{19}	17th March	1st-4th June	78	1456.42	118.18±1.77^{fg}	17.50±0.29^{a}	8.00±0.00^{ab}
Hy.ER-R_2P_{19}	18th March	1st-4th June	77	1447.37	108.75±6.98^{g}	9.50±0.29^{k}	9.50±0.29^{cde}
Hy.ER-R_2P_{36}	15th March	25th-28th May	73	1312.77	316.45±16.28^{a}	15.25±0.75^{bcde}	11.75±1.03^{ab}
Madeline Angevine (P1)	20th March	8th-12th June	82	1588.57	144.25±22.05^{efg}	12.75±0.25^{hi}	9.13±0.31^{def}
Banqui Abyad (P2)	17th March	1st-5th June	78	1456.42	292.93±14.33^{ab}	14.38±0.38^{defg}	8.50±0.29^{efg}
Beauty Seedless (P3)	19th March	5th-8th June	80	1519.22	278.23±34.60^{b}	17.50±1.04^{a}	11.75±1.03^{ab}
Pearl-of-Csaba (P4)	15th March	25th-28th May	73	1312.77	114.55±2.89^{fg}	11.75±0.63^{ij}	7.00±0.41^{g}
Hur (P5)	27th March	12th-15th June	79	1596.82	289.85±41.98^{ab}	14.25±0.48^{efg}	12.25±1.18^{a}
Cardinal (P6)	21st March	8th-15th June	83	1630.77	165.3±5.83^{cde}	15.75±0.25^{bcd}	7.75±0.25^{fg}
Ruby Red (P7)	22nd March	10th-15th June	83	1645.12	127.5±6.75^{fg}	13.50±0.29^{fgh}	8.00±0.00^{efg}
A-5 (P8)	21st March	5th-10th June	79	1525.87	134.5±8.49^{efg}	11.50±0.29^{ij}	8.25±0.48^{efg}
Black Muscat (P9)	24th March	14th-17th June	85	1678.47	325.23±17.88^{a}	16.50±16.5^{ab}	11.5±0.87^{ab}

The dates were recorded during the growing season of 2015. GDD= growing degree days. Values represent the mean ± standard error of four replicates. Means with same superscript within a column are not significantly different at 5% level of significance when compared with LSD value. Different letters in the same column represent statistically different results (P<0.05).

meter was used to measure the pH of juice extracted from each sample. The pH meter was calibrated before taking the observations with buffer solution of known pH, viz. 4.00, 7.00 and 9.00. The titratable acidity of the juice present in all the samples was determined by titration against 0.1 N NaOH solution using 1-2 drops of phenolphthalein as an indicator (AOAC 2000). The content of the ascorbic acid was analyzed by titration method. Dye of 2, 6-dichlorophenol indophenol used along with metaphosphoric acid as a stabilizing agent (AOAC 2000).

The data sets were analyzed through statistical tool univariate analysis of variances. The means were compared using Duncan's multiple range test (DMRT). The statistical analysis software SPSS 12 was used. In some cases values of different parameters were expressed as the mean ± standard error. A difference was considered statistically significant when the p-value was less than 0.05 ($P<0.05$).

RESULTS AND DISCUSSION

Date of flowering

The key transition phase in plant growth cycle is "flowering period". Early flowering is the desirable trait for subtropical grape growing, which is mainly influenced by climatic conditions particularly temperature. The data pertaining to flowering date clearly revealed the variability in flowering time in genotypes under study ranged from 2nd to 4th week of March. The data pertaining to the full bloom presented in the Table 2. Among all the genotypes the full bloom lasted for 12 days (15th to 27st March). The earliest full bloom was recorded in hybrid/parental genotypes Hy.ER-R_2P_{36} and Pearl of Csaba (15th March) followed by Hy.ER-R_1P_{19}, Banqui Abyad (17th March), Hy.ER-R_2P_{19} (18th March), Beauty Seedless and Hy.16/2A R_1P_8 (19th March, 2015). Genotype Hur (27th March) was last to reach at full bloom stage among the accessions studied. Similar variability among genotypes in time of full bloom was also reported by earlier workers under varied climatic conditions (Jawanda *et al.* 1965, Bharat 1997, Huang and Lu 2000).

Berry maturity

The data for time of berry maturity is given from Table 2. The early maturity of bunches was recorded in hybrids Hy.ER-R_2P_{36} (3rd week of May) followed by Hy.ER-R_2P_{19}, Hy.ER-R_1P_{19} (3rd - 4th week of May). However,

Table 3 Bunch compactness and berry characteristics in grape hybrids and parents

Genotype	Bunch compactness	Berry weight (g)	Berry length (mm)	Berry diameter (mm)	Berry colour
Hy.16/2A R_1P_2	Very loose	2.10 ± 0.07^{efg}	12.65 ± 0.21^{i}	12.42 ± 0.18^{hi}	Blue black
Hy.16/2A R_1P_7	Very loose	1.13 ± 0.09^{hi}	11.75 ± 0.55^{ijk}	11.18 ± 0.36^{jk}	Blue black
Hy.16/2A R_1P_8	Very loose	1.45 ± 0.06^{h}	12.77 ± 0.07^{i}	11.99 ± 0.11^{ij}	Blue black
Hy.16/2A R_1P_{14}	Very dense	4.80 ± 0.27^{a}	21.04 ± 0.31^{a}	18.71 ± 0.37^{a}	Blue black
Hy.16/2A R_1P_{18}	Very loose	0.85 ± 0.03^{i}	11.30 ± 0.42^{jk}	10.62 ± 0.39^{kl}	Blue black
Hy.16/2A R_1P_{19}	Very loose	1.40 ± 0.09^{h}	10.90 ± 0.16^{k}	10.20 ± 0.26^{l}	Blue black
Hy.16/2A R_3P_{12}	Very loose	2.03 ± 0.09^{g}	14.03 ± 0.43^{h}	13.82 ± 0.14^{g}	Blue black
Hy.16/2A R_4P_{13}	Very loose	4.00 ± 0.09^{b}	16.65 ± 0.36^{de}	14.78 ± 0.45^{f}	Blue black
Hy.ER-R_1P_{19}	Very loose	1.38 ± 0.05^{h}	12.26 ± 0.27^{ij}	13.29 ± 0.23^{g}	Blue black
Hy.ER-R_2P_{19}	Very loose	3.35 ± 0.18^{c}	17.85 ± 0.51^{c}	16.22 ± 0.42^{cd}	Blue black
Hy.ER-R_2P_{36}	Medium loose	2.33 ± 0.05^{defg}	14.62 ± 0.34^{gh}	15.46 ± 0.25^{def}	Blue black
Madeline Angevine	Very dense	2.05 ± 0.06^{g}	14.89 ± 0.53^{fgh}	13.00 ± 0.08^{gh}	Blue black
Banqui Abyad	Very dense	3.53 ± 0.09^{c}	18.55 ± 0.33^{bc}	16.69 ± 0.31^{bc}	Green yellow
Beauty Seedless	Medium loose	2.38 ± 0.10^{def}	15.54 ± 0.16^{fg}	15.24 ± 0.48^{ef}	Blue black
Pearl-of-Csaba	Very loose	2.60 ± 0.07^{d}	15.88 ± 0.26^{ef}	15.80 ± 0.15^{de}	Green yellow
Hur	Very loose	3.65 ± 0.12^{c}	17.79 ± 0.34^{c}	17.44 ± 0.21^{b}	Green yellow
Cardinal	Very loose	4.05 ± 0.45^{b}	17.56 ± 1.19^{cd}	17.56 ± 0.89^{b}	Rose
Ruby Red	Medium loose	2.40 ± 0.07^{de}	15.36 ± 0.16^{fg}	15.72 ± 0.37^{de}	Blue black
A-5	Very loose	2.38 ± 0.14^{def}	14.93 ± 0.39^{fgh}	16.15 ± 0.28^{cd}	Blue black
Black Muscat	Very loose	4.48 ± 0.09^{a}	18.96 ± 0.31^{b}	17.16 ± 0.14^{b}	Blue black
Mean	-	2.62	15.26	14.67	
LSD ($P \leq 0.05$)	-	0.34	1.03	0.87	

Values represent the mean ± standard error of four replicates. Means with same superscript within a column are not significantly different at 5% level of significance when compared with LSD value. Different letters in the same column represent statistically different results ($P<0.05$).

hybrids Hy.16/2A R_4P_{13} and Hy.16/2A R_1P_{18} mature late (15th-20th June). The minimum growing degree days (early maturity) was observed in hybrids/parents Hy.ER-R_2P_{36} and Pearl-of-Csaba each having 1312.77 days (73 days after full bloom), whereas genotype Hy.16/2A R_1P_{18} exhibited maximum growing degree days of 1760.17 days to reach at maturity. The phenological phases under subtropical climatic conditions requires shorter duration, which results in early berry maturity (Flora 1977). The organ growth and development were positively accelerated in the presence of high temperatures from bloom to fruit maturity (Ben Mimoun and DeJong 1999). Rate of heat unit accumulation are closely associated with the vine phenological developments (Barnuud *et al*. 2014).

Bunch traits

The data on bunch related traits is presented in Table 2. The maximum bunch weight was observed in hybrids Hy.ER-R_2P_{36} (316.45 g), followed by parental varieties, *viz*. Banqui Abyad (292.93 g), Hur (289.85 g), and Beauty Seedless (278.23 g). However, the minimum bunch weight was recorded in hybrid Hy.ER-R_2P_{19} (108.75 g). The other genotypes had intermediate bunch weight. The differences among the genotypes were found to be highly statistically significant. The average mean weight of all the 20 genotypes was 178.63 g. The significant differences were also recorded for bunch length, which ranged from 9.5 cm (Hy.ER-R_2P_{19}) to 17.5 cm (Hy.ER-R_1P_{19} and Beauty Seedless). The maximum bunch length was recorded in hybrids Hy.ER-R_1P_{19} (17.50±0.29 cm) followed by 16/2A R_1P_{19} (16 cm), Hy.16/2A R_4P_{13} (15.5 cm), and Hy.ER-R_2P_{36} (15.25 cm). However, the similar trend was also noticed for bunch weight among the genotypes. The differences were also found significant for hybrids/parental varieties (Table 2). The maximum bunch width were recorded in Hur (12.25 cm) followed by hybrid Hy.ER-R_2P_{36} (11.35±1.03 cm). Other berry parameters such as berry length and diameter also showed significant differences among the genotypes (Table 3). Maximum berry length and diameter was recorded in Hy.16/2A-R_1P_{14} (21.04 mm, 18.71 mm) and minimum was recorded in Hy.16/2A-R_1P_{19} (10.90 mm, 10.20 mm), respectively. Bunch compactness is one of the important

Table 4 Juice recovery, juice pH and seedlessness traits in grape hybrids and parents

Genotype	Juice recovery (%)	Juice pH	Juice colour	Number of seeds per berry	Seed weight (100 seeds) (g)
Hy.16/2A R_1P_2	72.40±0.48^{bc}	3.28±0.03^{g}	Coloured	3 ± 0 .41^{ab}	7.09±0.05^{de}
Hy.16/2A R_1P_7	62.28±0.83^{g}	3.60±0.00^{c}	Slight coloured	2.75 ± 0.25^{abc}	5.60±0.03^{g}
Hy.16/2A R_1P_8	66.43±0.21^{e}	3.68±0.03^{b}	Slight coloured	2.25 ± 0.25^{cde}	5.30±0.09^{g}
Hy.16/2A R_1P_{14}	76.15±0.40^{a}	3.68±0.03^{b}	Slight coloured	2.5 ± 0.29^{bcd}	8.97±0.07^{b}
Hy.16/2A R_1P_{18}	73.00±0.36^{b}	3.70±0.00^{b}	Slight coloured	1.75 ± 0.25^{efg}	3.02±0.01^{i}
Hy.16/2A R_1P_{19}	56.21±0.87^{h}	3.38±0.03^{ef}	Slight coloured	2.25 ± 0.25^{cde}	3.96±0.02^{h}
Hy.16/2A R_3P_{12}	72.40±0.38^{bc}	3.78±0.03^{a}	Slight coloured	3.0 ± 0.41^{ab}	6.12±0.05^{f}
Hy.16/2A R_4P_{13}	77.20±0.36^{a}	3.40±0.00^{ef}	Slight coloured	3.25 ± 0.25^{a}	6.75±0.06^{e}
Hy.ER-R_1P_{19}	63.87±0.65^{fg}	3.78±0.03^{a}	Slight coloured	0.0 ± 0.00^{h}	0.00±0.00^{k}
Hy.ER-R_2P_{19}	69.68±0.60^{d}	3.48±0.03^{d}	Slight coloured	0.75 ± 0.29^{fg}	1.85±0.02^{j}
Hy.ER-R_2P_{36}	70.38±0.63^{d}	3.35±0.03^{f}	Slight coloured	0.75 ± 0.25^{fg}	1.95±0.01^{j}
Madeline Angevine	69.33±1.71^{d}	3.60±0.00^{c}	Coloured	2 ± 0^{def}	6.04±0.05^{f}
Banqui Abyad	70.08±0.11^{d}	3.58±0.03^{c}	Slight coloured	2.25 ± 0.25^{cde}	7.08±0.06^{de}
Beauty Seedless	59.15±0.75^{h}	3.05±0.03^{h}	Slight coloured	0 ± 0^{h}	0.00±0.00^{k}
Pearl-of-Csaba	70.86±0.53^{cd}	3.25±0.03^{g}	Slight coloured	2.50 ± 0.29^{bcd}	5.19±0.07^{g}
Hur	72.65±0.31^{b}	3.60±0.00^{c}	Slight coloured	1.25 ± 0.25^{g}	4.05±0.03^{h}
Cardinal	69.48±0.39^{d}	3.43±0.03^{de}	Slight coloured	1.50 ± 0.29^{fg}	7.24±0.07^{d}
Ruby Red	69.35±0.27^{d}	3.48±0.03^{d}	Slight coloured	2.25 ± 0.25^{cde}	6.88±0.03^{de}
A-5	65.48±0.30^{ef}	3.43±0.03^{de}	Slight coloured	2.5 ± 0.29^{bcd}	7.96±0.01^{c}
Black Muscat	63.85±0.28^{fg}	3.23±0.03^{g}	Slight coloured	2.5 ± 0.29^{bcd}	10.54±0.19^{a}
Mean	68.51	3.49		2.11	0.55
LSD ($P \leq 0.05$)	1.72	0.06		0.74	0.177

Values represent the mean ± standard error of four replicates. Means with same superscript within a column are not significantly different at 5% level of significance when compared with LSD value. Different letters in the same column represent statistically different results (P<0.05).

criteria in commercial point of view. The texture of the grape bunch is very important. Therefore, bunches are usually classed in three groups-very dense, medium loose and very loose type bunches. The details have been presented in the Table 3. Out of twenty genotypes 20 (hybrids and their parents), 20% were of very dense, 65% very loose and 15% were medium loose bunch type.

Berry traits

The largest berry in terms of berry weight was noticed in hybrids Hy.16/2A R_1P_{14} (4.80 g) and Hy.16/2A-R_4P_{13} (4.0 g), whereas lowest berry weight was observed Hy.16/2A R_1P_{18} (0.85 g) followed by Hy.16/2A R_1P_7 (1.13 g), Hy.ER-R_1P_{19} (1.38 g), Hy.16/2A-R_1P_{19} (1.40 g), Hy.16/2A-R_1P_8, and Hy.16/2A-R_3P_{12} (Table 3). These differences were found to be significant ($P \leq 0.05$, LSD = 0.34) for the berry weight for hybrids as well as parental genotypes.

Seedlessness

Seedlessness is primarily genotype specific trait. It was studied in terms of number of seeds per berry among all the hybrids and parental genotypes. The seed content observed from seed traces to 1-4 seeds. Accordingly, grape genotypes were categorized into seeded and seedless. Out of eleven hybrids only one hybrid (Hy.ER-R_1P_{19}) was found seedless followed by rudimentary seeds in Hy.ER-R_2P_{19} and Hy.ER-R_2P_{36} and rest had the seed content ranging from 2.00 to 4.00 per berry (Table 4). It was observed that the maximum seed weight (10.54 g/100 seeds) was found in 'Black Muscat' and minimum in Hy.ER-R_2P_{19} (1.8 g/100 seeds) among the seeded genotypes (Table 4). In this regards, Zosangliana and Narasimham (1993) reported about the presence of multi-layered pericarp in seeded berries which contained seeds in one to four in number and having maximum seed weight. However, in seedless grapes, the number of pericarp layers are less but not specific in corresponding to the number of seeds. In grapes, stenospermocarpy is the main cause for seedlessness (Ledbetter and Ramming 1989) and responsible for development of seedless berries.

Juice recovery

The juice recovery was measured in grape hybrids and parental genotypes (Table 4) which ranged from 56.21% (Hy.16/2A R_1P_{19}) to 77.20% (Hy.16/2A R_4P_{13}) and found statistically significant ($P \leq 0.05$). Among all the hybrids, the maximum juice recovery was recorded in Hy.16/2A R_4P_{13} (77.20%) followed by Hy.16/2A R_1P_{14} (76.15%),

Table 5 Total soluble solids, total titratable acidity, TSS: acid ratio and total ascorbic acid in grape hybrids and parents.

Genotype	TSS (°B)	Total titratable acidity (%)	TSS:Acid ratio	Ascorbic acid (mg/100g)
Hy.16/2A R_1P_2	16.28±0.25^{j}	0.76±0.01^{d}	21.42±0.28^{gh}	5.34±0.05^{c}
Hy.16/2A R_1P_7	19.70±0.73^{b}	0.84±0.01^{c}	23.37±0.64^{de}	7.12±0.10^{a}
Hy.16/2A R_1P_8	18.68±0.34^{cde}	0.77±0.01^{d}	24.35±0.66^{cd}	7.12±0.02^{a}
Hy.16/2A R_1P_{14}	19.05±0.62^{bcd}	0.86±0.01^{c}	22.27±0.57^{ef}	5.34±0.02^{c}
Hy.16/2A R_1P_{18}	18.40±0.23^{def}	0.93±0.00^{b}	19.79±0.30^{hi}	3.06±0.00^{g}
Hy.16/2A R_1P_{19}	18.00±0.09^{efg}	0.69±0.01^{f}	26.08±0.15^{ij}	6.44±0.08^{b}
Hy.16/2A R_3P_{12}	17.83±0.19^{ghi}	1.05±0.01^{a}	16.98±0.09^{ij}	3.57±0.01^{f}
Hy.16/2A R_4P_{13}	17.90±0.04^{ghi}	0.86±0.01^{c}	20.81±0.17^{gh}	4.08±0.04^{e}
Hy.ER-R_1P_{19}	19.98±1.00^{bc}	0.69±0.00^{ef}	28.95±1.39^{bc}	3.57±0.05^{f}
Hy.ER-R_2P_{19}	19.45±0.74^{bc}	0.76±0.02^{d}	25.66±1.32^{c}	3.57±0.01^{f}
Hy.ER-R_2P_{36}	23.55±0.47^{a}	0.67±0.01^{f}	35.28±0.26^{a}	2.38±0.01^{h}
Madeline Angevine	16.70±0.45^{ij}	0.69±0.01^{ef}	24.23±0.89^{cd}	4.08±0.04^{e}
Banqui Abyad	17.10±0.13^{ghi}	0.70±0.01^{e}	24.53±0.36^{cd}	4.08±0.04^{e}
Beauty Seedless	16.28±0.15^{j}	0.92±0.01^{b}	17.69±0.11^{hi}	3.57±0.01^{f}
Pearl-of-Csaba	17.03±0.18^{hi}	0.84±0.01^{c}	20.22±0.24^{gh}	2.38±0.00^{h}
Hur	17.65±0.23^{fgh}	0.76±0.01^{d}	23.39±0.29^{de}	4.76±0.03^{d}
Cardinal	17.50±0.89^{fghi}	0.69±0.00^{ef}	25.35±1.21^{c}	4.83±0.04^{d}
Ruby Red	17.08±0.10^{ghi}	0.77±0.01^{d}	22.26±0.31^{ef}	4.76±0.03^{d}
A-5	17.08±0.14^{ghi}	0.69±0.00^{ef}	24.75±0.30^{cd}	2.38±0.02^{h}
Black Muscat	17.43±0.14^{ghi}	0.59±0.01^{g}	29.83±0.75^{bc}	6.42±0.01^{b}
Mean	18.13	0.78	23.75	4.44
LSD ($P \leq 0.05$)	0.93	0.03	1.60	0.11

Values represent the mean ± standard error of four replicates. Means with same superscript within a column are not significantly different at 5% level of significance when compared with LSD value. Different letters in the same column represent statistically different results ($P < 0.05$).

Hy.16/2A R_1P_{18} (73.00%). The hybrids developed were coloured skin with non-tenturier character except in hybrid Hy.16/2A-R_1P_2 and therefore coloured juice was recovered from the hybrid.

TSS, titratable acidity and TSS:Acid ratio

Grape being a non-climacteric nature, the berry maturity time is one of the most important factors influencing the future of quality grape production. The technological maturity of grapes is associated to accumulation of certain amount of sugars, titratable acidity and pH value. Therefore, it is suggested to harvest the grapes at the stage when the berry attains characteristics and optimum levels of TSS/TA ratio (18-20 value) and characteristic colour. Crisosto (2002) also advocated TSS/TA value of 20/1 for commercial harvesting of table grapes. Accordingly, grapes were harvested and evaluated for TSS (Table 5). The TSS values ranged from 16.28°B (Beauty Seedless) to 23.55°B (Hy.ER-R_2P_{36}). Higher total soluble solids were recorded in Hy.ER-R_2P_{36} followed by Hy.16/2A R_1P_7 (19.70°B), Hy.ER-R_2P_{19} (19.45°B), Hy.16/2A R_1P_{14} (19.05°B), Hy.16/2A R_1P_8 (18.68°B), Hy.16/2A R_1P_{18} (18.40°B), and Hy.16/2A R_1P_{19} (18.00°B). The berry juice acidity ranged from 0.59% to 1.05% (Table 5). The pH values of the juice extracted from grape genotypes ranged from 3.05 ('Beauty Seedless') to 3.78 (Hy.ER-R_1P_{19} and Hy.16/2A R_3P_{12}).

The maturity index (MI) is the ratio between the TSS and TA, which represents a balance between sugar and acid, is very important to the general quality (Mota *et al*. 2006). Taste and flavour are the outcome of complex attribute of quality, in which there is blend of sugars, acids, and volatiles in a balanced ratio (Baldwin 2002). Similarly, the aroma of the fruits is also important which influences the consumer acceptance (Defilippi *et al*. 2009). The flavour and taste metabolites are the outcome of sugar (TSS) and organic acid (total titratable acidity expressed as tartaric acid) in a certain ratio (Ferguson and Boyd 2002, Shiraishi *et al*. 2010). Significant variations was observed for the sugar acid ratio (Table 5), which ranged from 16.98 (Hy.16/2A-R_3P_{12}) to 35.28 (Hy.ER-R_2P_{36}).

Ascorbic acid

In general, the amount of ascorbic acid is very low in grape genotypes. It was recorded higher in mid to late maturing genotypes as compared to early and very late maturing genotypes. These differences are supposed to be due to differential genetic makeup and also because of the differences in the berry development period and time of maturity. It was evident from the data presented in Table 5 that the maximum ascorbic acid content was in hybrids Hy.16/2A R_1P_7 and Hy.16/2A R_1P_8 (7.12 mg/100g each) followed by Hy.16/2A R_1P_{19} (6.44 mg/100g).

From the above study, it was inferred that the hybrids, Hy.ER-R_2P_{36} and Hy.16/2A-R_1P_{14} need to deserve a place in grape varietal trial under different agro-climatic regions of the country. The hybrid Hy.ER-R_2P_{36} is the earliest maturing with minimum growing degree days, and also with higher TSS with good juice recovery, hence well suited for sub-tropical plains. So, it is implicated that quantification of the biochemical traits could help to understand the potential of genotypes for further utilization in improvement programme.

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