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Physico-morphological response and fruit performance index of four different grapes (*Vitis vinifera* L.)varieties grown under semi-arid environmental condition of Balochistan-Pakistan

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Abstract

The study area (Mastung) is the main growing region of thecommercially important fruit crops especially grapes (*Vitis vinifera* L.), therefore the main objective of this study was to examine approximately all important grape characteristics of four local varieties (Saibi, Kaduko, Kishmishi and Aitha) of Mastung region and the results revealed novel information required to explain best grapes for farming. Allphysio-morphologicalattributes and fruit performance index of examined grapes varieties were determined through different standard techniques.Data showed the highest average No. of bunches/vine and No. of berries per vine (66.33/vine and 5549/vine) were recorded in 'Kaduko' while the maximum No of berry per bunch (124.0/bunch) was found in 'Kishmishi' variety. Statistics regarding soluble solids concentrations (SSC) in different grape berries at harvest exhibited significant variation that ranged from 29.2 - 34.4 %. The range of total sugars in four grapes varieties were 15.6 - 21.5 %. Leaf area index (LAI) and Relative Growth Rate (RGR) in four grape varieties ranged between 1.24 - 1.4 (m^2 m^{-2}) m^2/m^2 and 12.0 - 12.7 cm cm^{-1} $month^{-1}$ respectively.Resultalso indicated that the grape variety 'Kishmishi' was found as early variety, 'Saibi' and 'Kaduko' as mid and 'Aitha' variety was recorded as late variety.Statistical analysis indicated that almost all investigated grapes berry morphological and yield variables found significantly different among the four grapes varieties at $P \leq 0.05$ significance level.Data concerning Fruit quality assessment (FQA) by fruit *Quality characteristics*/fruit performance index (FPI) and valuation classes designated that the grape variety 'Kishmishi' and 'Saibi' owed to the uppermost grade points and decent economic value and are predictable to be the best performers. So, the grapes variety 'Kishmishi' and 'Saibi' are recommended to be cultivated in the agro-climatic conditions of Mastung (study area).

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Introduction

Botanically, grapes (*Vitis vinifera* L.) grow in cluster on the perennial and deciduous woody vine. Grapes vary in diversity and its nutritional components all over the world. Moreover, flavonols, phenolic acids, carotenoids and various phytonutrients are present in grapes which are beneficial for human health. Moreover, it is rich in oligopeptides and hormone (Nassiri-Asl and Hosseinzadeh, 2009; Kanagarla *et al.,* 2013). Every agro ecological zone offers distinct climatic conditions for production of different fruit variety. Around the globe grapes are widely cultivated in semi-arid regions however, they are adapted to extensive weather conditions. Chaves *et al.,* (2007) narrated that drought conditions and climate change become the main problem and play a pivotal role for the cultivation and production of grapes around the world. Considering grapevines multiple studies are reported like gases exchange, water use, biomass distribution, biochemical change and fruit yield quality with response to different levels of drought conditions. According to Tripti and Gautam, (2007) and Leghari and Zaidi, (2013), the air pollution is responsible factor thatis altering the climatic conditions that affect the different biological and chemical activities and physio-morphological process of plants. Engelstaedtrr *et al.* (2006) reported life cycle is affected by dust both on local and global level. Wang *et al.* (2006) documented that due to low rainfall in arid and semi-arid areas the dust-related problem are increasing day by day. Chauhan, (2010) explained that dust particles damage the chlorophyll, carotenoid and other pigments, it also affect the content of ascorbic acid in the leaves of various plant species like *Mangifrea indica*, *Delonix regia* and *Polyalthia longifolia*. In Balochistan; Kalat, Pishin, Quetta and Mastung district grapes are cultivated in abundance. Province Balochistan contributes 90 percent of grape, production of Pakistan. Balochistan have distinctive climatic condition i.e. from tropical, sub-tropical and temperate, therefore produces various fruit crops. Commercially the province is well known for different variety of grapes like 'Kishmishi', 'Sundarkhani' and many other local varieties.Many researcher indicated that the use of morphologicalcharacteristics for the evaluation of fruit quality performance in many fruit crops in different growth environment such as pots (Bavaresco and Poni, 2003; Ksouri *et al.,* 2007), containers (Jiménez *et al.,* 2007), in vitroculture (Tangolar *et al.,* 2008) as well as field trials (Bertamini and Nedunchezhian, 2005).

Investigations on many plants species such as grapes, apples, apricots, olive and peaches, cultivated in arid environmental revealed that these plant species are significantly diverse in physiological and morphological reply to ecological variables (Larsen *et al.,* 1989; Johnson *et al.,* 2009; Sabir and Yazar, 2015; Sabir, 2016).

Previously the importance of research on the grapes physiology has been highlighted however, there is still inadequate information about the excellence guides and values for the abundant and commercially important grapes varieties (Saibi, Kaduko, Kishmishi and Aitha) of Balochistan, Pakistan.

Therefore, this study was designed to evaluate the variation in Physico-morphological response and development of FPI for four common varieties of *Vitis vinifera* L. growing under the semi-arid environmental conditions of Mastung area.

Material and methods

Study area

For the field experiment district Mastung (which is most grapes growing area of the Balochistan Province) was selected.Climatological figures of the study area designated the maximum and minimum mean temperature in the region throughout investigated period, study year and last 5 years average was recorded 41.51, 34.3 & 33.17 ^{o}C and 18.62, 8.34 & 7.25 ^{o}C, correspondingly. Humidity percentage was documented 24.43, 30.5 and 52.0 %, and rainfall was found only 6.37 mm and 8.15 mm during the investigated period and throughout the study year respectively, while during last 5 year average was found 107.0 mm as presented in Table 1 (Ayatullah *et al.,* 2019).

Plant materials

Three years old, four grapes varieties including; 'Saibi', 'Kaduko', 'Kishmishi' and 'Aitha', full-grown in open fieldsemi-arid climatic condition of Balochistan were chosen for the investigation. The typical images of berries of the examined varieties are presented in Fig. 1.

Plant leaf variables measurement

Fresh developed, fully prolonged foliage (100) were randomly separated from selected grape varieties for the measurement of leaf area. The leaf area was measured by using Leaf Area Meter (CI-202, USA) and graph paper method in the laboratory of Botany Department University of Balochistan, Quetta Pakistan. All the determination was carried out on the replicates of three and then average was calculated as the method used by Leghari and Zaidi, (2013). Later, these leaves were dried in an oven at 70°C to get the leaf dry weight (DW) and then Specific Leaf Area (SLA) was determined by applying the following formula;

$$SLA = LA/DW \quad \text{(Eq. 1)}$$

The leaf area index (LAI) was determined by the following formula;

LAI = leaf area / ground area, (m^2 / m^2) in broadleaf canopies (Eq. 2)

Primary pleiotropic branches were selected to determine the Relative Growth Rate (RGR) (cm cm^{-1} $month^{-1}$), their length was measured at the beginning and at the end of the trial by measuring scale/tape.

Leaf chlorophyll contents

Chl. A & b, total chl., carotenoid, Chl. a: Chl. b ratio and total Chl: carotenoid ratio were examined from newly leaf samples.

From each variety, 2 gm fresh leaves were crushed in acetone (90 v/v), filtered the mixture and ended up to final volume of 50 mL. Pigment contents were calculated in mg g^{-1} fresh weight (fw) by the methods designated by Lichtenthaler, (1987).

$$\text{Chl. a} = [(11.75A_{663} - 2.35A_{645}) \times 50] / 500 \quad \text{(Eq. 3)}$$

$$\text{Chl. b} = [(18.61A_{645} - 3.96 A_{663}) \times 50] /500 \quad \text{(Eq. 4)}$$

$$\text{Carotenoids} = [1000 A_{470} - (2.27 \times \text{Chl. a}) - (8.14 \times \text{Chl. b}) / 227 \times 50] / 500 \quad \text{(Eq. 5)}$$

$$\text{Total Chl.} = \text{Chl. a} + \text{b} \quad \text{(Eq. 6)}$$

Where A is the observance of extract at 663, 648 and 470 nm

Relative Water Content (RWC) was estimated through the method (Galmés *et al.,* 2007) established by the following formula;

$$RWC (\%) = (FW - DW / TW - DW) \times 100 \quad \text{(Eq. 7)}$$

Where, FW, TW and DW designates fresh weight, turgid weight and dry weight, respectively.

Yield and fruit quality analysis

The fruit yield parameters [No. of bunches per vine, berry color, No. of berries/bunch. No. of berries/vine, length of berry (cm), diameter of berry, average weight (g) of one berry, average weight of 100 fresh berry, average weight of 100 dry berries (g)] were determined using measuring tape and electrical balance. The fruit quality characteristics [number of seeds/berry, moisture percentage in berries, berry color and Bunch /berry compactness, pH of berry juice, soluble solids concentrations (SSC) % age, titrated acidity (TA %), ratio between SSC and TA and Ascorbic acid (mg/100g)] were also determined through different standard methods. The pH was determined by pH meter. SSC of berry juice was noted through hand refractometer. TA of berry juice was determined by the method described by Hortwitz, (1960). 10 ml of berry juice was diluted up to 50 ml distilled water in 100 ml conical flask. It was titrated against 0.1 N NaOH, using 2-3 drops of phenolphthalein as an indicator until pink color end point was attained and TA was expressed as percentage. SSC: TA ratio was found by dividing SSC with corresponding TA value.

Ascorbic acid and sugars contents

Ascorbic acid from berry juice was determined through the methods described by Ruck, (1969). 10

ml of berry juice was diluted by 0.4 % oxalic acid solution in 100 ml volumetric flask. 5 ml of diluted and filtrated aliquot was titrated against 2, 6-dichlorophenolindophenol dye, to light pink color end point. Sugar in berry juice was assessed by the method used by Khan *et al.,* (2012). 10 ml berry juice was diluted with 100 ml waster, 25 ml 25% lead acetate solution and 10 ml 20 % potassium oxalate in 250 ml volumetric flask.

Then the filtrate was used for the determination of different forms of sugars (total sugars, reducing and non-reducing sugars) and expressed as percentage. All the observation were noted in triplicates.

Fruit moisture contents (FMC) and fruit color determination

Fruit moisture contents (MC) was noted through AOAC, (1995) methods (Horwitz, 2010). For fruit moisture contents 5.0 gm berries sample was dried in an oven for 24hr at 70 ^{o}C and moisture contents was noted in gm water g-100 samples. The fruit color was determined by the use of color difference meter and fruit size was noted on 10 separate fruits per replicate (Aleid *et al.,* 2014).

Fruit quality assessment (FQA)

Fruits quality assessment was determined as the procedure described by Leghari *et al.,* (2019) with some modification. Completely mature fresh berries were collected from four grapes designated varieties. Berry size and shape, berry color, Bunch compactness, No. of seeds per berry, SSC:TA ratio, fresh weight of 100 berries, moisture contents (%) in berries, Ascorbic acid, Reducing sugar were noted rendering by the standard techniques. A board of six skilled juries including one from food department, two grapes growers, two Ph.D. Professor from Botany department university of Balochistan Quetta and other one from agriculture department tested acidity, Taste and flavor of the berries. The values/scales were specified from 1-3/1-5 (Leghari *et al.*, 2019). 20 berries from each investigated variety was arbitrarily designated for taste, flavor and acidity for each expert/judge.

Fruit performance index (FPI) by fruit quality and valuation classes

FPI was determined by combining the diverse fruit quality parameters (Berry size and shape, berry colour, Bunch compactness, No. of seeds per berry, SSC: TA ratio, fresh weight of 100 berries, moisture contents (%) in berries, Ascorbic acid, Reducing sugar) of four grapes varieties based on characters categorizing (+ or -) secure to the grapes fruits. For FPI the methods designated by Prajapati and Tripathi, (2008) and Leghari *et al.,* (2019) was used.

Statistical analysis

Statistical analysis of data of each experiment was carried out using analysis of variance (ANOVA) to evaluate the relationship affect between the main factors, SPSS software version 16.0 and for the comparison among the means of different grapes parameter behaviors, Duncan multiple-range test ($P \leq 0.05$) was used (Steel and Torrie, 1980).

Result and discussion

Harvesting time, berry size, color, taste and bunch compactness

Data regarding harvesting time, berry size, color and taste and bunch compactness of four grapes varieties are shown in Table 2. On the basis of harvesting time the investigated grapes varieties were classified into early, mid and late variety. Results indicated that 'Kishmishi' was early variety with small berry size, light green berry color, normal bunch compactness and with delicious taste. The varieties 'Saibi' and 'Kaduko' were reported mid variety with medium to small berry size, red to light red berry color and normal to loose bunch compactness, respectively while the berry taste for 'Saibi' was tasteful and 'Kaduko' with poor taste. The variety 'Aitha' was observed as the late variety with large berry size, dark green berry color, very compact bunches and with slightly berry taste. The variation in berries characteristic like; berries production, colors, size, shape and taste and berry compactness was also reported in other fruit crops like dates plum grown in the same climatic condition (Aslam *et al.,* 2019). Jackson and Lombard, (1993), found normal to loose

bunch in black variety and light green variety showed compact to very compact bunch.

Various growth and yield variables

Data concerning various growth variables and leaf attributes are presented in *Table 3*. Result regarding average LA and SLA among examined grapes varieties grown under same environmental condition of Mastung was found significantly different at $P \leq 0.05$ significance level. Maximum LA and SLA (55.4 cm^2 and68.6 cm^2/g) was noted for 'Aitha' variety followed by 'Saibi and Kaduko' and minimum was recorded for 'Kishmishi' (32.7 cm^2 and 47.0 cm^2/g) respectively. LAI and RGR in four grapes variety ranged between 1.24 - 1.4 (m^2 m^{-2}) m^2/m^2 and 12.0 - 12.7 cm cm^{-1} $month^{-1}$ respectively. Highest LAI was found in 'Kishmishi' variety and lowest in 'Aitha' while the highest RGR was noted for 'Aitha' and lowest for 'Kaduko'. Statistical analysis indicated that the LAI, RGR and LC on greenness scale found to be non-significant, in all the investigated grape varieties (Table 3).

Table 1. Meteorological data of the study area during growing months (March 2018-October 2018), study year and last 5 year average**.**

Variables	Ave. Study period	Study Year	Last 5 year Ave.	*P* value (0.05)
Max. Ave. Tem. (°C)	41.51	34.3	33.17	0.001*
Min. Ave. Tem. (°C)	18.62	8.34	7.25	0.002*
Overall Ave. Tem. (°C)	32.8	29.5	28.7	0.002*
Relative Humidity (%)	24.43	30.5	52.0	0.023*
Rainfall (mm)	6.37	8.15	107.0	0.031*

Each value is the mean of three replicates, Ave; average, Max; maximum, Min; Minimum, *; Significant.

Table 2. Indication of harvesting time, berry size, color, taste and bunch compactness of four grapes varieties under grown under semi-arid ecological environment.

Quality variables	Name of variety			
	Saibi	Kaduko	Kishmishi	Aitha
Harvesting time	1st August – 10th August Mid variety	5th August – 15th August Mid variety	20th July – 30th July Early variety	25th August -15th September Late Variety
Berry size	Medium	Small	Small	Large
Berry colour	Red	Light red	Light green	Dark green
Bunch compactness	Normal	Loose	Normal	Very compact
Berry Taste	Tasteful	Poor taste	Delicious	Slightly tasty

The significant variation in leaf growth parameters were also reported by other researchers under same agro climatic conditions which might be due to variation in varieties. Sabır, (2016) reported significant variation in different growth parameters like leaf area, shoot length, leaf No., shoot fresh weight, shoot dry weight, root dry weight and root fresh weight in four different grapes varieties growing under same environmental conditions and different iron treatments. Leghari and Zaidi, (2013) reported differences in leaf growth parameters in different plants of the same environment of Quetta. Karami *et al.,* (2017) also found variation in morphological and physiological responses of different grape plant grown under same ecological condition and they found that these variations are might be due to drought and dust stress.

Khan *et al.,* (2011) studied seven different grape varieties ('Black Prince', 'Gold', 'Dehkani', 'Cardinal', 'Shamas Guru', 'King's Early' & 'Anab-e-Shahi') for their pheno-physiological characteristics grown under the same agro-climatic conditions of Faisalabad Pakistan.

Table 3. Averages and Statistical Analysis of Various Plant Leaves and Growth Variables in Response to the Grapes Plants.

Variables	Name of variety				P value
	Saibi	Kaduko	Kishmishi	Aitha	
LA (cm^2)	44.6 ±14.5	40.4 ±19.0	32.7 ±6.50	55.4 ±2.4	0.012*
SLA (cm^2/g)	60.0 ±14.9	54.9 ±15.5	47.0 ±4.41	68.6 ± 3.2	0.001*
LAI (m^2 m^{-2}) m^2/m^2	1.35 ±0.04	1.36 ±0.02	01.4 ±0.02	1.24 ±0.01	1.72ns
RGR (cm cm^{-1} $month^{-1}$)	12.5 ±1.15	12.0 ±0.12	12.4 ±0.13	12.7 ±0.07	2.03ns
LC (value on greenness scale)	-7.4 ±0.01	-7.3 ±0.02	-7.5 ±0.01	-7.5 ±0.00	1.23ns

LA; leaf area, SLA; specific leaf area, LAI; Leaf area Index, RGR; Relative growth rate, LC; Leaf color.

Variation in grapes leaf growth variable grown under same environmental condition was also reported by Ayatullah *et al.,* 2019, when they investigated the influence of sun and shade on the growth, yield and quality of *Vitis vinifera* L. (grapes) grown under semi-arid environmental conditions of Mastung.

Statistical analysisregarding various yield attributes i.e. No. of bunches/vine, No. of berries/bunch, No. of berries/vine, length and breadth (diameter) of berry, single berry weight, weight of 100 fresh berries, weight of 100 dry berries and No. of seeds /berry are presented in Table 4. Data showed the highest average No. of bunches/vine and No. of berries per vine (66.33/vine and 5549/vine) were recorded in 'Kaduko' while the maximum No of berry per bunch (124.0/bunch) was found in 'Kishmishi' variety. Average length and diameter (2.5 and 1.8 cm) of berry was noted highest in 'Saibi' and lowest (1.62 cm and 1.5 cm) in 'Kaduko and Aitha', respectively. The average of (100 berries) single berry weight ranged from 2.24 - 2.87 g the maximum was for 'Kaduko' and minimum for 'Kishmishi'.

Table 4. Various yield variables of four different grapes varieties under semi-arid climatic condition.

Variables	Name of variety				*P* value
	Saibi	Kaduko	Kishmishi	Aitha	
No. of bunches/vine	13.33 ±1.5	66.33 ±16.7	42.0 ±8.7	32.66 ±13.6	0.000**
No. of berries/vine	1262 ±13.4	5549 ±15.6	5208 ±18.0	3636 ±13.0	0.000**
No. of berries/bunch	94.7 ±12.2	83.7 ±8.5	124 ±19.1	111.3 ±19.1	0.005**
Length of berry (cm)	2.5 ±0.12	1.62 ±0.12	1.74 ±0.24	2.3 ±0.31	0.007**
Dimeter of berry (cm)	1.8 ±0.27	1.6 ±0.12	1.76 ±1.8	1.5 ±0.2	0.049ns
Single berry weight (g)	2.74 ±0.04	2.87 ±0.02	2.24 ±0.05	2.64 ±0.02	0.041*
Weight of 100 fresh berries (g)	456.2 ±5.7	367.4 ±4.6	224.8±11.2	476.4 ±9.3	0.000**
Weight of 100 dry berries (g)	118.5 ±2.9	63.04 ±2.6	50.6±3.3	90.8 ±3.7	0.000**
No. of seeds /berry	2.0 ±0.0	3.5 ±0.0	0.0 ±0.0	2.0 ±0.0	0.004*

Each value is the mean of 5 replicates, ±; Standard deviation, Ave.; Average, **; Significant and ns; non-significant.

The Maximum average weight of 100 fresh berries (476.4 g^1) and 100 dry berries (118.5 g) was recorded in 'Aitha and Saibi', respectively, whereas the lowest was (224.8 g and 50.6 g) in 'Kishmishi' variety. The number of seeds per berry ranged between 2.0 – 3.5. The maximum number of seeds per berry was found in the variety 'Kaduko' and other variety 'Aitha' and 'Saibi' showed equal No. of seeds (2.0), however 'Kishmishi' was seedless. Statistical analysis indicated that almost all investigated yield variables except one

(berry diameter) wasstatistically significantdifferent among the four grapes varieties at *P≤ 0.05* significance level (Table 4). Similar variation in different fruit crops yield/ productivityalso observed byJackson and Lombard, (1993) and Aslam *et al.,*(2019). Khan, (2011) reported similar findings in different grapes varieties ('Black Prince', 'Gold', 'Dehkani', 'Cardinal', 'Shamas Guru', 'King's Early & 'Anab-e-Shahi') of Faisalabad, Pakistan, they opine that these differences might be due the variation in varieties of grapes.

Table 5. Quality characteristics of four grapes varieties grown under the semi-arid climatic conditions of Balochistan.

Variety	pH	SSC (%)	TA (%)	SSC: TA ratio (%)	Ascorbic acid (mg/ 100 g)
Saibi	3.94 ± 0.04	32.6 ± 2.23	0.43 ± 0.01	75.81 ± 2.42	16 ± 1.02
Kaduko	3.91 ± 0.01	29.2 ± 2.41	0.41 ± 0.02	71.22 ± 2.71	20 ± 1.03
Kishmishi	3.83 ± 0.02	34.4 ± 2.22	0.55 ± 0.01	62.55 ± 2.50	13 ± 1.04
Aitha	3.99 ± 0.05	31.5 ± 2.05	0.39 ± 0.03	80.77 ± 2.41	17 ± 1.01
P value (0.05)	0.04*	0.00**	0.01*	0.00**	0.00**

Physico-chemical properties of grapes fruits

The pH value of grape juice of investigated grape varietes ranged between 3.83 - 3.99. The maximum pH value was found in 'Aitha' and minimum in 'Kismishi' berry juice. Statistical analysis showed significant variation in pH value of grapes variety under investigation (Table 5). The variation in pH of different grapes variety grown in same ecological condition was also noted by other researchers like Ayatullah *et al.,* (2019). Khan *et al.,* (2011) reported significant higher pH in 'Black Prince, 'Gold', 'Dehkani', 'King's Early' and 'Anab-e-Shahi' variety than 'Shamas Guru and 'Cardinal' grown in same agro climatic environment of Faisalabad, Pakistan.

Table 6. Sugar contents in four grapes variety grown under semi-arid climatic conditions of Balochistan Pakistan.

Variety	Total sugar	Reducing sugar	Non-reducing sugar
Saibi	18.7 ± 2.14	9.40 ± 0.42	6.2 ± 0.21
Kaduko	16.4 ± 2.32	7.20 ± 0.50	4.5 ± 0.23
Kishmishi	21.5 ± 2.04	10.3 ± 0.34	5.0 ± 0.27
Aitha	15.6 ± 2.04	5.20 ± 0.42	3.1 ± 0.25
P value (0.05)	0.02*	0.01*	0.01*

Amerine, (1973) reported that the pH level in grapes is very important factor for flavor and resistance to spoilage. Moisture contentsin berry was also statistically significant different among the four different grapes varieties grown in semi-arid environmental conditions (Fig. 2).Data regarding SSC in different grapes berries at harvest exhibited significant variation that ranged from 29.2 - 34.4 %. SSC values for 'Kaduko' remained lower than all other variety and 'Aitha' showed highest SSC % age. The range of TA in four grapes variety varied from 0.39 – 0.55 % (Table 5), which was higher than that reported by Khan *et al.,* (2011) and lower than that of reported by Johnson and Carroll, (1973), who found 1.24%TA on an expressed juice fraction. This variation is might be due to climatic difference. Lower TA has been also reported from the grapes grown in subtropical climatic conditions as compared to temperate climates (Poudel *et al.,* 2009). In the entire results the TA contents was found inversely related to the pH value, as TA of grapes increase their pH value decreases, similar observation was also reported by

Khan *et al.,* (2011) and Kliewer, (1971). The ratio between SSC and TA was found significantly different among all four evaluated varieties (Table 5). 'Aitha' exhibited highest (80.77%) and 'Kishmishi' lowest (62.55 %) SSC:TA ratio. The highest SSC:TA ratio of 'Aitha' might be attributed to higher SSC and lesser TA value. Similar results were also reported by Khan *et al.,* (2011). The calculation of ratio between SSC and TA is an important flavor quality factor which is used to calculate the quality index of many fruit product (Flora, 1977).

Table 7. Photosynthetic Pigments (mg/g fw) in Leaves of Grapes Plant grown under semi ecological condition.

Variables	Name of variety				*P* value
	Saibi	Kaduko	Kishmishi	Aitha	
Chl a (mg/g fw)	2.23 ±0.18	2.54 ±0.23	2.05 ±0.42	2.26 ±0.23	0.030*
Chl b (mg/g fw)	2.16 ±0.08	2.54 ±0.19	2.03 ±0.21	2.31 ±0.14	0.021*
Total Chl (mg/g fw)	4.39 ±0.12	5.08 ±0.23	4.07 ±0.12	4.57 ±0.15	0.023*
Car (mg/g fw)	2.67 ±0.05	3.46 ±0.05	2.61 ±0.09	3.09 ±0.01	0.002*

The ascorbic acid contents in four investigated grape varieties showed significant variation which ranged from 13 - 20 mg/100 g. Highest ascorbic acid content was found in variety 'Kaduko' followed by 'Aitha', 'Saibi' and lowest was noted in grape variety 'Kishmishi' (Table 5). Significant variation in ascorbic acid content were also reported by Khan *et al.,* (2011) from seven grapes variety grown in same climatic condition of Faisalabad Pakistan.The level of total sugar, reducing and non-reducing sugars found to be significantly different in four investigated varieties. The range of total sugars in four grapes varieties were from 15.6 - 21.5 %. The highest total sugars was noted in 'Saibi' followed by 'Kaduko', 'Kishmishi' and lowest was recorded in 'Aitha'. Among all examined varieties the 'Saibi' showed maximum reducing sugars (10.3 %), while 'Aitha' displayed lowest (5.2 %).

Table 8. Standard of grade point for fruit quality [reference: Prajapati and Tripathi, (2008): Govindaraju *et al.*, (2012); Leghari *et al.*, (2019)].

Evaluation classes	Scoring %age	Grade point
Not recommended	30	0
Very poor	31-40	1
Poor	41-50	2
Moderate	51-60	3
Good	61-70	4
Very good	71-80	5
Best	81-90	6
Excellent	91-100	7

The percentage of non-reducing sugar ranged from 3.1-6.2 %. The highest non-reducing sugars contents was observed for 'Kaduko' followed by 'Saibi' and 'Kishmishi' while the lowest was observed for 'Aitha' (Table 6). Similarly Tang, (1978), Khan, *et al.,* (2011) reported significant differences in sugars contents of different grapes varieties of European, American, French and Faisalabad (Pakistan) origin. Mira de Orduna, (2010) found greater variations in sugar level of grapes of cold and hot regions.

The physio-morphological (No. of cluster per plant, No. of berries per cluster, berries size & weight) and biochemical (SSC, TA, sugars, amino acids,Minerals Nutritional Contents) features of grape varieties have been also reported to vary with change in the area,

locality, topography and environment (Artes-Hdez *et al.,* 2002, Shiraishi *et al.,* 2010). The results of entire study prove the significant fruits characteristics under examination such as; berry weight, size, TA and SSC varies, which probably due to the variation in varieties. Statistical analysis indicated that the four different grapes varieties grown in semi-arid ecological condition showed significantly altered contents of photosynthetic pigments i.e. Chl. a, b, total chl. and carotenoid at 0.05 significance level (Table 7).

Table 9. Fruit Quality Assessment through fruit performance index (FPI) and evaluation classes References.

Quality variables	Values/Scale	Grapes variety			
		Saibi	Kaduko	Kishmishi	Aitha
Berry taste and flavor	1-10	++++++++	+++	++++++++++	+++++
Berry acidity	1-10	+++++++	+++	+++++++++	+++++
Berry size, shap and colour	1-5	++++	+++	+++	+++++
Bunch compactness	1-5	++++	+++	++++	++
No. of seeds /berry	1-5	+++	+	+++++	+++
Weight of 100 fresh berries	1-5	++++	+++	++	++++
Moisture content in berries	1-5	+++	++	++++	++
Reducing sugar	1-5	++++	+++	+++++	++
Obtain Plus/50		37	21	42	28
Score %age		74	42	84	56
Grade point		5	2	6	3
Valuation Classes		Very good	Poor	Best	Moderate

However ratio between Chl. a and Chl. b (Chl. a/Chl. b) and ratio between total Chl. and Carotenoid (Total Chl. / caro.) exhibited non-significant variation at 0.05 significance level among the four grapes varieties grown in the semi-arid ecological region i.e. Mastung (Fig. 3).

Fig. 1. Four investigated grapes varieties grown under semi-arid climatic condition of Balochistan.

Similar observation for example variation in chlorophyll contents was also reported by the other investigators during different studies (Kara and Sabir, 2010; Leghari *et al.,* 2014; Leghari and Zaidi, 2013; Mehmet and Sabir, 2016). This difference in chlorophyll contents might be due the different factors such as difference in varieties and ecological conditions. Likewise, Kara and Sabir, (2010) measured understandable vitalization of the green mass of the leaves with dark green color. The findings would imply that Herbagreen might accelerate the photosynthetic activity in leaves. Mehmet and Sabir (2016) reported variation in chlorophyll contents of *Vitis vinifera* while examining the response of grapevine leaves to different leaf fertilizers under a semi-arid condition. Relative water contents (RWC), leaf membrane stability index (LMSI) in four different grapes variety grown in same ecological condition were found significantly different at P≤0.05 while leaf malondialdehyde (LMDA) was non-significant.

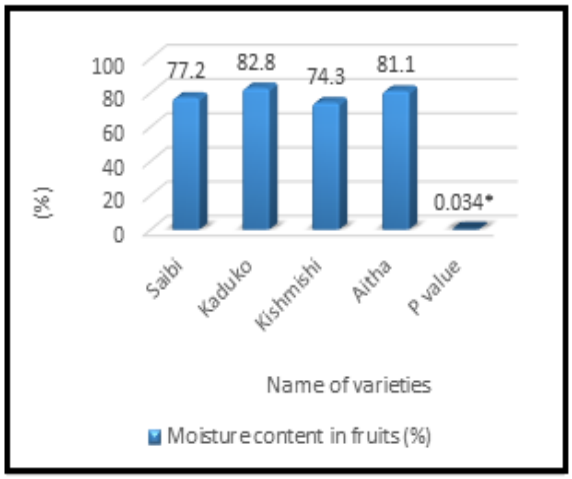

Fig. 2. Moisture content (%) in berries of four different grapes varieties grown in same environmental condition.

Highest RWC and LMSI percentage (97.7 and 99.6%) was noted in 'Saibi' variety followed by 'Kaduko' and 'Kishmishi' while the lowest was observed (82.2 and 86.3%) in 'Aitha' variety (Fig. 4a & 4b).

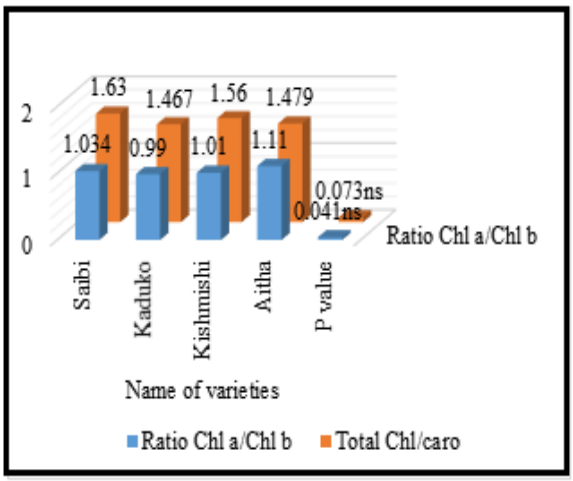

Fig. 3. Ratio between Chl a and Chl b and ratio between Total Chl/carotenoids in Leaves of investigated grapes Plants.

Fruit quality assessment (FQA)

Fruit quality assessment (FQA) by fruit performance index (FPI) and valuation classes designated that Kishmishi variety got maximum grade point (6) and positioned in best class, followed by Saibi with 5 grade point and designated as very good variety however other two grapes varieties namely Aitha and Kaduko scored 3.0 and 2.0 grade points and categorized into moderate and Poor classes respectively (Tables 8 & 9). Variation in fruit quality assessment on the basis of fruit performance index was also reported by Aslam *et al.*,(2019).

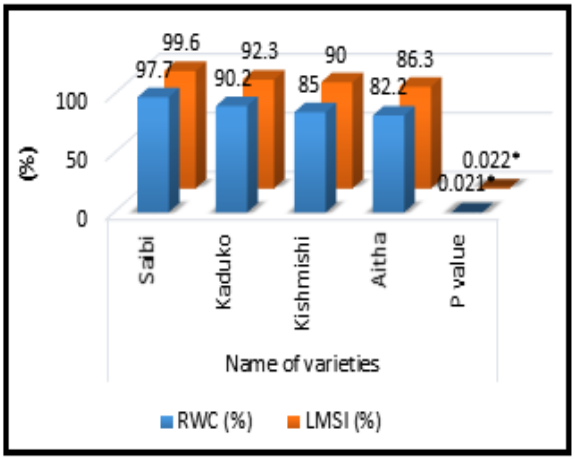

Fig. 4a. Relative water content (RWC) and Leaf membrane stability index (LMSI).

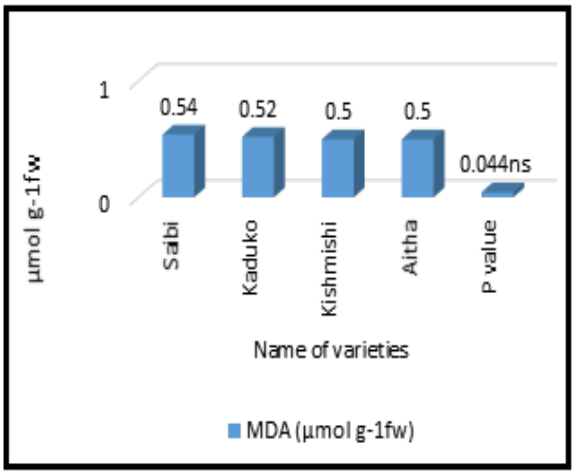

Fig. 4b. Leaf malondialdehyde (LMDA).

Conclusion

In a nutshell, the present study on four grape varieties grown in the semi-arid climatic conditions of Mastung district revealed novel information required to explain best grapes standard for farming in the district by studying approximately all important grape attributes of the experimental varieties. Grape variety 'Kishmishi' was designated as an early ripening variety, 'Saibi' and 'Kaduko' was found mid and Aitha as late ripening variety. Furthermore, assessment of the fruit performance or quality index of the examined grape varieties was highly significant for the grapes of local area Mastung. On the basis entire research, it can be concluded that the grape variety 'Kishmishi' and 'Saibi' owe to the uppermost grade points and decent economic value and are

predictable to be the best performers. Thereby, the grape varieties 'Kishmishi' and 'Saibi' are recommended to be cultivated in the agro climatic conditions of Mastung (study area) however, variety 'Kaduko' found to be least appropriate for farming in agro climatic condition of Mastung Balochistan-Pakistan.

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