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Multivariate analysis of white grape grown under subtropical conditions of India

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Abstract

Forty-two white grape accessions were evaluated for various yield and biochemical parameters. Multivariate analysis and genetic variability were carried out for yield and biochemical parameters of the grape accession grown under subtropical condition. High genotypic and phenotypic coefficient of variation were observed in bunch weight, berry weight, pruning weight, number of berries per bunch, total tannin content and acidity in the grape berries. All the parameters showed very high estimated heritability for broad sense ($h^2_{b.s.}$). Higher genetic gain was recorded for average bunch weight, berry weight, reducing sugar and carbohydrate content while low genetic gain was observed for skin thickness. The multivariate analysis suggested that biochemical parameters could potentially serve as a means to distinguish between grape genotypes. The principal component analysis (PCA) revealed that, first PC explained 20.3% variance while second contributed for 15.2% variance through fruit and biochemical traits. Cluster and principal component analyses showed a considerable fruit diversity in the studied white grape accessions.

Keywords: *Vitis vinifera*, accessions, principal component analysis, cluster analysis

Introduction

Grape (*Vitis vinifera* L.) taxonomically belongs to the Vitaceae family, is believed to have originated in the Middle East. Grape was among the earliest fruit crops cultivated by humans for producing table fruits, dried fruits, juice, and wine (Frederique *et al.*, 2010) [3]. It is a good source of minerals such as calcium, phosphorus, and iron, as well as vitamins like B1 and B2. In India, grape cultivation is carried out in three distinct regions: temperate (Jammu and Kashmir, and Himachal Pradesh), sub-tropical (Punjab, Haryana, Rajasthan, and western Uttar Pradesh), and tropical (Andhra Pradesh, Maharashtra, Karnataka, and Tamil Nadu). The tropical region accounts for 94% of India's grape production (Dolkar *et al.*, 2018) [2], with Maharashtra leading in both area (71.5%) and contribution (80%) to the country's total production, followed by Karnataka and Andhra Pradesh, which are in the southern part of Peninsular India (Karibasappa *et al.*, 2006) [8].

Grapes are considered as one of the most nutritious fruits. They are consumed fresh, dried as raisins, or processed into juice and wine. Of these, approximately 78% are used for table consumption, 17-20% for raisin production, and only 0.5% for winemaking. Yield is a complex quantitative trait influenced by factors such as berry weight, bunch weight, and bunch volume. These traits are mostly polygenic, with their inheritance governed by multiple genes. Examining the variation in these traits across different accessions, along with assessing genetic variability and heritability, is valuable when establishing selection criteria. It is important to assess grape genotypes for their quality attributes and yield potential, which contribute to their nutritional value. Evaluating the variability within the crop will serve as a trait marker for selection and aid in developing superior, trait-specific varieties. Fruit traits are commonly used as key morphological characteristics in the characterization of fruit trees. When combined with multivariate statistical techniques like principal component analysis (PCA), cluster analysis, genetic variability, heritability and genetic advance in grape accessions for yield-related traits, and biochemical.

Materials and Methods

The study was carried out in the experimental vineyards of ICAR-National Research Centre for Grapes, Pune (Maharashtra) during the year October 2023-April 24. Forty-two white grape accessions (Coarna Alba, Frumaosa Alba, Muscat White, Arka Chitra, Arka Kanchan, Bianca, Muscat of Alexandria, Rosaria Bianca, Gold, Aledo, Anab-E-Sahebi, Hussain Kadu, Golden Queen, Cheema Sahebi, Sahebi Ali, Dilkhush, Sundekhani, Seeded, Italia, Thompson Seedless, Tas A Ganesh, H-5 Clone, Manik Chaman, Manjari Naveen, Superior Seedless, Perlette, Pusa Seedless, Kishmish Belly, Centennial Seedless, James, Peru White, Jaos Belly, Banqui Ahyad, Symphony, Aka Soma, Arka Hans, Tigrosa, Arka Krishna, Angoor Kalan, Rose of Peru, Pusa Swarnika, and Pusa Trishar) grafted on Dogridge rootstock trained on Y trellises were selected for the study. All the standard recommended cultural practices were followed to maintain the vines healthy. The observations on bunch and quality parameters were recorded at harvest. The experiment was conducted in a randomized block design consisting of five replications.

Data recording for yield associated traits

Pruned biomass: The fresh weight of the pruned canes at the time of October pruning was measured with the help of a weighing balance. Three groups of vine vigour viz., low, medium, and high were designated based on pruning weight as a) low vigour-pruning weight less than 0.2 kg; b) medium vigour-pruning weight 0.2 kg to 0.4 kg; c) high vigour-pruning weight more than 0.4 kg (Havinal *et al.*, 2008).

Days taken for bud burst: The number of days taken for bud sprouting after October pruning was recorded for each treatment to determine the earliness or lateness of the variety. Following the October pruning, ten canes from each vine of every cultivar were tagged and observed to record the days required for sprouting.

Average bunch weight (g): The mean weight of five randomly selected healthy bunches per replication was recorded after harvesting and their combined weight was measured using a weighing balance. The resulting average bunch weight was then expressed in grams.

50 berry weight (g): Fifty berries were selected from five different bunches in each replication and the weight of 50-berries was measured using a weighing balance and expressed in grams.

Number of bunches per vine: The mean bunch number were calculated based on five average of vines under each variety.

Bunch length and width (cm): The length and width of the bunch were derived by averaging the length of ten bunches randomly selected from each variety and expressed in centimeters.

Number of berries per bunch: The number of berries per bunch was determined by counting the fruits on five bunches per vine and calculating the average.

Berry diameter and length (mm): Berry diameter and length were recorded with the help of vernier calipers at harvest by selecting ten berries randomly in each variety and was expressed in mm.

Fruit yield (kg/vine): The number of bunches produced on the tagged spurs in each treatment was recorded and weighed. The total weight of these bunches was taken as the overall yield per treatment and expressed in kilograms.

Biochemical analysis

For acidity determination, a 0.1N NaOH standard solution was prepared. Simultaneously, 5 ml of grape juice was transferred to an Erlenmeyer flask, diluted to 50 ml with distilled water, and a few drops (approximately 1 ml) of phenolphthalein indicator were added. The sample was titrated with the standard NaOH solution until the endpoint was reached at pH 8.2, where a consistent pink color was maintained for 30 seconds. The acidity percentage was calculated using the formula:

$$\text{Acidity (\%)} = \frac{(\text{TV} \times \text{Normality of alkali} \times \text{Eq wt. of acid} \times \text{Volume made (ml)} \times 100)}{(\text{Volume of aliquot (ml)} \times \text{Weight of sample (g)} \times 1000)}$$

A refractometer was used to measure the total soluble solids (TSS) of grape berries. The berries were squeezed, and the grape juice samples were measured using a portable handheld refractometer (Erma Refractometer, Japan) at room temperature. The displayed value was based on the ratio of the speed of light in a vacuum to the speed of light through the sample, and the TSS value was given in degrees Brix. All the experimental measurements were replicated three times. The juice pH was determined using a pH meter, calibrated with standard buffer solutions (pH 4.0 and 7.0). The juice sample was placed in a 100 ml beaker, and the electrode was immersed in the sample to obtain the pH reading.

The total phenol and tannin content were measured using the Folin-Ciocalteu colorimetric method. Gallic acid served as the calibration standard, and the results were expressed as gallic acid equivalents (mg of gallic acid per gram of dried sample). Lowry's method was used for determination of soluble protein content of the sample. Total carbohydrates were measured using the Anthrone method while reducing sugar was determined using the 2, 4-dinitrosalicylic acid (DNSA) method.

Statistical analysis

The collected data was subjected to the Analysis of Variance (ANOVA) using randomized block design by t-test to determine the variations among white grape accessions. The data was analyzed using SAS software version 9.3. Different genetic parameters like phenotypic variance and genotypic variance were computed based on the method suggested by Burton and DeVane (1953) ^[1].

i) Genotypic variance was calculated using the following formula

$$\text{Genotypic variance } (\sigma^2_g) = \frac{\text{Treatment mean square} - \text{Error mean square}}{\text{Number of replications}}$$

ii) Phenotypic variance was calculated according to the formula

Phenotypic variance (σ^2_p) = Genotypic variance (σ^2_g) + Error variance (σ^2_e)

iii) The phenotypic and genotypic coefficient of variations (PCV and GCV) was calculated using the formula suggested by Burton and Devane (1953)^[11]

$$\text{GCV (\%)} = \frac{\sqrt{\sigma^2_g}}{X} \times 100$$

$$\text{PCV (\%)} = \frac{\sqrt{\sigma^2_p}}{X} \times 100$$

Where, X is the grand mean of the character

iv) The heritability in the broad sense (h^2_{bs}) and genetic advance (GA) was estimated according to the method suggested by Johnson *et al.*, (1955)^[6].

$$h^2_{bs} = \frac{\sigma^2_g}{\sigma^2_p} \times 100$$

GA = K (σ_g) h^2_{bs} ,

where, K is the selection differential, K = 2.06 at 5% selection intensity

$$\text{Genetic Advance} = \frac{GA}{X} \times 100$$

The concentrations of five different biochemical in 40 white grapes accessions were analyzed using multivariate analysis with Metabo Analyst 4 software. Principal Component Analysis (PCA) was employed to identify biochemical parameters for varietal differentiation. A heat map was created using Ward's minimum variance method as the clustering algorithm, and squared Euclidean distances were calculated using hierarchical clustering with the Euclidean distance metric to assess the similarity in the concentration of biochemical parameters among grape genotypes.

Results and Discussion

The performance of different white grape accessions was studied for yield and biochemical parameters (Table 1 and 2). All the germplasm grown under Pune conditions showed significant variation for yield parameters. Pruning weight is regarded as an indirect indicator of vine vigor in grapes. Pruning weight was maximum in Dilkhush (1.89 kg) while minimum in Pusa Swarnika (0.07 kg). The amount of pruning weight is influenced by the vine's vigor, with highly vigorous varieties producing more pruning weight than those with low or medium vigor. Bud burst is a varietal characteristic that signifies the start of seasonal growth and is heavily affected by temperature. The number of days required for bud burst differs between varieties and depends on climatic conditions. The duration for bud burst serves as an indicator to categorize grape varieties into early, mid, and late types. However, variation was recorded for bud burst in

accession ranged from 8 days (Arka Soma) to 16 days (Kishmish Belly). Among the accessions studied, the accession Cheema Sahebi (448.5 g) was recorded with highest average bunch weight while lowest was recorded in James (50.3 g). Bunch weight is an important yield attributes in grape. The grape yield per vine increased with the increase in bunch number and bunch weight. Differences in bunch weight in different varieties can be attributed to the inherent genetic characteristics of the variety, differences in the number of canes, number of berries per bunch and berry size, as well as differences in the canopy size of the vine (Nale *et al.*, 2024)^[12]. The mean number of bunches per vine were ranged from 10 in Pandhari Sahebi to 73.5 in Muscat White. The number of bunches per vine is positively correlated with grape yield, leading to an increase in carbohydrate content in the berries to its maximum extent (Somkuwar *et al.*, 2013)^[14]. The mean fifty berry weight ranged from 49.0 g (Kishmish Belly) to 310.5 (Jaos Belly). The variation in the berry weight might be due to variation in the diameter of the berries and also due to number of berries per bunch. Highest berry diameter and length were recorded in Jaos Belly (21.6 mm) and Hussain Kadu (24.5 mm) while lowest berry diameter and length were observed in Manik Chaman (10.0 mm) and Perlette (11.8 mm) respectively. The larger berry diameter may be due to result of fewer berries in a bunch, as a higher number of berries in the bunch may lead to smaller berry diameters. The mean fruit yield was highest in Jaos Belly (18.22 kg) compared to all remaining accessions. There was more variation among white varieties for fruit yield of grape. In the present study, based on the yielding ability, varieties could be classified as high yielders ranging from 18.22 kg to 10.53 kg (Anoor Kalan, Arka Krishna, Italia, Arka Chitra, Arka Kanchan, Bianca, Muscat of Alexandria, Rosaria Bianca and Gold); medium yielders ranging from 8.95 kg to 5.03 kg and low yielding ranging from 4.47 to 0.3 kg. The variation in yield per vine among different grape cultivars could be attributed to factors such as bunch weight, number of bunches, berry weight, vine age, as well as their ability to adapt to different agro-climatic conditions in which they are grown (Joshi *et al.*, 2015)^[7].

The data on biochemical parameters, along with the mean, standard error (SE), critical difference (CD), and coefficient of variation (CV), are presented in Table 2. Significant variation for biochemical parameters was observed among the white grape genotypes. Total soluble solids varied from 17.47 °Brix in Hussain Kadu to 23.00 °Brix in Arka Krishna with an average of 19.15°Brix. Titratable acidity refers to the quantity of acid in grapes, which significantly influences the flavor of the grape berry. Generally, varieties with lower acidity are favored for table grapes. Both titratable acidity (TA) and pH are closely related and commonly used worldwide as indicators of grape maturity (Naik *et al.*, 2023)^[11]. The titratable acidity was in the range of 0.42% in Arka Krishna to 1.01 in Peru White with an average of 0.55%. Grape acidity is influenced by factors such as climate, grape variety, and farming practices (Liu *et al.*, 2006)^[10]. Highest concentration of phenol was recorded in 2.12 mg/g in Gold while lowest was recorded in 0.35 mg/g in Manik Chaman. It is widely recognized that both genetic and environmental factors have a major impact on phenolic composition (Jang *et al.*, 1997)^[5]. The total tannin content was varied from 0.48 (mg/gf resh weight) in Thompson Seedless to 4.55 (mg/g fresh weight) in Muscat of

Alexandria. Arka Krishna recorded maximum concentration of reducing sugar (354.73 mg/g) and carbohydrate (566.20 mg/g) whereas Cheema Sahebi recorded a maximum protein content (9.96 mg/g) among all studied white grape accessions. The lowest concentration of carbohydrate was noted in Aledo (197.33 mg/g) and reducing sugar in Angoor Kalan (110.3mg/g). At harvest, the reducing sugar content in grape berries increases as carbohydrates are converted into reducing sugars. Sugar accumulation can vary depending on the genotype and environmental factors.

The principal component analysis revealed the differences among the accessions studied (Fig 1). A biplot showed the relationship between the accessions and yield and biochemical parameters. The first principal component (PC1) scored 20.3% and the second principal component (PC2) scored 15.2%. The result revealed that parameters such as TTC, TPC, PW, TOV, BD, BL, BW had a strong correlation with accessions Hussain Kadu, Gold, Anab-E-Shahi, Muscat of Alexandria, Aledo, Symphony, Sahebi Ali, Dilkhush, Pandhari Sahebi and these characters had their positive contribution in these genotypes which included them in a similar group. In the opposite direction at the left lower quadrant, there were only two parameters NB and ST which were mostly similar in genotypes Bianca, Arka Hans,

H-5 Clone, Kishmish Belly, Superior Seedless and Coarna Alba was present in this quadrant. The yield and biochemical parameters present in the upper left side quadrant had a strong correlation with genotypes present in this quadrant. Similarly, the variables present on the lower right side had a strong correlation with accessions present in a similar quadrant. However, these two quadrants had a negative correlation between them. The result also revealed that white grape parameters present near to the center of the axis were closely related to each other and had less contribution in diversity while parameters away from the center of the axis showed a high level of variation in the white grape accessions. Based on biochemical parameters, 42 white grape accessions were divided into two main clusters, cluster-1 and cluster 2 (Fig 2). These cluster were further divided into sub cluster. Cluster 1 contained two cluster with two main sub cluster while cluster 2 contained two clusters in it with further sub clusters. The parameters that differentiate among accessions and the degree of inheritance are crucial factors in any crop improvement program. The study showed that biochemical markers are also valuable in grape improvement programs focused on specific traits.

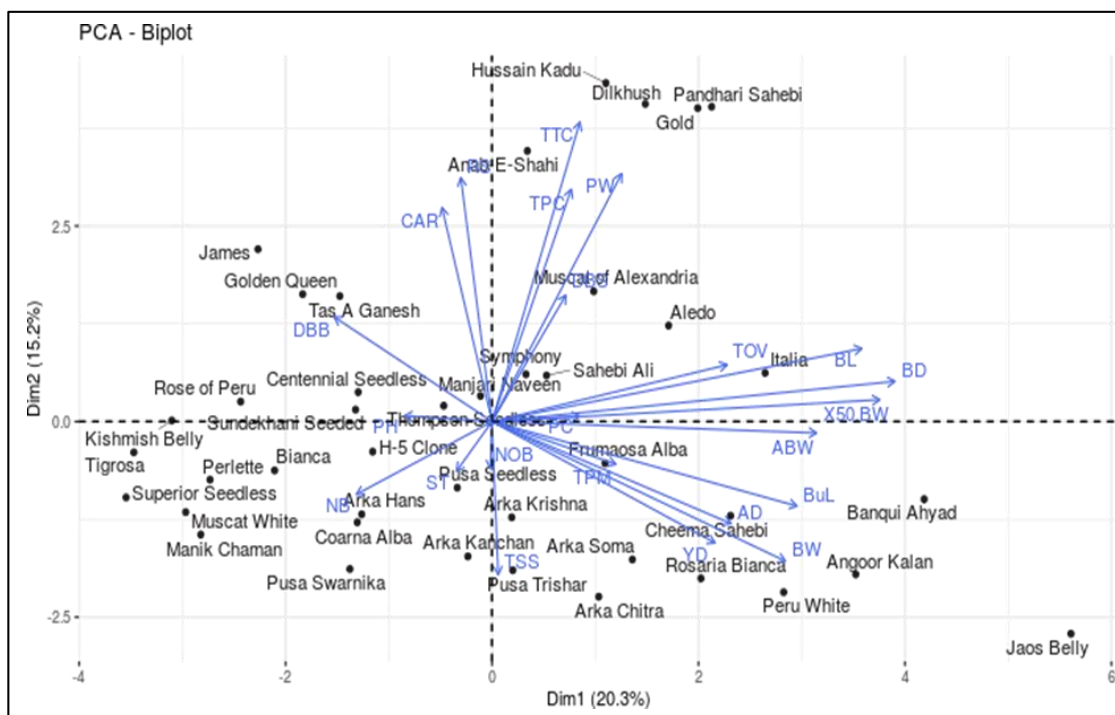


Fig 1: Principal component biplot for white grape accession based on 23 yield and biochemical parameters

The results on variability, heritability, and genetic advance as percent of for yield and biochemical traits evaluated for different grape accessions is presented in Table 3. The traits under study exhibited a higher phenotypic coefficient of variation (PCV) compared to the genotypic coefficient of variation (GCV), indicating that both genetic and environmental factors influenced the expression of these traits (Rosmaina *et al.*, 2016) [13]. The high estimates (>35%) of GCV and PCV for bunch weight, berry weight, fruit yield, pruning weight, number of berries per bunch and number of bunches per vine indicated the presence of genetic variation among the genotypes, making these traits suitable for further enhancement through selection. Among the yield traits, higher GCV was noted in fruit yield

(65.20%) followed by number of bunches per vine (62.95%) while the low GCV was recorded for days to bud burst (17.07%). Among the different biochemical parameters, higher GCV was noted for tannin content while lower GCV was observed in juice pH. Heritability is the quantitative study of variation that exists among genotype and phenotype. High heritability estimates (>90%) combined with high genetic advance percentage (100%), for bunch weight and berry weight confirmed that these traits are under the control of additive gene action and phenotypic selection for their improvement will be effective. Wei *et al.*, (2002) [16] also observed berry weight to be under strong additive genetic control. For biochemical, high heritability with high genetic advance percentage for reducing sugar and

carbohydrates. The traits showing moderate heritability coupled with low or moderate genetic advance indicated the role of non-additive gene action in their genetic inheritance. The genotypic and phenotypic correlation coefficients between different parameters are presented in Table 4. Fruit yield per vine showed significant positive correlation with bunch weight (0.4161), number of bunches per vine (0.601), bunch length (0.3501) and berry diameter (0.1832) while significant positive correlation with total soluble solids (0.2445). These traits also exhibited a strong correlation

with fruit yield per vine at the genotypic level, suggesting that environmental factors have minimal influence on their expression. Therefore, enhancing traits such as bunch length, bunch width, bunch weight, and bunch number appears to boost fruit yield per vine. Berry length, berry diameter, and berry weight were strongly positively correlated with each other, but negatively correlated with bunch number. This suggests that improving berry length, berry diameter, and berry weight may lead to a decrease in bunch number.

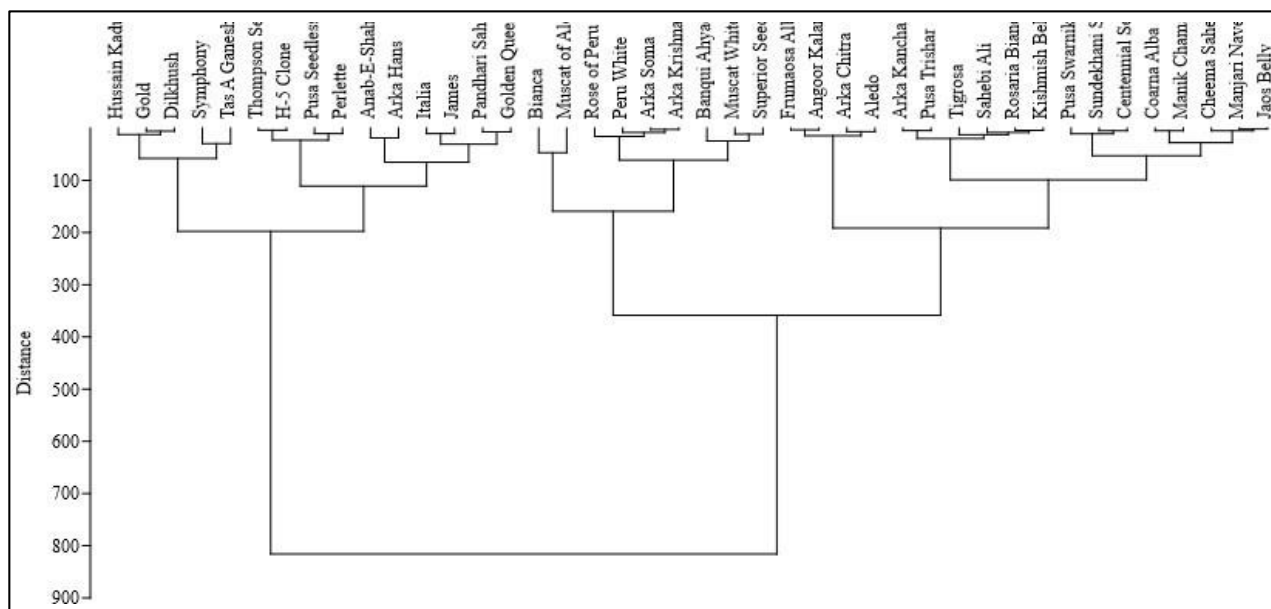


Fig 2: Hierarchical clustering white accession of grape grown under subtropical conditions.

Table 1: Performance of white grape accessions for fruit yield and quality parameter

Varieties	PW	DBB	ABW	50 BW	No of berries/bunch	No of bunches/vine	Yield/vine (kg)	Berry diameter (mm)	Berry length (mm)	Bunch length (cm)	Bunch width (cm)	Skin thickness (mm)
Coarna Alba	0.46	9.0	111.20	104.50	53.00	68.00	7.57	11.99	15.05	12.30	7.30	0.180
Frumoasa Alba	0.42	11.0	210.50	187.50	40.00	33.50	7.05	21.63	21.52	17.00	11.00	0.113
Muscat White	0.58	9.0	92.00	65.50	62.00	73.50	6.78	12.50	14.50	14.00	9.00	0.218
Arka Chitra	0.85	9.0	290.50	195.00	85.00	44.00	12.78	15.50	19.50	14.00	7.00	0.183
Arka Kanchan	0.47	9.0	250.50	140.50	75.00	42.00	10.53	13.50	15.50	17.00	11.00	0.278
Bianca	0.73	10.0	101.50	120.00	38.00	65.00	12.72	12.50	12.50	13.00	8.00	0.214
Muscat of Alexandria	0.32	9.0	255.00	255.50	48.00	61.50	15.69	15.22	17.16	14.00	6.00	0.179
Rosaria Bianca	0.35	9.0	245.00	120.50	70.00	63.00	15.47	19.50	22.80	18.00	12.00	0.209
Gold	1.65	9.0	370.50	148.00	84.00	42.50	15.75	16.50	19.50	14.00	6.00	0.152
Aledo	0.68	11.0	115.50	255.90	55.00	35.00	4.05	20.50	24.00	11.50	6.50	0.118
Anab-E-Shahi	1.63	10.0	192.50	181.50	58.00	15.00	2.88	18.50	18.25	11.50	6.50	0.201
Pandhari Sahebi	1.84	13.0	280.50	215.50	80.00	10.00	2.80	18.60	22.00	16.00	9.00	0.161
Hussain Kadu	1.36	10.0	160.00	120.00	35.00	12.00	1.92	18.36	24.57	14.00	7.00	0.164
Golden Queen	0.53	13.0	179.50	176.00	50.00	35.00	6.28	13.22	17.56	11.50	6.00	0.225
Cheema Sahebi	1.02	9.0	448.50	205.50	92.00	10.00	4.47	15.50	19.50	13.80	13.50	0.158
Sahebi Ali	0.59	9.0	289.50	190.00	90.00	12.00	3.47	16.50	19.50	9.75	9.50	0.092
Dilkush	1.89	10.0	278.50	215.50	65.00	16.00	4.45	15.50	21.60	13.00	8.00	0.228
Sundekhani Seeded	0.78	10.0	135.50	129.50	53.00	12.00	1.62	15.80	14.70	10.70	8.00	0.107
Italia	0.47	10.0	360.00	152.50	64.00	44.00	15.86	18.80	22.80	18.00	9.00	0.251
Thompson Seedless	0.93	11.0	260.50	154.50	80.00	31.00	8.07	16.86	18.25	13.50	7.50	0.217
TAS A Ganesh	1.14	11.0	260.50	90.00	130.00	70.00	18.24	13.45	15.98	15.00	7.00	0.198
H-5 Clone	0.47	9.0	260.00	92.00	115.00	24.00	6.24	14.00	15.00	17.50	6.20	0.146
Manik Chaman	0.51	9.0	115.50	59.00	80.00	30.00	3.47	10.00	14.00	12.40	4.50	0.073
Manjari Naveen	0.95	13.0	390.00	112.00	80.00	13.50	5.26	14.56	18.60	13.80	9.70	0.129
Superior Seedless	0.65	9.0	190.00	85.00	81.00	26.50	5.03	12.25	13.46	7.80	5.00	0.688
Perlette	0.52	10.0	130.00	70.00	99.00	27.00	3.51	10.36	11.88	14.30	8.30	0.099
Pusa Seedless	0.86	10.0	305.31	100.60	145.00	36.00	11.00	13.48	14.65	12.00	10.00	0.205
Kishmish Belly	0.82	16.0	85.00	49.00	62.00	31.50	2.68	10.98	15.28	10.00	9.00	0.108
Centennial Seedless	0.20	14.0	205.50	120.50	79.00	15.50	3.18	14.85	21.96	14.30	6.00	0.219

James	1.02	11.0	50.00	85.00	26.00	61.00	0.30	14.85	16.95	9.30	6.50	0.075
Peru White	0.72	9.0	270.50	190.50	90.00	32.50	8.79	17.00	19.50	18.20	12.00	0.210
Jaos Belly	0.91	9.0	348.00	310.50	80.00	10.50	3.65	19.20	21.80	17.50	15.00	0.199
Banqui Abyad	0.83	9.0	258.50	260.00	60.00	22.50	5.82	20.22	23.65	21.00	13.00	0.182
Symphony	0.50	9.0	220.50	107.00	110.00	23.00	5.08	16.00	17.50	13.00	10.50	0.143
Arka Soma	0.33	8.0	219.00	239.50	43.00	39.00	8.54	19.00	19.80	15.00	7.00	0.200
Arka Hans	0.30	9.0	130.50	105.00	62.00	68.50	8.95	14.80	17.90	11.00	5.00	0.102
Tigrosa	0.32	14.0	106.00	70.50	76.00	51.00	5.42	11.60	12.60	9.00	5.00	0.194
Arka Krishna	0.74	12.0	299.50	115.00	21.00	55.50	16.62	16.88	17.94	13.00	8.00	0.146
Angoor Kalan	0.59	9.0	360.00	248.50	90.00	47.50	17.11	21.50	22.00	17.00	11.00	0.222
Rose of Peru	0.59	10.0	136.00	70.50	99.00	44.50	6.06	12.90	14.90	12.00	3.50	0.153
Pusa Swarnika	0.07	10.0	149.00	79.50	58.00	29.00	4.32	10.84	20.22	13.00	10.00	0.182
Pusa Trishar	0.32	9.0	265.00	98.00	80.00	20.00	5.30	14.78	18.20	17.00	12.00	0.261
C.D.	0.03	0.26	8.52	5.18	3.15	2.23	0.80	0.42	0.51	0.44	0.31	0.008
SE(m)	0.01	0.09	3.02	1.84	1.12	0.79	0.29	0.15	0.18	0.16	0.11	0.003
SE(d)	0.02	0.13	4.28	2.60	1.58	1.12	0.40	0.21	0.25	0.22	0.15	0.004
C.V.	2.66	1.55	2.36	2.20	2.62	3.67	6.59	1.68	1.71	1.95	2.24	2.564

Table 2: Biochemical contents in fresh grape berries of 42 white grape genotypes

Variety	TSS (°Brix)	Acidity (%)	Juice pH	Phenol content (mg/g)	Tannin content (mg/g)	Protein content (mg/g)	Reducing Sugar (mg/g)	Carbohydrate (mg/g)
Coarna Alba	18.40	0.61	3.21	1.11	1.37	9.67	130.80	249.57
Frumaosa Alba	20.60	0.45	3.70	1.89	1.93	5.74	110.73	213.53
Muscat White	21.00	0.49	3.42	1.01	1.59	1.16	212.27	378.93
Arka Chitra	21.00	0.52	3.73	0.46	0.56	12.30	111.50	205.70
Arka Kanchan	17.50	0.58	3.48	0.71	1.29	6.86	170.17	319.19
Bianca	20.50	0.48	3.45	1.13	1.79	5.39	311.90	298.97
Muscat of Alexandria	19.40	0.54	3.64	1.98	4.55	6.78	277.50	356.27
Rosaria Bianca	18.60	0.55	3.82	0.76	0.76	10.50	161.20	311.11
Gold	17.80	0.57	3.38	2.12	4.35	8.79	346.33	513.54
Aledo	17.80	0.50	3.47	1.85	1.94	11.67	114.97	197.33
Anab-E-Shahi	18.40	0.56	3.49	1.09	3.66	5.97	305.10	424.70
Pandhari Sahebi	19.60	0.57	3.46	1.65	3.91	6.07	317.30	477.63
Hussain Kadu	17.47	0.49	3.54	1.53	3.55	7.44	354.73	502.80
Golden Queen	17.80	0.58	3.82	1.10	2.14	7.29	307.47	479.33
Cheema Sahebi	20.00	0.49	3.42	0.60	0.68	9.96	141.17	268.87
Sahebi Ali	19.20	0.51	3.32	1.52	1.86	8.61	167.43	308.84
Dilkhush	18.00	0.60	3.90	1.53	3.41	5.46	341.37	508.07
Sundekhani Seeded	18.20	0.49	3.81	0.83	1.22	6.44	152.33	288.80
Italia	18.00	0.74	3.50	1.11	2.78	6.34	289.87	461.47
Thompson Seedless	18.60	0.45	3.47	0.56	0.48	5.45	253.63	474.57
Tas A Ganesh	18.00	0.52	3.41	0.82	1.94	6.76	321.37	566.20
H-5 Clone	18.00	0.46	3.45	0.52	0.54	5.70	248.67	471.47
Manik Chaman	19.00	0.56	3.85	0.35	0.61	2.58	130.77	251.20
Manjari Naveen	18.60	0.46	3.21	1.37	1.52	8.23	142.27	274.00
Superior Seedless	19.20	0.45	3.84	0.48	0.53	4.14	199.93	389.13
Perlette	20.40	0.46	3.41	0.49	0.55	5.84	261.97	448.90
Pusa Seedless	22.00	0.58	3.45	0.56	0.60	6.29	250.83	458.70
Kishmish Belly	18.50	0.45	3.62	0.49	0.65	16.35	160.23	310.27
Centennial Seedless	18.00	0.44	3.77	1.41	1.53	9.48	145.93	289.47
James	18.73	0.51	3.46	1.15	3.13	7.20	300.73	451.17
Peru White	19.50	1.61	3.21	0.67	1.53	1.31	180.80	345.94
Jaos Belly	20.00	1.69	3.35	0.64	0.67	8.04	141.10	274.09
Banqui Ahyad	18.50	0.94	3.62	0.44	1.33	11.73	195.93	361.17
Symphony	19.00	0.54	3.38	0.55	1.62	7.59	326.70	524.27
Arka Soma	20.50	0.79	3.63	0.66	0.71	6.24	174.83	339.27
Arka Hans	22.00	1.13	3.60	0.67	1.53	6.99	331.30	420.53
Tigrosa	18.60	0.45	3.68	0.99	1.33	10.88	151.83	310.91
Arka Krishna	23.00	0.42	3.29	0.70	1.40	6.80	177.00	339.69
Angoor Kalan	19.50	0.47	3.25	1.02	0.68	9.78	110.03	211.80
Rose of Peru	18.40	0.49	3.29	1.53	1.70	5.26	171.53	356.00
Pusa Swarnika	18.70	0.54	3.52	0.54	0.62	5.32	157.07	297.53
Pusa Trishar	18.48	0.49	4.04	0.55	0.57	5.01	163.67	319.18
Mean	19.15	0.60	3.53	0.98	1.65	7.27	214.82	363.10
C.D.	0.45	0.02	0.09	0.15	0.11	0.53	8.90	12.54
SE(m)	0.16	0.01	0.03	0.05	0.04	0.19	3.16	4.45
SE(d)	0.23	0.01	0.04	0.08	0.06	0.26	4.47	6.29
C.V.	1.44	2.16	1.48	9.58	4.14	4.45	2.55	2.12

Table 3: Genetic variability and heritability for growth and biochemical traits evaluated for different grape genotypes

Character	GCV	PCV	Heritability (%)	GA	Genetic advance as percentage of mean (%)
YD	65.20	65.53	98.99	10.01	133.64
PW	58.05	58.11	99.78	0.87	119.45
DBB	17.07	17.14	99.11	3.57	35.01
ABW	43.70	43.77	99.71	199.86	89.90
BW	45.64	45.69	99.77	136.19	93.91
NOB	37.03	37.14	99.39	55.62	76.05
NB	62.95	63.10	99.54	49.12	129.39
BD	19.96	20.03	99.3	6.34	40.98
BL	18.73	18.80	99.18	6.99	38.42
BuL	20.85	20.94	99.13	5.90	42.77
BuW	31.53	31.61	99.5	5.43	64.79
ST	50.91	51.12	100.0	0.194	104.86
TSS	6.78	6.93	95.7	2.61	13.67
AD	43.01	43.07	99.71	0.53	88.48
PH	5.78	5.96	94.14	0.40	11.57
TPC	47.94	48.86	96.28	0.97	96.91
TTC	70.75	70.87	99.65	2.35	145.49
PC	39.67	39.91	98.76	5.90	81.21
RS	36.90	36.99	99.53	162.92	75.84
CAR	27.40	27.48	99.40	204.35	56.27

Table 4: Phenotypic (rp) and genotypic (rg) correlation coefficients of fruit yield and biochemical parameters in white grapes accessions

Characters	YD	PW	DBB	ABW	BW	NOB	NB	BD	BL	BuL	BuW	ST	TSS	AD	PH
YD	1**	-0.112NS	-0.232**	0.416**	0.115NS	0.050NS	0.601**	0.1832 *	0.042NS	0.350**	0.031NS	0.148NS	0.2445 **	0.0475 NS	-0.17
PW		1**	0.106NS	0.258**	0.241**	0.055NS	-0.2429 **	0.235 **	0.221*	-0.043NS	-0.001NS	-0.043NS	-0.1432 NS	0.0095 NS	-0.13
DBB			1 **	-0.207*	-0.250**	-0.113NS	-0.116 NS	-0.1852 *	-0.047NS	-0.305**	-0.199*	-0.159NS	-0.1399 NS	-0.1848 *	0.08
ABW				1 **	0.495**	0.3154**	-0.3228 **	0.4404 **	0.433**	0.503**	0.497**	0.133NS	0.0775 NS	0.2161 *	-0.2
BW					1**	-0.189*	-0.2156 *	0.7418 **	0.644**	0.411**	0.39**	-0.005NS	0.0305 NS	0.4217 **	-0.06
NOB						1**	-0.1956 *	-0.2008 *	-0.223*	0.084NS	0.048NS	0.022NS	-0.0224 NS	-0.0376 NS	-0.18
NB							1 **	0.2174 *	-0.342**	-0.071NS	-0.253**	0.014NS	0.3278 **	-0.0872 NS	-0.1
BD								1 **	0.344*	-0.072NS	-0.255NS	0.013NS	0.3324 *	-0.0874 NS	-0.11
BL									1**	0.489**	0.387**	-0.096NS	-0.1678 NS	0.2232 *	0.037
BuL										1**	0.607**	-0.039NS	-0.036 NS	0.3633 **	-0.0
BuW											1**	-0.024NS	0.1386 NS	0.4039 **	-0.15
ST												1**	-0.0793 NS	0.0159 NS	0.26
TSS													1 **	0.198 *	-0.1
AD														1 **	-0.22
PH															1 **
TPC															
TTC															
PC															
RS															
CAR															

(Where, YD= Fruit Yield; PW= Pruned weight; DBB= Days taken for bud burst; ABW= Average bunch weight; BW= Berry weight; NOB= Number of bunches per vine; NB= Number of berries per bunch; BD= Berry diameter; BL= Berry length; BuL= Bunch length; ST= Skin thickness; TSS= Total soluble solid; AD= Acidity; TPC= Total phenol content; TTC= Total tannin content; PC= Protein content; RS= Reducing sugar; CAR= Carbohydrate).

Conclusion

The current study identified the significant contribution of all bunch and biochemical parameters to the yield and quality characteristics of grape genotypes. Maximum average bunch weight, berry diameter, 50-berry as well as for biochemical parameters like total phenol, total soluble

solid and reducing sugar was obtained in Cheema Sahebi, Peru White. Based on the findings, it was concluded that parameters like average bunch weight, berry weight, number of berries per bunch, reducing sugar and carbohydrate content can serve as selection criteria in grape varietal development programs. These traits showed high heritability

and genetic advance. Therefore, both yield traits such as bunch and berry weight, along with biochemical markers can be valuable in genotype selection for various purposes.

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