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# Mechanical behaviour of seed hardness in relation to physico-chemical composition of grape

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## ABSTRACT

**Mechanical behaviour of seed hardness in relation to physico-chemical traits in grape (*Vitis vinifera* L.) was studied on grape raised under sub-tropical conditions of the north Indian plains. Twenty three varieties/ hybrids were assessed, of which six were seedless, 5- soft-seeded and 12- seeded types. Among genotypes studied, the largest bunch size was observed in seedless grape genotypes. However, maximum berry size was found in seeded genotypes. Total soluble solids content was slightly variable but was higher in seedless grapes than seeded ones. Seeded genotypes had high seed weight with higher seed hardness. High positive correlations was recorded between bunch weight to bunch length (r = 0.99), bunch weight to TSS (r = 0.91); and berry weight to seed weight (r = 0.98) and berry weight to seed hardness (r = 0.97). Significant negative correlation was estimated between bunch weight to berry weight (r = 0.96); bunch weight and seed weight (r = 0.98); bunch weight to seed hardness (r = 0.97) and berry weight to TSS (r = 0.99). These findings would help in screening of hybrids and genotypes with better berry quality particularly seedlessness under the sub-tropical conditions.**

**Key words**: Fruit quality, grape, mechanical behaviour, seed hardness, sub-tropical.

## INTRODUCTION

Seedlessness in table grape (*Vitis vinifera* L.) is considered a trait of importance to the consumers. Seedless berries either develop through parthenocarpy or through ovule abortion at an early stage of development (stenospermocarpy). A whole range of seed sizes and their traces, with a continuous nature was observed in grape varieties/ hybrids. The existence of small-but-noticeable, and large-but-undetected seed traces, makes it difficult to distinguish between off-springs, usually divided into groups (seeded and seedless) according to their seed content (Striem *et al*., 16). Similar categorization was also given by Stout (15) who proposed six types based on seed development, *viz*., fruits with normal seeds, empty seededness, seed which crush, brittle seeds, papery seeds and extremely partial seeds. The content and nature of seed traces is affected by several factors (Ristic and Iland, 12; Gray and Coombe, 8) and seed development affected by berry composition.

Correlation between the number and weight of seeds, and the size of fully ripened berries has been reported (Winkler and Williams, 19). Olmo (11) also reported correlations between berry weight and seed weight (seed index number), the frequency and types of mature seeds, and a correlation between seed number and berry weight. The number of seeds and the total weight of seeds in a berry are highly correlated to final berry size, fresh and dry berry weight (Cawthon and Morris, 4; Ebadi *et al*., 6). The present study was undertaken with the objective to determine whether natural variation in seed hardness could affect, i) grape composition, ii) relative proportions of seeds in the berry and, iii) to determine relationships between berry physico-chemical compositions with seed related traits under sub-tropical conditions.

## MATERIALS AND METHODS

The study was carried out in Division of Fruits and Horticultural Technology, IARI, New Delhi during 2011-2013 for three seasons. The genotype studied includes commercial varieties/ hybrids (Table 1). These genotypes were selected to study the seed trace, size and physico-chemical composition of berry. Twenty uniform bunches were collected from three plants of each genotype during last week of May to first week of June, each year, depending upon the maturity of respective variety/ hybrid. Twenty berries were randomly selected from top, middle and bottom portions of each bunch. The data was recorded for bunch weight (g), bunch length (cm), physico-chemical traits including, juice recovery (%), berry weight (g), TSS (ºBrix), average seed weight (mg) and seed break force. Total soluble solids was determined by hand held refractometer.

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**Table 1.** Classification of grape genotypes based on degree of seedlessness.

| Seedless | Soft seeded | Seeded |
|---|---|---|
| Perlette | Hybrid-PU × Cardinal (ER-$R_1P_{32}$) | Pearl of Csaba |
| Pusa Seedless | Hybrid-PoC × Perlette (ER-$R_2P_9$) | Hur |
| Pusa Urvashi | Hybrid- BA × Perlette (75-32) | Bharat Early |
| Hybrid (Hur × BE) × BS | Hybrid-BE × (BA × Perlette) (BE × 75-32) | Anab-e-Shahi |
| Hybrid- BS × Perlette (ER-$R_3P_1$) | Hybrid-PoC × BS (ER-$R_2P_{32}$) | Black Muscat |
| Hybrid- PU × Perlette (ER-$R_4P_{26}$) | | Pusa Navrang |
| | | Hybrid-PoC × Cardinal (ER-$R_4P_{20}$) |
| | | Hybrid-PoC × BS (ER-$R_1P_{19}$) |
| | | Hybrid-PU × BS (ER-$R_3P_{26}$) |
| | | Hybrid-Hur × Cardinal (76-1) |
| | | Hybrid-PoC × BE (ER-$R_2P_4$) |
| | | Hybrid-PoC × BS (ER-$R_3P_{22}$) |

On the basis of size and visibility of seeds in berries, variations in seeds were visually classified into three categories: (i) with normal seeds (seeded), (ii) large-to-medium traces or rudimentary (soft seeded), and (iii) small traces (seedless). Accordingly samples were classified into three categories, *viz*. seeded ('Cardinal'), soft-seeded with large to medium traces ('Flame Seedless'), and seedless with minute aborted seeds ('Perlette'). Seed hardness was measured by TA + Di Texture Analyzer (Stable Micro Systems, UK) using P/35 ø 35 mm stainless steel probe in compression mode with pre-test, test and post-test speed of 5, 1 and 10 mm/s, respectively as per method suggested by Letaief *et al*. (10). All statistical analyses were performed using SYSTAT 10 software. Statistical analysis was carried out using one-way ANOVA (Gomez and Gomez, 7). Correlation coefficients were calculated for various traits by taking mean values of the genotypes from each group of varieties/ hybrids.

## RESULTS AND DISCUSSION

The bunch weight and length varied considerably among the three categories of grape genotypes, *viz*. seedless (372.3 g), soft-seeded (322.6 g) and seeded (239.6 g) (Fig. 1 a&b). The variation within the groups was also found significant. However, the maximum bunch weight was recorded in Hybrid ('Hur' × 'Bharat Early') × 'Beauty Seedless' (508.9 g), which was closely followed by hybrid 'Banqui Abyad' × 'Perlette' (507.4 g). These two hybrids represent the seedless and soft-seeded group. However in case of seeded varieties, the size of bunch in terms of weight and length were smaller as compared to seedless and soft-seeded genotypes. This is mainly due to genetic behaviour of the individual genotype.

Berry weight is also a trait governed by genomic constitution of the genotype also affected by cultural and physiological means. This is clearly represented by all the varieties under study. The maximum berry weight was found in seeded genotypes (2.67 g) followed by soft-seeded (2.54 g) and seedless (2.33 g) (Fig. 1 c). This is mainly attributed due to presence of bold versus immature (aborted) seeds in two contrast groups. Within the groups, the maximum berry weight was recorded in hybrid 'Hur' × 'Cardinal' (6.3 g) and minimum was in 'Beauty Seedless' × 'Perlette' (1.4 g), followed by 'Pusa Urvashi' × 'Cardinal' (1.4 g), 'Pearl of Csaba' × 'Cardinal' (1.5 g), 'Bharat Early' (1.6 g), Pusa Navrang (1.7 g) and 'Pearl of Csaba' × Perlette' (1.9 g). Similar findings were also reported by Barbagallo *et al*. (1), wherein, a significant linear relationship was found in seed fresh weight to berry fresh weight. These findings are in agreement with the results reported by Boselli *et al*. (2) and Walker *et al*. (18).

Not much has been reported on how seedlessness influences the berry composition of grapes. However, in the present findings the maximum TSS was recorded in seedless hybrids/varieties (18.93ºBrix) followed by soft-seeded (18.40ºBrix) and seeded (18.11ºBrix) (Fig. 1 d). This variation clearly indicates the superiority of seedless over seeded varieties/ hybrids. However, this is not universally true, if it is relative to individual genotypes. For instance, in seeded genotypes like 'Bharat Early' (22.7ºBrix) and hybrid 'Hur × Cardinal' (20.9ºBrix) maximum soluble solids were observed. Similar trends for TSS were recorded in seedless ('Pusa Seedless', 'Beauty Seedless' × 'Perlette') and soft-seeded ('Banqui Abyad' × 'Perlette') varieties/ hybrids (Table 3). The accumulation of higher sugar content in seedless berries may be due the availability of the free spaces (Coombe and Matile, 5; Brown and

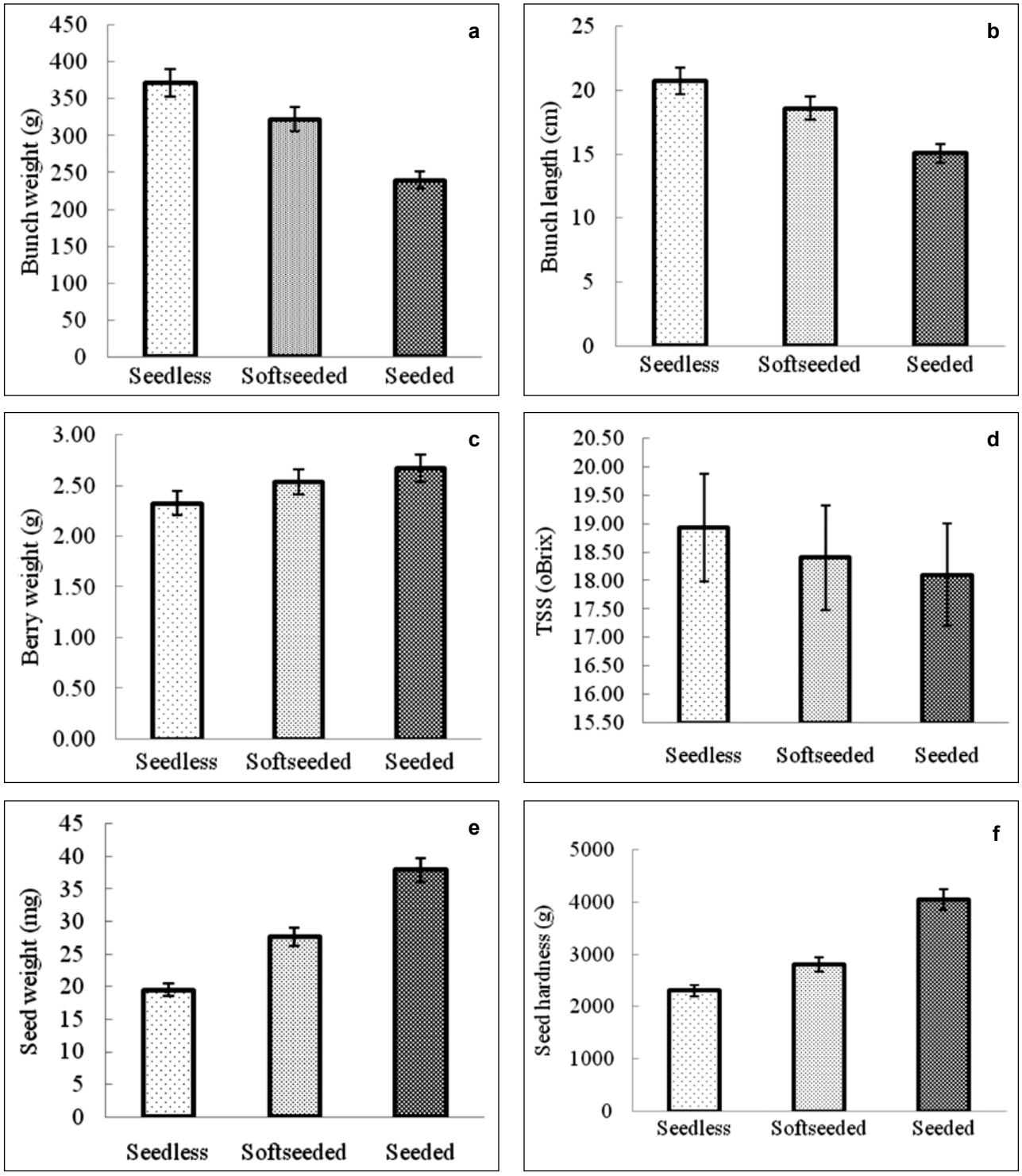


**Fig. 1.** Variation in bunch weight (a), bunch length (b), berry weight (c), total soluble solids (d), seed weight (e) and seed hardness (f) among different group of grape varieties/ hybrids (seedless, soft-seeded and seeded). Error bars ± 5 SE.

Coombe, 3). Scienza *et al*. (14) also found slightly higher TSS in 1- seeded grape berries as compared to 3- seeded.

Per berry seed weight was found maximum in variety 'Hur' (66.94 mg) followed by 'Anab-e-Shahi' (56.26 mg) and 'Pusa Navrang' (48.92 mg) representing

**Table 3.** Variation in total soluble solids (TSS), average seed weight and seed hardness in various grape varieties and hybrids grown under subtropical conditions.

| Genotype | TSS (ºBrix) | Mean seed weight (mg) | Seed hardness (g) |
|---|---|---|---|
| Seedless | | | |
| Perlette | 17.83 ± 0.35$^{cdef}$ | 4.90 ± 0.51$^{a}$ | 1465.1 ± 247.85$^{ab}$ |
| Pusa Seedless | 20.52 ± 0.56$^{bcde}$ | 12.68 ± 0.22$^{b}$ | 2716.3 ± 224.57$^{abcd}$ |
| Pusa Urvashi (Hur × BS) | 18.26 ± 0.44$^{defg}$ | 26.72 ± 1.06$^{cde}$ | 2612.3 ± 273.13$^{abcd}$ |
| (Hur × BE) × BS | 18.64 ± 0.24$^{bcde}$ | 10.74 ± 0.47$^{ab}$ | 1807.6 ± 258.22$^{ab}$ |
| ER- R3P1 (BS × Perlette) | 20.47 ± 0.39$^{fgh}$ | 10.44 ± 1.19$^{ab}$ | 2094.0 ± 442.25$^{abc}$ |
| ER- R4P26 (PU × Perlette) | 17.84 ± 0.73$^{ab}$ | 33.56 ± 1.94$^{fghi}$ | 3139.1 ± 61.383$^{abcd}$ |
| Mean | 18.93 | 16.51 | 2305.73 |
| Soft-seeded | | | |
| ER- R1P32 (PU × Cardinal) | 18.02 ± 0.29$^{cdef}$ | 14.08 ± 0.68$^{b}$ | 3611.9 ± 593.86$^{bcdefg}$ |
| ER- R2P9 (PoC × Perlette) | 18.80 ± 0.47$^{defg}$ | 26.08 ± 2.73$^{cde}$ | 1904.8 ± 192.57$^{abc}$ |
| 75-32 (BA × Perlette) | 21.12 ± 0.66$^{efg}$ | 21.74 ± 0.49$^{c}$ | 2458.4 ± 294.99$^{abcd}$ |
| BE × 75-32 (BE × (BA × Perlette)) | 18.73 ± 0.41$^{defg}$ | 38.60 ± 1.75$^{ij}$ | 2704.7 ± 74.234$^{abcd}$ |
| ER R2P32 (PoC × BS) | 15.34 ± .49$^{bc}$ | 37.96 ± 1.13$^{hij}$ | 3356.2 ± 381.87$^{abcdef}$ |
| Mean | 18.40 | 27.69 | 2807.2 |
| Seeded | | | |
| Pearl of Csaba | 16.79 ± 0.58$^{bcde}$ | 28.39 ± 1.13$^{defg}$ | 3255.7 ± 394.14$^{abcde}$ |
| Hur | 16.27 ± 0.72$^{bcd}$ | 66.94 ± 0.16$^{m}$ | 7598.2 ± 351.33$^{h}$ |
| Bharat Early | 22.72 ± 0.36$^{h}$ | 28.26 ± 1.10$^{defg}$ | 4372.7 ± 437.34$^{cdefg}$ |
| Anab-e-Shahi | 19.25 ± 0.33$^{efg}$ | 56.26 ± 1.39$^{l}$ | 4953.1 ± 316.82$^{defg}$ |
| Black Muscat | 16.89 ± 0.21$^{bcde}$ | 43.56 ± 1.07$^{jk}$ | 5998.3 ± 223.5$^{gh}$ |
| Pusa Navrang (MA × RR) | 18.77 ± 0.22$^{defg}$ | 48.92 ± 1.45$^{k}$ | 5572.3 ± 1222.5$^{efgh}$ |
| ER- R4P20 (PoC × Perlette) | 17.91 ± 0.37$^{cdef}$ | 14.86 ± 0.69$^{b}$ | 1087.7 ± 175.2$^{a}$ |
| ER- R1P19 (PoC × BS) | 17.74 ± 0.30$^{cdef}$ | 27.64 ± 0.90$^{cdef}$ | 3069.9 ± 447.71$^{abcd}$ |
| ER- R3P26 (PU × BS) | 16.88 ± 0.24$^{bcde}$ | 24.60 ± 0.92$^{cd}$ | 2031.9 ± 368.6$^{abc}$ |
| 76-1 (Hur × Cardinal) | 20.98 ± 0.59$^{gh}$ | 36.14 ± 1.29$^{hi}$ | 3593.5 ± 466.05$^{bcdefg}$ |
| ER- R2P4 (PoC × BE) | 16.29 ± 0.31$^{a}$ | 34.18 ± 0.73$^{ghi}$ | 3344.9 ± 820.16$^{abcdef}$ |
| ER-R3P22 (PoC × BS) | 16.79 ± .50$^{bcde}$ | 32.08 ± 1.07$^{efgh}$ | 3605.1 ± 668.5$^{bcdefg}$ |
| Mean | 18.11 | 36.82 | 4040.28 |
| HSD (P ≤ 0.05) | 1.45 | 3.68 | 1429.4 |

Data represents the mean ± standard error of five replicates. Means within a column that did not differ significantly at 5% level of significance when compared with Tukey's HSD test are followed by the same superscript letters.

seeded genotypes. Whereas, the minimum seed weight was recorded in seedless genotypes like 'Perlette' (4.90 mg), followed by Hybrid 'Pusa Urvashi' × 'Perlette' (10.44 mg), Hybrid ('Hur' × 'Bharat Early') × 'Beauty Seedless' (Table 3). The seed breakforce was also measured (at 7% moisture content of seeds) in all the varieties which ranges from 1.08 kg ('Pearl of Csaba' × 'Perlette') to 7.59 kg ('Hur') (Table 3). It was recorded highly significant within the varieties. An interesting feature was recorded in the seeded group of a hybrid ('Pearl of Csaba' × 'Perlette'- ER-$R_4P_{20}$) that the seeds were bold but the hardness was low as soft-seeded varieties. This indicates the existence of poor sclerification of seeds in ripened berries. It also indicates that the bold seeds are always are not a total indicator seed hardness (Table 3). However, in general the average values calculated based on different groups indicate clearly the linear trends corresponding

to each groups, *i.e.*, seedless group of genotypes had low seed hardness as compared to seeded ones (Fig. 1 e). Larger berries had more flesh compared to smaller berries. The higher level of soluble solids content was recorded in berries located at the shoulder of bunch followed by middle of bunch and minimum in bottom of the bunch etc. The similar findings were also reported by many researchers (Olmo *et al*., 11; Cawthon and Morris, 4; Boselli *et al*., 2; Ummarino and Di Stefano, 17; Roby and Matthews, 13; Walker *et al*., 18).

Significant correlations ($p < 0.05$ and $p < 0.01$) were observed among different traits studied (Fig. 2 a, b, c, d, e). High degree of positive correlations was recorded between bunch weight and bunch length ($r = 0.99$); bunch weight and TSS ($r = 0.91$); berry weight and seed weight ($r = 0.98$) and berry weight to seed hardness ($r = 0.97$); whereas, a significant negative correlation were observed between bunch weight and berry weight ($r = -0.98$); bunch weight and seed weight ($r = -0.98$); bunch weight and seed hardness ($r = -0.99$) and berry weight to TSS ($r = -0.99$). Similar correlations were also reported by Leao *et al*. (9). The positive genetic correlation between bunch size and the ºBrix is of immense use in the breeding programmes.

All traits studied in this paper are important for table grape breeding programmes. Seedlessness, seed hardness, bunch and berry dimensions, total soluble solids content contribute to the commercial value and storage quality under subtropical conditions, where the fruit development period is very small. Therefore, these findings would assists the breeders in screening hybrids and genotypes with better berry quality particularly for seedlessness under the sub-tropical conditions.

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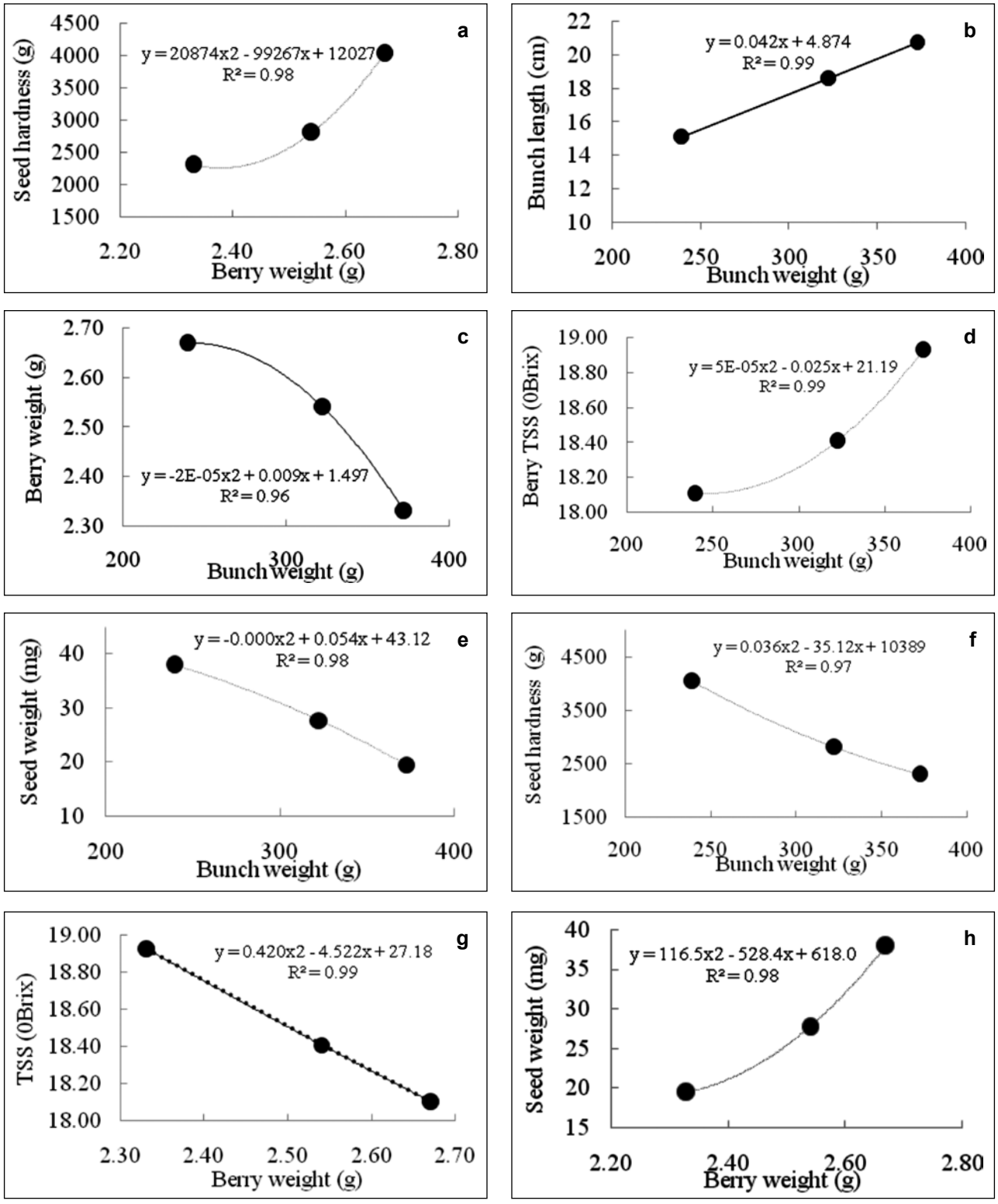


**Fig. 2.** Relationship between different grape seed and berry traits bunch weight/ bunch length. (a), bunch weight/ berry weight (b), bunch weight/ TSS (c), bunch weight/ seed weight (d), bunch weight/ seed hardness (e), berry weight/ TSS (f), berry weight/ seed weight (g) and berry weight and seed hardness (h) calculated based on the mean values of grapes fall in three different categories (seedless, soft-seeded and seeded).

**Table 2.** Variation in bunch weight, bunch length and berry weight in grapes grown under sub-tropical conditions.

| Genotype | Bunch weight (g) | Bunch length (cm) | Berry weight (g) |
|---|---|---|---|
| Seedless | | | |
| Perlette | 393.7 ± 22.85$^{jhi}$ | 21.2 ± 0.91$^{ij}$ | 2.1 ± 0.05$^{defgh}$ |
| Pusa Seedless | 246.5 ± 20.69$^{abcdef}$ | 19.4 ± 0.45$^{fghi}$ | 2.5 ± 0.03$^{abcdef}$ |
| Pusa Urvashi (Hur × BS) | 424.0 ± 23.30$^{hij}$ | 20.1 ± 0.65$^{ghi}$ | 2.2 ± 0.12$^{efgh}$ |
| (Hur × BE) × BS | 508.9 ± 40.35$^{j}$ | 23.1 ± 1.76$^{ij}$ | 2.6 ± 0.21$^{ghi}$ |
| ER- R3P1 (BS × Perlette) | 325.1 ± 21.11$^{efg}$ | 19.9 ± 0.62$^{ghi}$ | 1.4 ± 0.07$^{abc}$ |
| ER- R4P26 (PU × Perlette) | 335.6 ± 24.45$^{fgh}$ | 20.7 ± 0.49$^{hi}$ | 3.2 ± 0.04$^{ij}$ |
| Mean | 372.3 | 20.73 | 2.33 |
| Soft seeded (rudimentary seeds) | | | |
| ER- R1P32 (PU × Cardinal) | 265.1 ± 11.81$^{bcdef}$ | 16.7 ± 0.82$^{defg}$ | 1.4 ± 0.07$^{ab}$ |
| ER- R2P9 (PoC × Perlette) | 229.2 ± 8.73$^{abcde}$ | 15.4 ± 0.51$^{cde}$ | 1.9 ± 0.06$^{bcdef}$ |
| 75-32 (BA × Perlette) | 507.4 ± 3.53 $^{j}$ | 24.9 ± 1.39$^{j}$ | 3.4 ± 0.22$^{j}$ |
| BE × 75-32 (BE × (BA × Perlette)) | 211.8 ± 12.99$^{abcd}$ | 14.9 ± 0.42$^{bcde}$ | 2.7 ± 0.14$^{hi}$ |
| ER R2P32 (PoC × BS) | 399.4 ± 15.77$^{ghi}$ | 21.1 ± 0.60$^{i}$ | 3.3 ± 0.07$^{j}$ |
| Mean | 322.58 | 18.60 | 2.54 |
| Seeded | | | |
| Pearl of Csaba | 149.7 ± 11.57$^{a}$ | 10.6 ± 0.60$^{a}$ | 2.1 ± 0.08$^{cdef}$ |
| Hur | 185.4 ± 7.69$^{abc}$ | 15.6 ± 0.62$^{cde}$ | 2.1 ± 0.03$^{defg}$ |
| Bharat Early | 182.1 ± 16.35$^{abc}$ | 12.9 ± 0.76$^{abcd}$ | 1.6 ± 0.12$^{abcd}$ |
| Anab-e-Shahi | 383.4 ± 23.71$^{ghi}$ | 14.7 ± 0.61$^{bcde}$ | 3.3 ± 0.05$^{j}$ |
| Black Muscat | 200.44 ± 14.13$^{abc}$ | 12.6 ± 0.37$^{abc}$ | 2.3 ± 0.09$^{fgh}$ |
| Pusa Navrang (MA × RR) | 180.2 ± 3.87$^{abc}$ | 15.2 ± 0.46$^{cde}$ | 1.7 ± 0.08$^{abcde}$ |
| ER- R4P20 (PoC × Cardinal) | 223.7 ± 11.06$^{abcd}$ | 15.8 ± 0.49$^{cdef}$ | 1.5 ± 0.08$^{abc}$ |
| ER- R1P19 (PoC × BS) | 190.7 ± 8.41$^{abc}$ | 17.1 ± 0.63$^{efgh}$ | 3.4 ± 0.06$^{j}$ |
| ER- R3P26 (PU × BS) | 270.6 ± 9.31$^{cdef}$ | 12.7 ± 0.55$^{abc}$ | 3.2 ± 0.08$^{ij}$ |
| 76-1 (Hur × Cardinal) | 437.9 ± 31.32$^{ij}$ | 20.9 ± 0.58 $^{i}$ | 6.3 ± 0.22$^{k}$ |
| ER- R2P4 (PoC × BE) | 303.6 ± 20.08$^{defg}$ | 21.4 ± 0.29$^{ij}$ | 2.3 ± 0.13$^{fgh}$ |
| ER-R3P22 (PoC × BS) | 167.9 ± 4.01$^{ab}$ | 11.4 ± 0.33$^{ab}$ | 2.2 ± 0.12$^{efgh}$ |
| Mean | 239.64 | 15.08 | 2.67 |
| HSD (P ≤ 0.05) | 56.38 | 2.16 | 0.33 |

Data represents the mean ± SE of five replicates. Means within a column that did not differ significantly at 5% level of significance when compared with Tukey's HSD test are with same superscript letters.


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