Journal of Pure and Applied Agriculture (2022) 7(3): 25-32
ISSN (Print) 2617-8672, ISSN (Online) 2617-8680
http://jpaa.aiou.edu.pk/

Performance of various grapes cultivars under agro-climatic conditions of Central Punjab, Pakistan

Allah Bahksh[1], Sitwat Riaz[1], M. Amna Jamil Kanwal[1], Maryam Nasir[1]*, Malik Mohsin Abbas[1], Aamir Hameed[2], Nida Mahreen[1] and Muhammad Maaz Aziz[1]

[1]Horticultural Research Institute, Ayub Agricultural Research Institute, Faisalabad, Pakistan
[2]Statistical Section, Ayub Agricultural Research Institute, Faisalabad, Pakistan

*Corresponding author: Maryam Nasir (maryamnasir26@gmail.com)

Abstract

Grapes are a rich source of sugars, vitamins, minerals and organic acids which are an important part of human nutrition and vital for growth and development. Climate plays an important role in berry development, growth, fruit ripening and physical as well as biochemical properties of the berry fruits such as size, colour, sugars and taste. Grapes are an important crop that have been grown throughout the world. In Pakistan it is mostly grown in Balochistan and temperate areas. The performance of grapes under climatic conditions of central Punjab are still unexplored. Hence, the experiment was designed to study the performance of nine cultivars of grapes viz., White Seedless, Pearlette, Badana, Black Seedless, Haita, Flame Seedless, King's Ruby, NARC black, Cardinal under agro-climatic conditions of Central Punjab during the year 2019-20. Results showed that higher bunch size (307.3 cm), bunch weight (456.2g), berry size (176.8mm), and berry weight (3.82g) was observed in King's ruby compared to other varieties. TSS (21.8 ° Brix), TSS: TA ratio (90.9) was higher in white seedless and maximum TA (0.46%) was found in Flame seedless. Vitamin C content was higher in pearlette (26.9 mg /100 g) and NARC Black (27.3 mg/100 g). It is concluded that the performance of King's ruby and NARC Black were better in central Punjab condition as compared to other cultivars grown as they have more berry weight and better fruit quality.

Keywords: Vitamin C, Grape cultivars, Growth, Performance, Sugars, Taste

To cite this article: Bahksh, A., Riaz, S., Kanwal, M. A. J., Nasir, M., Abbas, M. M., Hameed, A., Mahreen, N., & Aziz, M. M. (2022). Performance of various grapes cultivars under agro-climatic conditions of Central Punjab, Pakistan. *Journal of Pure and Applied Agriculture, 7*(3), 25-32.

Introduction

Grapes (*Vitis vinifera* L.) are cultivated on a large scale because of the handsome economic returns. Grapes belong to the family "Vitaceae". It is a rich source of organic acids, vitamins, sugars and minerals, that are necessary part of the human diet and are required for normal growth (Engel et al., 2010). It occupies top position in the world in respect to area (6.9 million ha) and production (77 million tons) (FAOSTAT, 2019). Grapes are grown around the world for several purposes like 70% of its portion used for wine preparation, while 25% of grapes used for fresh consumption and only 5% of it is used for drying purpose (Akram et al., 2020)

Grapes ranked as 10th most important fruit crop in Pakistan. In the year 2018-19, the total cultivated area of grapes in Pakistan was 38730 acres with an estimated production of 68470 tones (GOP, 2019-20). It is the highest production of grapes from the past nine years. Almost 70% of the grape's cultivars are being cultivated in Balochistan which has a share of 19 tons per hac production against the potential of 25 tons per hac. The remaining 30% of grapes are grown in the districts of Punjab and Khyber Pakhtunkhwa (Khan et al., 2011).

Berry growth, development and quality are highly dependent upon climatic conditions of the area. Grapes require long warm to dry hot summers and cool rainy winters for the development and growth of berries. Grape's diversity and production were greatly affected by the climatic conditions (Silva-Sanzana et al., 2016; Akram et al., 2019). Temperature, light, wind, humidity and precipitation are the key factors that are included in climate which may affect the plants in a particular area. Temperature plays an important role in the successful growth of grapes among these factors. For shoot growth and physiological processes, the ideal range of average temperature is from 25-30 °C (Ramos et al., 2013). Chemical composition of grape juice could be affected by environmental factors such as soil, light, temperature, rain and a combination of these factors (Hunter & Bonnardot, 2011; Kaur et al., 2019). However, grapes require a temperature lower than 10° C to open the buds and for berry ripening 30-35 as a temperate fruit. In Punjab average temperature in summer is 30 to 45°C, whereas, in winter the average temperature ranges from 1-18 °C (Fig. 1). These conditions fulfill the temperature requirement for grapes cultivation (Akram et al., 2020).

The temperature in Punjab befits the requirement for grapes cultivation, but the onset of monsoon rains early in central Punjab is a concerning issue for growers. Usually, grapes get ripened from June to August and at that time rain occurs (Fig. 1). Monsoon rains at the time of maturity causes cracking, rotting and splitting of berries that eventually provoke different fungal diseases and cause rapid berry rotting (Khan et al., 2011). Grapes have high sugar contents (Engel et al., 2010), this high sugar along with increased humidity and temperature during summer time provides the ideal condition for fungal growth. This

fungus affects the fruit quality and growth of berries (Tello, J. & Ibanez, J. 2017). On the basis of physical and chemical characteristics early ripening grape cultivars should be selected to solve the berry rotten issue due to monsoon rains.

Climate is also significantly involved in changing the ripening and biochemical qualities of the grape fruits. In grapes the variation in germplasm and quality of fruits could be attributed to the climatic variation. Generally, climate affects nutritional value and chemical characteristics of grapes as compared to any other factor (Attia and Farag, 2017). Cultivar, agro-climatic conditions and geo-graphic location affects the time of ripening and harvesting of fruits. According to Gonzalez, C.V., et al., (2016) different varieties of grape have different tolerance to temperature fluctuations, rainfall and humidity. The fruit weight, size and diameters reach their peak level; it will be known as physical maturity whereas the chemical maturity depends upon maximum sugar contents and TSS/TA ratio (Khan et al., 2008; Bahar, A., et al., 2017). Color, aroma, size, time of maturity, time of ripening and yield are the physical characteristics that are affected by the factors involving climate, soil, topography and substrate which also affects the biochemical characteristics like total sugars and total soluble solids of grape berry (Carey et al., 2008), In addition to these environmental factors, the genotype of grapes cultivars deeply affects the chemical composition of berries (Naradisorn M., 2013).

Kose, (2014) described that the key factor for the grape cultivation is the grapes phenology. The phenological phases include bud opening, blooming, fruit setting and harvesting (Mira de Orduna, 2010). In subtropical conditions, the bud opening in grapes starts in the last week of February when the dormancy starts to break. And fruit ripening starts in the last of June and onwards. But that is the time of onset of monsoon rains. Therefore, to reduce berry loss including splitting and rotting caused by monsoon rains there is a need to find out early maturing grapes cultivars that will harvest before onset of monsoon rains and have enhanced performance regarding fruit quality enhanced physicochemical properties under central condition of Punjab, Pakistan.

Material and Methods

Plant material

The study was carried out at Horticultural Research Institute, Ayub Agricultural Research Institute (Latitude 31.42^{o} N, Longitude 73.09^{o} E, Elevation 189 m) during the year 2019-20. Nine cultivars of grapes *viz.*, White Seedless, Pearlette, Badana, Black Seedless, Haita, Flame Seedless, King's Ruby, NARC black and Cardinal were selected for the study. Within a treatment single vine was replicated four times. A total of thirty-six plants were selected for the study. All cultivars selected were of similar age (seven years old) and disease free. The management practices including pruning, plowing, irrigation, fertilizer, insecticides and pesticide application were similar for all plants. After the dormant season during January-February, all plants were pruned severally leaving four to six nodes. During the complete study duration meteorological data regarding relative humidity, rainfall and temperature were recorded daily (Fig. 1). Soil analysis report of the experimental area is mentioned in Table 1.

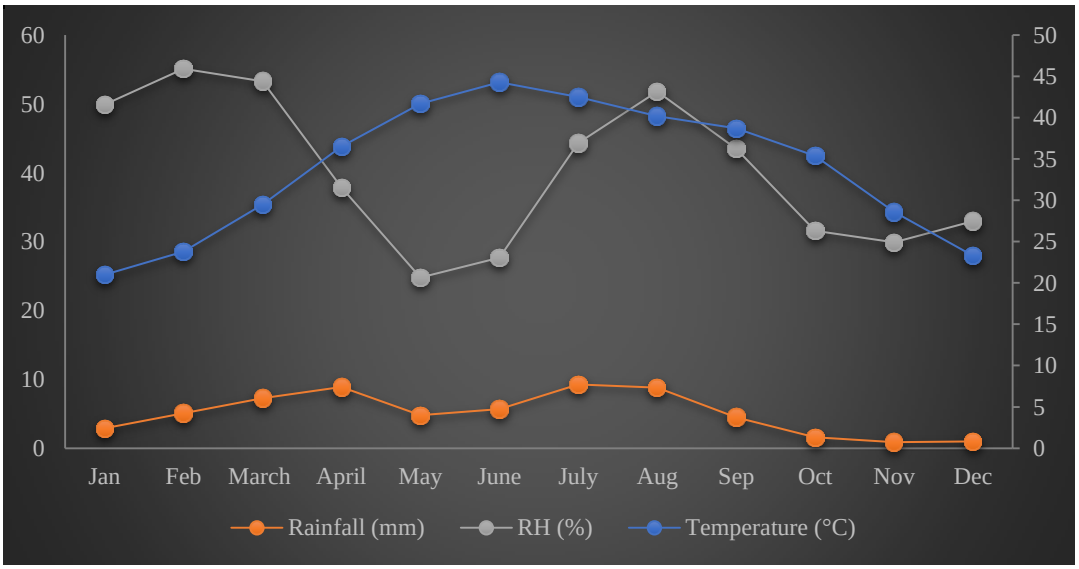

Fig. 1 The average temperature, rainfall and relative humidity of Faisalabad, during the year 2019-20

Table 1 Soil analysis report of experimental AARI research orchard

Depth	EC mScm^{-1}	pH	Organic matter (%)	Available phosphorus (mb Kg^{-1})	Available potassium (mg Kg^{-1})	Saturation (%)	Texture	Gypsum required (Ton/acre 6")
0-15	2.78	8.4	0.98	37.1	149	34	loam	Nil
15-30	2.29	8.3	1.19	30.2	129	34	-	-
30-45	2.81	8.1	1.54	19.2	129	32	-	-

Physico-chemical fruit quality characteristics

The fruits were harvested at full mature stage. After harvesting they were brought to the horticultural laboratory. They were washed thoroughly with cleaned water in order to remove debris and impurities. Physico-chemical fruit quality characteristics include bunch length (cm), bunch width (cm), bunch size (cm^2), berries per bunch (number), berry length (mm), berry width (mm), berry size (cm^2), bunch weight (g), total soluble solids (° Brix), juice pH, titratable acidity (acidity %), TSS: TA ratio, total sugar percentage (%), non-reducing sugar percentage (%) and reducing sugar percentage (%), vitamin C (mg/ 100 g) and total phenols (mg GAE/100 g) were calculated for all nine cultivars.

Fruit physical parameters

Bunch width and bunch length was calculated using normal meter rod and expressed in cm. Bunch size (cm^2) was calculated by multiplying bunch length into width. The number of berries per bunch was counted by counting the number of berries per bunch. Length and width of the berry was measured with Vernier caliper and expressed in mm. Berry size (mm^2) was calculated by multiplying length into width, respectively.

Fruit biochemical parameters

TSS of the juice was readied through a hand refractometer (ATAGO, RS 5000) and expressed as (° Brix). The TA of berry juice was measured using the method of Hortwitz (1960). According to this method 10 mL of juice was taken on a conical flask and dilute it with distilled water up to 50 mL. Then the solute was titrated using 0.1N NaOH using phenolphthalein as an indicator till pink color was attained as an end point and expressed as %. The TSS: TA ratio was calculated by dividing the TSS with their respective TA. Digital pH meter was used to measure the pH of berry juice (HI 98107, Hanna Instruments, Mauritius).

Vitamin C, sugars and total phenolics

Ruck's 1969 method was used to determine the vitamin C contents of berry juice. In this method, 10mL of juice was taken in 100mL of flask diluted with 0.4% oxalic acid solution. 2, 6- dichlorophenol indophenol dye was used to titrate 5mL of diluted and filtered aliquot to a light pink color end point. Sugars in juice were determined by following the methods explained by Khan et al. (2009). In this method, in a volumetric flask of 250mL, 10mL of juice was diluted with 100mL of water, 10mL 20% potassium oxalate and 25ml 25% lead acetate solution. The remaining volume was completed by adding distilled water. The filtrate was then used to determine total sugar, non-reducing and reducing sugar. The value was expressed in %.

Total phenolics were determined by following the method of Ainsworth and Gillespie (2007) with few modifications explained by Ullah et al. (2012). 0.02-0.1 mg/mL concentrated average gallic acid curve graph was used and determined values were explained in unit as gallic acid equivalents mg/100 g GAE fresh weight (FW).

Statistical analysis

The response of various varieties was evaluated using ANOVA (analysis of variance) technique and Fisher's least significant in software statistix 8.1 at significance probability of ≤ 0.05. PCA (Principal component analysis) -Biplot analysis is used to study the interaction between varieties and traits (Steel et al., 1997).

Results and Discussion

Physical parameters

All grapes' cultivars exhibited significant variation in their bunch characteristics shown in (Table 2). Similarly, bunch length and width show the significant difference among the cultivars. Kings ruby showed highest bunch length (25.6 cm), whereas, highest bunch width was found in NARC black (13.9 cm). Biggest bunch size was observed in Kings Ruby (307.3 cm^2) while smallest bunch size was observed in Badana (96.1 cm^2). Similarly, highest bunch weight was observed in Kings Ruby (456.2 g) and NARC Black (395.1 g), respectively, compared to other cultivars (Table 2). Pearson correlation analysis ($P \leq 0.05$) showed significant positive correlation between berry length, berry weight, berry size, number of berries, berry length and berry size, respectively (Fig. 2). The increase in size and weight could be related to the fact that Kings Ruby and NARC black performed well in agro-climatic conditions of Faisalabad. Similar results were found in various grape cultivars grown in different agro-climatic conditions and their results described that king's ruby and cardinal performed well in sub-tropical climate (Khan et al., 2011; Uddin et al., 2011). The number of berries were found to be significantly different in each cultivar. Highest number of berries was counted in Kings Ruby (177) followed by NARC Black (167). Whereas, minimum number of berries per bunch were observed in flame seedless (133). The berry length, width, size and weight also showed significant variation. Largest berry length was observed in Kings Ruby (21.7 mm) and smallest in Haita (9.3 mm). Largest berry width was highest in Flame seedless (9.4mm) and smallest in cardinal (7.4 mm). Maximum berry size was observed in Kings Ruby (176.8 mm^2), whereas, the smallest berry size was observed in Hiata (67.8 mm^2). Similarly, maximum berry weight was observed in Kings Ruby (3.82g) followed by NARC Black (3.44g) whereas the lowest berry weight was found in Badana (1.66 mm). Hence, the climatic conditions of central Punjab are conducive for better growth of berries and it was observed that among various cultivars grown Kings Ruby and NARC Black performed better (Uddin et al., 2011).

Table 2 Physical characteristics of grapes cultivars under agro-climatic conditions of Central Punjab

Cultivars	Bunch Length (cm)	Bunch Width (cm)	Bunch Size (cm^2)	Bunch Weight (g)	Number of berries/bunch	Berry length (mm)	Berry width (mm)	Berry size (mm^2)	Berry weight (g)
White Seedles	11.6^{h}	8.6^{e}	100.2^{d}	352.1^{e}	146.2^{d}	13.1^{de}	8.3^{b}	107.9^{cd}	1.79^{gh}
Pearlette	13.4^{f}	9.2^{de}	122.7^{c}	387.5^{c}	156.5^{c}	12.4^{e}	7.9^{cd}	96.5^{e}	1.81^{fg}
Badana	12.3^{g}	7.8^{f}	96.1^{d}	292.9^{f}	137.3^{e}	13.4^{d}	7.5^{d}	100.1^{de}	1.66^{h}
Black Seedless	16.4^{d}	11.2^{c}	182.5^{b}	284.8^{g}	135.9^{ef}	16.3^{c}	9.3^{a}	153.2^{b}	3.20^{c}
Haita	12.4^{f}	9.9^{d}	129.1^{c}	371.0^{d}	146.8^{d}	9.3^{h}	7.2^{d}	67.8^{g}	1.94^{f}
Flame Seedless	17.5^{c}	11.4^{bc}	194.9^{b}	270.8^{h}	133.8^{fg}	11.6^{f}	9.4^{a}	109.9^{c}	2.71^{e}
Kings Ruby	25.6^{a}	12.1^{b}	307.3^{a}	456.2^{a}	177.0^{a}	21.7^{a}	8.1^{a}	176.8^{a}	3.82^{a}
NARC black	22.4^{b}	13.9^{a}	302.1^{a}	395.1^{b}	167.8^{b}	18.3^{b}	9.3^{a}	170.5^{a}	3.44^{b}
Cardinal	14.4^{e}	9.5^{d}	136.1^{c}	267.8^{i}	132.3^{g}	10.9^{g}	7.4^{d}	81.1^{f}	2.85^{d}
LSD(P≥0.05)	0.2988	0.3867	7.5820	1.2900	1.4613	0.3564	0.2224	3.9166	0.0639

Treatments having same letter are non-significant at *P≤0.05.*

Biochemical parameters

The biochemical quality of all grape cultivars under experiment showed significant differences (Table 3 and 4). Among these cultivars TSS ranged between 14.5 to 21.8 Brix. Maximum TSS was observed in white seedless (21.8Brix) followed by pearlette (20.8 Brix) and Kings ruby18.6 Brix). Whereas, the minimum TSS was observed in Badana (14.5 Brix) and Black seedless (14.5 Brix). The difference in TSS among various cultivars may be associated with the fact that the various cultivars perform differently under similar conditions. Moreover, the consumer demand for table grapes is also directly related to the TSS of grapes, usually higher TSS is preferred by consumers (Fahmi et al., 2012). The TSS parameter is broadly accepted as a maturity indicator for grapes (Sah et al., 2014; Guzman, Y., et al., 2021). It was observed that large berries usually have higher TSS and small to medium size berries have normal to low TSS. Fahmi et al. (2012) agreed with these results who evaluated the range of TSS from 14 to 21% of different grape cultivars and Aponso et al. (2017) observed that in different grape varieties the TSS ranged between 11.33% to 20%. The organoleptic quality of grapes is also affected by the TA, as the TA increases it causes tartness in berry taste (Guzman, Y., et al., 2021)). Total acidity value in these nine cultivars ranged between 0.2-0.5%, that is far less as reported earlier by Jayasena and Cameron (2009). They report that acidity ranged between 1-2% in grape juice of Crimson seedless. This could be explained on the basis of the fact that the higher temperatures cause early maturing/ripening of varieties, whereas in temperate regions they take longer time to get mature and ripen, hence accumulation of acids is not high in berries (Eyduran, et al., 2015). The highest TA was observed in Black seedless (0.48%) and the low TA was found in White seedless (0.24%) followed by pearlette (0.25%). Maximum TSS: TA ratio was exhibited in white seedless (90.9) followed by pearlette (84.7) and the minimum ratio was found in Badana (31.7) and Flame seedless (33.7). TSS: TA ratio is a quality affecting factor with high TSS: TA ratio; the higher the ratio the better and more desirable taste of the fruits (Fahmi et al., 2012; Alva, O., et al., 2015). Moreover, Pearson correlation analysis ($P \leq 0.05$) showed significant negative correlation between TSS and TA (Fig. 2). The pH range in grapes was between 4.3 to 5.2 (Table 2). This pH range falls under the same category as documented earlier by Khan et al. (2011).

Vitamin C content in grape fruits showed significant variation among different grape cultivars (Table 2). The maximum Vitamin C content was exhibited by NARC Black (27.3 mg/100 g^{-1}) followed by pearlette (26.9mg/100g^{-1}), respectively. Whereas the minimum vitamin C contents were found in cardinal (22.7mg/100g^{-1}) (Table 3). Franke et al. (2004) described that with growing conditions and fruit exposure to sunlight, vitamin C contents vary in fruits. NARC black and pearlette are early ripening varieties, so increase in their vitamin C content can be related to their early maturing nature. Our findings were further supported by the findings of Khan et al. (2009); Ghorbani et al. (2017) who reported that vitamin C decreased in berries as the time of ripening increased especially in grape cultivars kings early and Anab-e-shahi.

Table 3 Biochemical characteristics of different grapes cultivars under agro-climatic conditions of Faisalabad

Cultivars	TSS (Brix)	TA (%)	TSS/TA	pH	Vitamin C (mg /100g^{-1})
White Seedles	21.8^{a}	0.24^{d}	90.9^{a}	4.7^{b}	23.4^{b}
Pearlette	20.8^{b}	0.25^{d}	84.7^{b}	4.3^{de}	26.9^{a}
Badana	14.5^{fg}	0.46^{a}	31.7^{f}	4.8^{b}	23.6^{b}
Black Seedless	14.5^{g}	0.48^{a}	30.2^{f}	5.2^{a}	19.2^{c}
Haita	15.2^{efg}	0.36^{c}	42.5^{d}	4.3^{e}	14.8^{d}
Flame Seedless	15.3^{ef}	0.46^{a}	33.7^{ef}	4.7^{b}	23.1^{b}
Kings Ruby	18.6^{c}	0.35^{c}	53.5^{c}	4.7^{bc}	23.9^{b}
NARC black	17.3^{d}	0.33^{c}	52.0^{c}	4.5^{cd}	27.3^{a}
Cardinal	15.7^{e}	0.42^{b}	37.2^{e}	4.6^{bc}	22.7^{b}
LSD(P≥0.05)	0.3953	0.0157	2.5065	0.0891	0.9342

Treatments having same letter are non-significant at *P≤0.05*.

As mentioned earlier sugar content was significantly different in all grape's cultivars (Table 4). Maximum total sugar content was found in White seedless (13.64%) while the least total sugar contents were observed in cardinal (10.67%) (Table 4). Similarly, maximum reducing sugars contents were found highest in cultivar Flame seedless (8.44%) followed by pearlette (8.19%) and lowest reducing sugars were exhibited by the cultivar cardinal (6.93%) (Table 4). Likewise, maximum non-reducing sugars were shown by White seedless cultivar (6.04%) and minimum non-reducing sugars were found in pearlette (3.71%) (Table 4). The maximum sugar content in white seedless is may be due to the fact that it is early maturing variety and after berry formation the most expressed sugars such as sucrose and fructose start assimilating into berries (Mulet et al., 2017; Tripathi et al., 2017). Furthermore, under warmer climates like subtropical regions the berries attain early maturity and increase in size that cause translocation of sugars stored in leaf and vine roots towards berries and cause increase in sugar content of early maturing varieties (Eyduran et al., 2015). TSS is mostly known as a sugar indicator parameter and generally examined that the higher sugar content in fruits is directly proportional to the fruits. Muñoz-Robredo et al., (2011) also confirmed these results that the higher the TSS the more sugar content in grapes. Khan et al., (2011); Yinshan et al., (2017) also confirmed these results and described the total sugars value range from 11.44 to 13.60%. In temperate climatic zones grape growers tend to wait for a longer period for ripeness due to slow increase in sugar contents but during high temperature the acids were converted to sugars (Hunter & Bonnardot, 2011; Kumar et al., 2017).

Total phenolics showed significantly different results among the grape cultivars ranging from 117.7mg/ 100g GAE to 329.7 mg/ 100G GAE. The maximum phenols were observed in NARC black (329.7mg/ 100 g GAE) followed by Flame Seedless and the minimum value was observed in cardinal (117.7 mg/ 100 g GAE) (Table 4). Grape fruits are rich in phenols and the concentration range 23.8 mg/g GAE to 352 mg/ g GAE in skin, seed flesh and leaf, respectively (Mullen et al., 2007; Xia et al., 2010; Murcia et al., 2016). In grape skin the total phenols show variation depending upon cultivar, soil composition, climate, cultural practices and geographical regions (Bruno et al., 2007). Usually, the pigmented varieties have more phenolic content as compared to lighter varieties (Falchi et al., 2006; Dopico-Garcia et al., 2008). Hence, NARC black and flame seedless are darker varieties having higher phenolic contents.

Table 4 Sugars and total phenolic of different grapes cultivars under agro-climatic conditions of Faisalabad

Cultivars	Total Sugars (%)	Reducing Sugars (%)	Non-Reducing Sugars (%)	Total phenolics (mg/ 100 g GAE)
White Seedles	13.64^{a}	7.60^{ab}	6.04^{a}	299.0^{b}
Pearlette	11.90^{b}	8.19^{ab}	3.71^{c}	233.1^{d}
Badana	11.84^{b}	7.57^{ab}	4.27^{bc}	250.4^{c}
Black Seedless	12.43^{b}	6.99^{b}	5.44^{ab}	226.6^{d}
Haita	12.51^{b}	7.74^{ab}	4.77^{abc}	175.5^{e}
Flame Seedless	12.21^{b}	8.44^{a}	3.77^{c}	304.4^{b}
Kings Ruby	11.78^{b}	7.01^{b}	4.77^{abc}	294.2^{b}
NARC black	12.26^{b}	7.35^{ab}	4.91^{abc}	329.7^{a}
Cardinal	10.67^{c}	6.93^{b}	3.74^{c}	117.7^{f}
LSD(P≥0.05)	0.4478	0.6593	0.6952	6.0210

Treatments having same letter are non-significant at *P≤0.05*.

The PCA-Biplot analysis showed a clearer understanding of the relationship between varieties and traits. It explained 64.5% of the total variation of the data (Fig. 3). The biplot exhibited that 9 varieties of grapes were grouped into 4 clusters based on different traits. It indicated 4 groups i.e., V1 (White seedless) and V2 (Pearlette) are from one group, V3 (Badana), V5 (Haita) and V9 (Cardinal) are in another group. Similarly, other two groups consist of V7 (Kings Ruby) and V8 (NARC Black); and V4 (Black seedless) and V6 (Flame seedless), respectively (Fig. 3).

On the other hand, maximum variation is observed between character TA, followed by TSS, berry size (BS), bunch size (BuS), number of berries (NOB), as these vectors are of maximum length as compared to others. The angle between the vectors TA and TSS is close to 180, which indicates a correlation in the negative direction. Whereas, vectors Berry length (BeL), berry size (BS), bunch length (BuL), bunch size (BuS) and bunch weight (BuW) observed low angle, which showed a high positive correlation between them. Similarly, vectors observing angles close to 90° are not closely related (Fig. 3).

Finally, group-I (V1, V2) these varieties are rich in TSS, NOB and BuWT and have all likable traits that can be further recommended for cultivation.

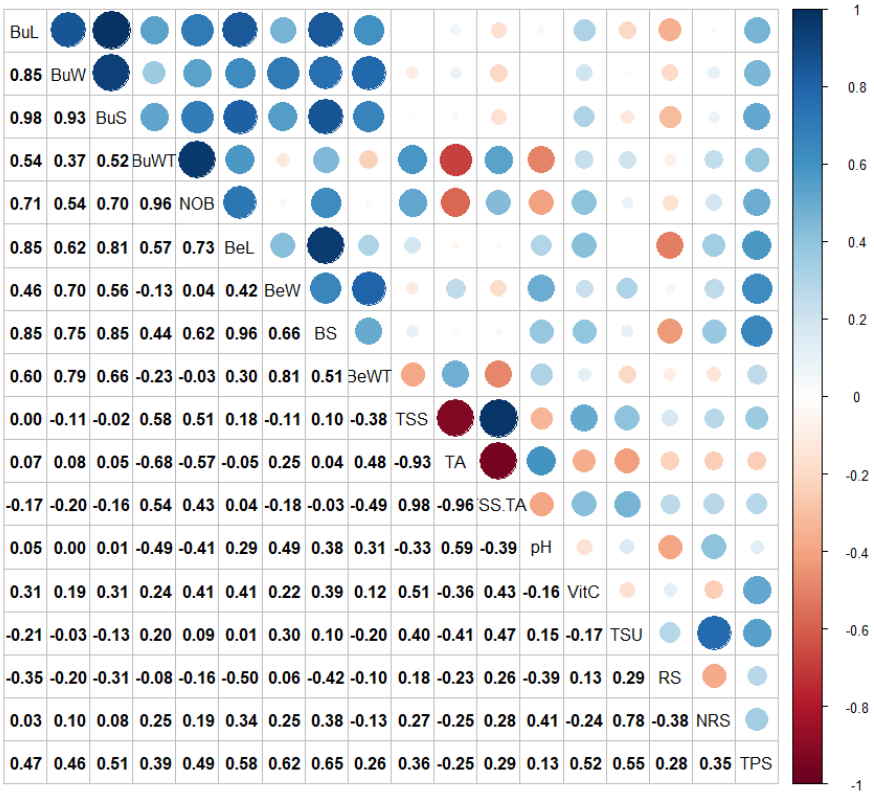

Fig. 2 Pearson's correlation analysis for physico-chemical attributes of different grape cultivars

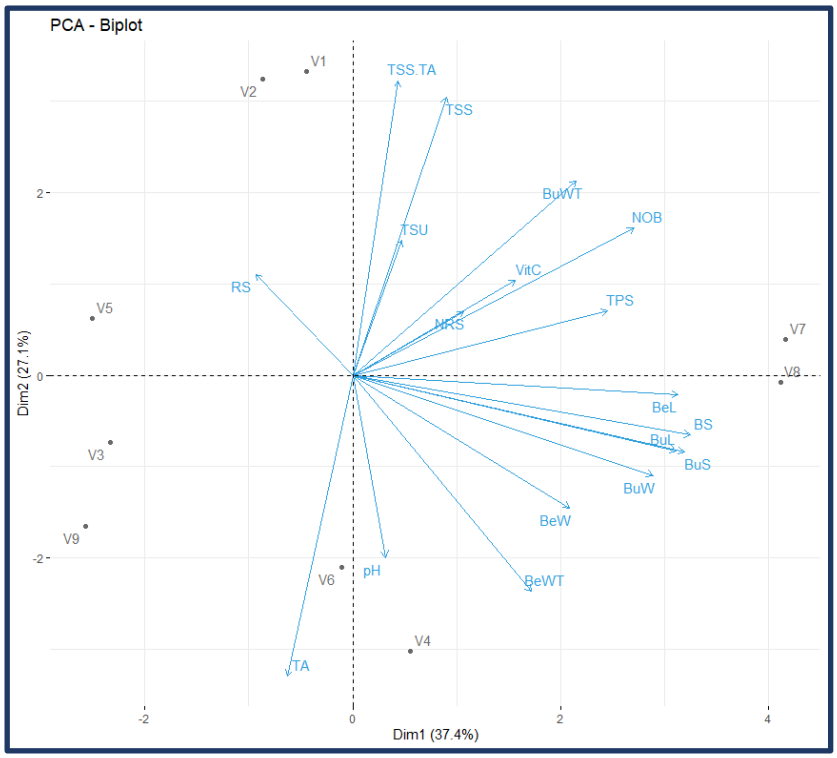

Fig. 3 PCA-Biplot of different varieties of grapes

Conclusion

Agro-climatic conditions play a vital role in berry ripening, taste and flavor development. The sub-tropical conditions of central Punjab are not very conducive for grape cultivation. For this, adaptability of nine grape cultivars under climatic conditions of central Punjab was studied and it was observed that NARC black and King's Ruby are not only early maturing varieties, but they performed well and have desirable quality traits in them. So, they can be recommended for further cultivation.

References

Ainsworth, E. A., & Gillespie, K. M. (2007). Estimation of total phenolic content and other oxidation substrates in plant tissues using Folin-Ciocalteu reagent. *Nature Protocol*, *2*, 875-877.

Akram, M. T., Qadri, R. W. K. Jaskani, M. J., & Awan, F. S. (2020). Phenological and physicochemical evaluation of table grapes germplasm growing under arid subtropical climate of Pakistan. *Pakistan Journal of Botany*, *52*(3), 1-8.

Akram, M. T., Qadri, R. W. K., Jaskani, M. J., & Awan. F. S. (2019). Ampelographic and genetic characterization of grapes genotypes collected from Potohar region of Pakistan. *Pakistan Journal of Agricultural Sciences*, *56*, 595-605.

Alva, O., Roa-Roco, R. N., P´erez-Díaz, R., Y´anez, ˜M., Tapia, J., & Moreno, Y. 2015. Pollen morphology and boron concentration in floral tissues as factors triggering natural and GA-induced parthenocarpic fruit development in grapevine. *PLOS One*, *10*, e0139503. https://doi.org/10.1371/journal.pone.0139503.

Aponso, M. M. W., Marapana, R. A. U. J., & Manawaduge, R. (2017). Physicochemical analysis of grape juice from Israel blue (*Vitis vinifera* L.) grape cultivar under different processing conditions and a comparison with Red Globe and Michele Palieri grape cultivars. *Journal of Pharmacogn Phytochem*istry, *6*(3), 381-385.

Attia, S. M., & Farag, K. M. (2017). Effect of some preharvest treatments on the incidence of water berry disorder and on fruit quality characteristics of "Thompson Seedless" table grapes. *American-Eurasian Journal of Agriculture and Environmental Science*, *17*(5), 392-400.

Bahar, A., Kaplunov, T., Alchanatis, V., & Lichter, A. (2017). Evaluation of methods for determining rachis browning in table grapes. *Postharvest Biology & Technology*, *134*, 106–113. https://doi.org/10.1016/j.postharvbio.2017.08.016.

Bruno, G., & Sparapano, L. (2007). Effects of three esca-associated fungi on *Vitisvinifera*. Changes in the chemical and biological profile of xylem sap from diseased cv. Sangiovese vines. *Physiology and Molecular Plant Pathology*, *71*, 210-229.

Carey, V. A., Archer, E., Barbeau, G., & Saayman, D. (2008). Viticultural terroirs in Stellenbosch. South Africa. II. The interaction of Cabernet-Sauvignon and Sauvignon Blanc with environment. *International des Sciences de la Vigne et du Vin,42(4),* 185-201.

Dopico-Garcia, M. S., Fique, A., Guerra, L., Afonso, J. M., Pereira, O., Valentao, P., Andrade, P. B., & Seabra, R. M. (2008). Principal components of phenolics to characterize red Vinho Verde grapes: anthocyanins or non-coloured compounds, *Talanta*, *75*, 1190-1202.

Engel, L., Hegedus, A., Abranko, R., Balogh, E., Blazovics, A., Herman, R., Halasz, J., Ercisl, S., Pedryc, A., & Banyai, E. S. (2010). Antioxidant and antiradical capacities in apricot (*Prunus armeniaca* L.) fruits variation from genotypes, years, and analytical methods. *Journal of Food Sciences, 75*(9), 722-730.

Eyduran, S. P., Akin, M., Ercisli, S., Eyduran, E., & Maghradze, D. (2015). Sugars, organic acids, and phenolic compounds of ancient grape cultivars (*Vitis vinifera* L.). *Biology of Research*, *48*, 202-206.

Fahmi, A. I., Nagaty M. A., & Shehawi, A. M. E. (2012). Fruit quality of Taif grape (*Vitis vinifera* L.) cultivars. *Journal of American Sciences*, *8*, 590-599.

Falchi, M., Bertelli, A., Scalzo R. L., Morassut, M., Morelli, R., Das, S., Cui, J. H., & Das, D. K. (2006). Comparison of cardioprotective abilities between the flesh and skin of grapes. *Journal of Agriculture and Food Chemistry*, *54*, 6613-6622.

FAOSTAT. (2019). Food & Agricultural commodities production data. (Available online with updates at http://faostat.fao.org/ site/ 339/default.aspx).

Franke, A. A., Custer, L. J., Arkaki, C., & Murphy, S. P. (2004). Vitamin C and flavonoid levels of fruits and vegetables consumed in Hawaii. *Journal of Food Composition and Analysis*, *17*, 1-35.

Ghorbani, B., Pakkish, Z., & Najafzadeh, R. (2017). Shelf life improvement of grape (*Vitis vinifera* L. cv. Rish Baba) using nitric oxide (NO) during chilling damage. *International Journal of Food Properties*, *20*(3), 2750-2763.

Gonzalez, C. V., Jofr´e, M. F., Vila, H. F., Stoffel, M., Bottini, R., & Giordano, C. V. (2016). Morphology and hydraulic architecture of *Vitis vinifera* L. cv. Syrah and Torront´es Riojano plants are unaffected by variations in red to far-red ratio. *PLOS One 11*, e0167767; doi: 10.1371/journal.pone.0167767.

GOP. (2019-20). Fruit, Vegetables & Condiments Statistics of Pakistan 2019-20.

Guzman, Y., Pugliese, B., Gonzalez, C. V., Travaglia, C., Bottini, R., & Berli, F. (2021). Spray with plant growth regulators at full bloom may improve quality for storage of 'Superior Seedless' table grapes by modifying the vascular system of the bunch. *Postharvest Biology and Technology*, https://doi.org/10.1016/j.postharvbio.2021.111522

Hortwitz, W. (1960). Official & Tentative Method of Analysis, 9th edition. *Association of Official Agriculture Chemists*, Washington, DC

Hunter, J. J., & Bonnardot, V. (2011). Suitability of some climatic parameters for grapevine cultivation in South Africa, with focus on key physiological processes. *South African Journal of Enology and Viticulture*, *32*(1), 137-154.

Jayasena, V., & Cameron, I. (2009). The effect of ethephon and clone on physical characteristics and sensory quality of Crimson Seedless table grapes after 1 month storage. *International Journal of Food Science and Technology*, *44*, 409-414.

Kaur, S., Arora, N., Gill, K., Sharma, S., & Gill, M. (2019). Hexanal formulation reduces rachis browning and post-harvest losses in table grapes cv. 'Flame Seedless'. *Sciencetia Horticulturea*, *248*, 265–273. https://doi.org/10.1016/j.scienta.2019.01.011.

Khan, A. S., Ahmad, N., Malik, A. U., Saleem, B. A., & Rajwana, I. A. (2011). Pheno-physiological revelation of grapes germplasm grown in Faisalabad,

Pakistan. *International Journal of Agriculture Biology*, *13*(5), 791-95.

Khan, A. S., Malik, A. U., Pervez, M. A., Saleem, B. A., Rajwana, I. A., Shaheen, T., & Anwar, R. (2009). Foliar application of low-biuret urea and fruit canopy position in the tree influence the leaf nitrogen status and physico-chemical characteristics of kinnow mandarin (*Citrus reticulate* blanco). *Pakistan Journal of Botany*, *41*, 73-85.

Khan, W. A., Shafiq, T., & Ahmed, M. (2008). Physical and biochemical changes in commonly grown grapes (*Vitis vinifera*) in Pakistan at different maturity levels. *Pakistan Journal of Sciences*, *60*(3), 94-99.

Köse, B. (2014). Phenology and ripening of *Vitis vinifera* L. and *Vitis labrusca* L. cultivars in the maritime climate of samsun in Turkey's black sea region. *South African Journal of Enology and Viticulture*, *35*(1), 90-102.

Kumar, N., Arora, N. K., Kaur, G., Gill, M. I. S., & Brar, J. S. (2017). Effect of pre-harvest sprays of ascorbic acid, calcium chloride and ethephon on fruit quality of grapes (*Vitis vinifera* L.). *Journal of Krishi Vigyan*, *6*(1), 71-77.

Mira de Orduna, R. (2010). Climate change associated effects on grape and wine quality and production. *Food Research International*, *43*, 1844-1855.

Mulet, M. A., Molinelli, J. P., & Pugliese, M. B. (2017). Effect of spray combinations of IAA, GA3 and zeatin on berry growth and quality in' Superior Seedless'. *Acta Horticulture 1157*, 125–130. https://doi.org/10.17660/ActaHortic.2017.1157.20.

Mullen, W., Marks, S. C., & Crozier, A. (2007). Evaluation of phenolic compounds in commercial fruit juices and fruit drinks. *Journal of Agriculture Food Chemistry*, *55*, 3148-3157.

Muñoz-Robredo, P., Robledo, P., Manríquez, D., Molina, R., & Defilipi, B. (2011). Characterization of sugars and organic acids in commercial cultivars of table grapes. *Journal of Agriculture Research*, *71*, 453-458.

Murcia, G., Pontin, M., Reinoso, H., Baraldi, R., Bertazza, G., Gomez-Talquenca, S., Bottini, R., & Piccoli, P.N. (2016). ABA and GA3 increase carbon allocation in different organs of grapevine plants by inducing accumulation of non-structural carbohydrates in leaves, enhancement of phloem area and expression of sugar transporters. *Physiology Plantarum*, *156*, 323–337. https://doi.org/10.1111/ ppl.12390.

Naradisorn, M. (2013). Effect of calcium nutrition on fruit quality and postharvest diseases. *International Journal of Science, Innovations and Discoveries.*, *3*(1), 8-13.

Ramos, A. M., Lorenzo, N., Taboada, J., & Lorenzo, J. (2013). Influence of climate variability on grape production and wine quality in the Rias Baixas, north-western Spain. *EGU General Assembly Conference. Abstracts*, *15*, 3011.

Ruck, J. A. (1969). Chemical Methods for Analysis of Fruit and Vegetables. *Summerland Research Station, Department of Agriculture, Canada*, *50*, 27-30.

Sah H., Kumar P. R., & Topwal M. (2014). Response of NPK on growth, yield and quality of Oriental pear. *Indian Horticulture Journal*, *4*(1), 1-8.

Silva-Sanzana, C., Balic, I., Sepúlveda, P., Olmedo, P., Leon, G., Defilippi, B. G., Blanco-Herrera, F., & Campos-Vargas, R. (2016). Effect of modified atmosphere packaging (MAP) on rachis quality of 'Red Globe' table grape variety. *Postharvest Biology & Technology*, *119*, 33–40.

Steel, R. G. D., Torrie, J. H., & Dickey, D. A. (1997). Principles and Procedures of Statistics: *A Biometrical Approach, 3rd edition. McGraw-Hill, New York, USA.*

Tello, J., & Iba´nez, J. (2017). What do we know about grapevine bunch compactness? A state-of-the-art review. *Australian Journal of Grape Wine Research. 24*, 6–23.

Tripathi, A., Uniyal, S., Sajwan, P., & Negi, S. S. (2017). A review on impact of preharvest foliar sprays of macronutrients on yield and quality improvement of fruit crops. *Research Journal of Recent Sciences*, *6*(6), 43-56.

Uddin, M., Shah, M., Rahman, K. U., Alam, R., & Rauf, M. A. (2011). Evaluation of local and exotic grapes germplasm at mingora, Swat. *Sarhad Journal of Agriculture*, *27*(4), 553-556.

Ullah, S., Khan, A. S., Malik, A. U., Afzal, I., Shahid, S., & Razzaq, K. (2012). Foliar application of boron influences the leaf mineral status, vegetative and reproductive growth, yield and fruit quality of 'Kinnow' mandarin (*Citrus reticulata Blanco.*). *Journal of Plant Nutrition*, *35*, 2067-2079.

Xia, E. Q., Deng, G. F., & Guo, Y. J. (2010). Biological activities of polyphenols from grapes. *International Journal of Molecular Sciences*, *11*(2), 622–646.

Yinshan, G., Zaozhu, N., Kai, S., Jia, Z., Zhihua, R., Yuhui, Z., Quan, G., Hongyan, G., & Xiuwu, G. (2017). Composition and content analysis of sugars and organic acids for 45 grape cultivars from northeast region of China. *Pakistan Journal of Botany*, *49*(1), 155-160.