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# Pheno-physiological Revelation of Grapes Germplasm Grown in Faisalabad, Pakistan

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*ABSTRACT*

Seven grape varieties ('Black Prince', 'Gold', 'Dehkani', 'Cardinal', 'Shamas Guru', 'King's Early' & 'Anab-e-Shahi') were evaluated for their pheno-physiological characteristics grown under the agro-climatic conditions of Faisalabad. 'Anab-e-Shahi', 'King's Early', 'Dehkani' and 'Cardinal' were observed as late maturing varieties and thus become un-suitable for cultivation in Punjab due to early occurrence of monsoon rains. The varieties 'Black Prince', 'Dehkani' and 'Shamas Guru' exhibited early fruit maturity and ripening. The vines of 'Black Prince' acquired minimum days from bud sprout to ripening (77 days) as compared to all other varieties. Berries of variety 'Shamas Guru' exhibited highest weight (4.5 g) followed by 'Black Prince' (2.86 g) and 'Gold' (2.5 g). 'Anab-e-Shahi' produced highest bunch weight (490.12 g) and yield (14.9 kg per vine) as compared to all other varieties. Maximum number of bunches per vine were exhibited by 'Gold' (41) and minimum in 'Cardinal' (24). The berries of 'Black Prince' exhibited highest soluble solids concentration (SSC) (23.5%), SSC: titratable acidity (TA) ratio (99.3) and lowest TA (0.24%) as compared to all other varieties. The varieties 'Cardinal' and 'Shamas Guru' produced barries with maximum amount of ascorbic acid (23.3 mg 100 $g^{-1}$) and total sugars (13.83%), respectively. 'Black Prince' being early maturing variety with large berry size, loose bunch and better SSC: TA ratio is a potential table-grape variety to be cultivated under the agro-climatic conditions of Faisalabad. 

***Key Words*:** Black Prince; Grapes; Germplasm; Pheno-physiological

## INTRODUCTION

In Pakistan, grapes are grown mostly in Balochistan and some districts of Khyber Pakhtunkhwa with annual production of 122 thousand tons having average yield of 19 tons $ha^{-1}$ against the potential of 25 tons $ha^{-1}$ (GOP, 2010). Grapes can also be grown in central Punjab if suitable cultivars are available as monsoon rains at the time of berry ripening is the main barrier in successful cultivation of grapes. To cope with the problem of berry rottening due to monsoon rains, early maturing variety of grapes must be evaluated for their physico-chemical quality characteristics.

For the best berry growth and development, grapes requires long warm to hot dry summer and cool rainy winter (Winkler *et al*., 1974). The grapes producing regions in the world are generally divided into two groups: (a) areas with 18.7°C average temperature during mid summer months below, which ripening is difficult and (b) areas with -1°C average of coldest months below, which winter killing may occurs (Coombe, 1987). The quality of grapes depends on both biotic as well as abiotic factors (Winkler *et al.*, 1974; Ahmed *et al*., 2004 a & b). The climactic variations in grape-growing regions accounts for the diversity of grapes germplasm, berry quality and other viticulture products. In general, the influence of climatic conditions on the chemical characteristics and nutritional quality of grapes is more pronounced as compared to any other factor (Coombe, 1987). Environmental components such as temperature, sunshine, rain, soil and combinations of these affect chemical composition of grapes juice (Amerine *et al*., 1967). Among various component of climate, the temperature is considered to be has major influence on grape composition and quality.

During berry growth and development, the climate plays an important role for berry maturity, ripening, development of physical, as well as chemical characteristics of the berry quality such as size, colour, aroma, accumulation of anthocyanins (Jackson & Lombard, 1993). For the table grape industry, climate is a dominant contributor to quantity and quality of grapes (White *et al*., 2009). The maturity, ripening and harvesting time of grapes depend upon cultivar, geo-graphic location and agro-climatic conditions. Different table grapes cultivars have been found to have varying tolerance to temperature, heat stress, rainfall and their distribution through the season (Cameron & Pasqual, 2004).

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Grapes undergo a series of phenological stages, like bud break, vegetative growth, full bloom, fruit set, maturation, leaf fall and dormancy, during each production year (Poudel *et al*., 2010). Grapevines undergo dormancy in winter and bud break starts in the first week of March, while the rains arrive after first week of June. Therefore, only 90-100 days are available from berry setting to harvest. At present, sparse information is available about the suitability of some potential early maturing table grapes germplasm for cultivation in central Punjab. Hence, the objective of this study was to evaluate suitability of different grape varieties for cultivation in Punjab by analyzing their pheno-physiological characteristics under the semi-arid climactic conditions of Faisalabad, Pakistan.

## MATERIALS AND METHODS

**Plant materials:** Fifteen years old seven table grapes varieties ('Anab-e-Shahi', 'Black Prince', 'Cardinal', Gold', 'Dehkani', 'King's Early' & 'Shamas Guru'), grown in the Experimental Fruit Garden, Institute of Horticultural Sciences (31°25'N; 73°09'E), University of Agriculture, Faisalabad were selected for the study. All varieties were pruned after dormant season during third week of February at four to six nodes. The climatic data consisting of daily observations of average temperature, relative humidity and rainfall were also recorded during the whole study period (Fig. 1).

**Pheno-physiological characters:** Data were collected for pheno-physiological characters such as bud burst, panicle emergence, date of full bloom, berry formation and berry harvest date. The harvest dates of cultivars were recorded, when the berries attained full ripening.

**Physico-chemical fruit quality characteristics:** Physico-chemical fruit quality characteristics such as berry size, berry colour, numbers of berries per bunch, bunch compactness, numbers of seeds per beery, berry weight (g), average bunch weight (g), number of bunches per vine, yield per vine (kg), soluble solids concentrations (SSC, Brix), pH of berry juice, titratable acidity (TA, percent), SSC: TA ratio, total sugars (percent), reducing sugars (percent), non-reducing sugars and ascorbic acid contents (mg 100 $g^{-1}$) were also determined. All data observations were taken in triplicate.

**SSC, TA and SSC:TA ratio:** SSC of berry juice was determined by hand refractometer (ATAGO, RS-5000 Atago, Japan). The pH was determined by using digital pH meter (HI 98107, Hanna Instruments, Mauritius). The method outlined by Hortwitz (1960) was used to determine the TA of berry juice. In which 10 mL of juice taken in 100 mL conical flask was diluted up to 50 mL with distilled water. It was titrated against 0.1 N NaOH, using 2-3 drops of phenolphthalein as an indicator till pink colour end point was achieved and TA was expressed as percentage (percent). SSC:TA ratio was calculated by dividing SSC with corresponding TA value.

**Ascorbic acid and sugars:** Ascorbic acid contents of berry juice were determined following the method described by Ruck (1969). Ten mL of juice was diluted with 0.4% oxalic acid solution in 100 mL volumetric flask. Five mL of diluted and filtrated aliquot was titrated against 2, 6-dichlorophenolindophenol dye, to light pink colour end point. Sugars in juice were estimated following the method described by Khan *et al*. (2009). Ten mL juice taken in 250 mL volumetric flask was diluted with 100 mL water, 25 mL 25% lead acetate solution and 10 mL 20% potassium oxalate. Then the volume was made with distilled water. The filtrate was used for the estimation of different forms of sugars (reducing non-reducing & total sugars). All sugars were expressed as percentage.

**Statistical analysis:** The data were subjected to analysis of variance (ANOVA) using Genstat (release 31.1; Lawes Agricultural Trust, Rothamsted Experimental Station, Rothamsted, UK) by using one-way ANOVA. Single grapevine was used as experimental unit replicated three times. The effects of various treatments were assessed within ANOVA and Fisher's least significant differences were calculated following a significant ($P \leq 0.05$) F test. All the assumptions of analysis were checked to ensure validity of statistical analysis.

## RESULTS AND DISCUSSION

All grapevine varieties exhibited different pheno-physiological characteristics. The bud burst in 'Black Prince' was commenced 4 days earlier than 'Gold', 6-days earlier than 'Shamas Guru' and 8 days earlier than 'Dehkani', 'Anab-e-Shahi' and 'Cardinal' (Fig. 2). The time of panicle emergence was also significantly different among all varieties. 'Black Prince' exhibited 5-8 days earlier panicle emergence as compared to all other varieties (Fig. 2). Similarly, the flower opening in 'Black Prince' was started 3-6 days earlier in contrast to all other varieties (Fig. 2). The results revealed that the 'Black Prince' exhibited shortest fruit maturity time followed by 'Gold', 'Shamas Guru', 'King's Early', 'Cardinal' and 'Dehkani' (Fig. 2). Maximum time (149 days) from the bud burst to harvest was recorded for 'Anab-e-Shahi' about 58 days later than 'Black Prince' (Fig. 3). Harvest dates also showed pronounced differences within the varieties. In the present study the phenological stages under the subtropical conditions of Faisalabad were completed in shorter period of time than in temperate zone. This difference may be ascribed to the high mean day and night temperature, which accelerated the growth and shortened the phenological stage than in comparatively cooler climate of temperate zones. Harvest date of black, red and green colour varieties of grapes have been reported to be correlated with cultivar character, geographic location and climatic conditions (Flora, 1977).

All varieties exhibited significant variation in their berry characteristics (Table I). Largest berry size was noted

**Table I: Bunch characteristics of seven grape varieties under the agro-climatic conditions of Faisalabad**

| Varieties | Berry size | Berry colour | Berries per bunch (No.) | Bunch compactness | Berry weight (g) | Seeds per berry (No.) |
|---|---|---|---|---|---|---|
| 'Black Prince' | Medium | Black | 115bc | Normal | 2.86c | 2 |
| 'Gold' | Small | Light red | 135b | Loose | 2.50bc | 2 |
| 'Dehkani' | Medium | Light green | 95c | Compact | 2.90bc | 2 |
| 'Shamas Guru' | Largest | Black | 80c | Loose | 4.50a | 2 |
| 'King's Early' | Large | Light green | 140b | Very compact | 3.01b | 2 |
| 'Anab-e-Shahi' | Large | Light green | 157a | Very compact | 3.15b | 2 |
| 'Cardinal' | Large | Black | 80c | Normal | 3.06b | 2 |
| ($P \leq 0.05$) | - | - | 30.7 | - | 0.68 | NS |

Any two means in a column followed by same letters are not significant at ($P \leq 0.05$), NS = not significant, n = three replicates

**Table II: Quality characteristics of seven grapes varieties grown under the agro-climatic conditions of Faisalabad**

| Variety | pH | SSC (%) | TA (%) | SSC:TA ratio | Ascorbic acid mg 100 $g^{-1}$ |
|---|---|---|---|---|---|
| 'Black Prince' | 3.95 a | 23.5 a | 0.24 c | 99.3 a | 12.2 b |
| 'Gold' | 3.92 a | 22.3 ab | 0.27 b | 80.5 b | 20.0 a |
| 'Dehkani' | 3.96 a | 19.8 c | 0.32 a | 80.1 b | 18.8 ab |
| 'Shamas Guru' | 3.81 b | 20.5 bc | 0.25 bc | 68.5 c | 12.1 b |
| 'King's Early' | 3.95 a | 19.6 c | 0.28 b | 61.1 c | 17.7 ab |
| 'Anab-e-Shahi' | 3.94 a | 19.9 c | 0.33 a | 60.7 c | 21.1 a |
| 'Cardinal' | 3.80 b | 19.7 c | 0.33 a | 60.0 c | 23.3 a |
| LSD ($P \leq 0.05$) | 0.12 | 1.82 | 0.03 | 9.77 | 6.98 |

Any two means in a column followed by same letters are not significant at ($P \leq 0.05$), n = three replicates

**Table III: Yield and yield component data of seven grapes varieties grown under the agro-climatic conditions of Faisalabad**

| Variety | Average bunch weight (g) | Number of bunches per vine | Yield per vine (Kg) |
|---|---|---|---|
| 'Black Prince' | 330.5 c | 38.0 ab | 13.0 abc |
| 'Gold' | 270.17 d | 41.0 a | 11.2 bc |
| 'Dehkani' | 276.73 d | 34.0 bc | 9.42 cd |
| 'Shamas Guru' | 360.5 c | 37.0 abc | 13.22 ab |
| 'King's Early' | 422.5 b | 33.0 bc | 14.10 ab |
| 'Anab-e-Shahi' | 483.71 a | 31.0 cd | 14.87 a |
| 'Cardinal' | 244.93 d | 24.0 d | 6.0 d |
| LSD ($P \leq 0.05$) | 85.15 | 6.12 | 3.38 |

Any two means in a column followed by same letters are not significant at ($P \leq 0.05$), n = three replicates

in the variety 'Shamas Guru', whilst it was smallest in 'Gold'. At harvest the berries of 'Black Prince', 'Shamas Guru' and 'Cardinal' exhibited good black colour (their varietal characteristic), which indicated that these varieties accumulated normal levels of anthocyanins under the warmer climatic conditions of Faisalabad (Fig. 1). Whereas, the 'Dehkani', 'King's Early' and 'Anab-e-Shahi' exhibited light green and 'Gold' produced light red colour berries. 'Shamas Guru' produced small and loose bunch with larger berry size as compared to all other varieties (Table I). Different varieties exhibited significant differences for bunch compactness. Maximum bunch compactness was recorded in 'King's Early' and minimum in 'Gold'. In general noraml to loose bunches are found in black varieties and light green varieties show compact to very compact bunch (Jackson & Lombard, 1993). The numbers of barriers per bunch were significantly different among the grapevine varieties. Maximum numbers of berries per bunch were exhibited in 'Anab-e-Shahi' (157) and minimum in 'Shamas Guru' (80). Among all varieties evaluated, the 'Shamas Guru' exhibited significantly highest average berry weight (4.5 g) and 'Gold' had significantly lowest (2.5 g) average berry weight (Table I). Bunch weight of 'Anab-e-Shahi' (490.12 g) and 'King's Early' (422.34 g) was higher than all other varieties. Maximum number of bunches per vine were exhibited in 'Gold' and minimum in 'Cardinal'. Significant differences in yield per vine were also observed (Table III). Considerable variabilities were found in berry size, berry colour, berries per bunch, bunch compactness, berry weight, bunch weight, bunches per vine and yield per vine. Results suggest the best adaptability of 'Black Prince' to subtropical climactic conditions of Faisalabad. This variation in the phenological stages of different varieties is ascribed to the differences in phenotypic and genotypic expression under existing climatic conditions (Coombe, 1987). Various physiological processes such as cell division, growth and development, sugar metabolism, enzyme reactions, photosynthates assimilation and transportation are partially subjected to influence of temperature variation. Guelfat-Reich and Safran (1971) categorized the table grapes into three main groups on the basis of their quality and time of harvest: (a) very sweet, (b) acidic and (c) medium acidic. Table grapes cv. 'Italia' has been found to exhibit variable response to ripening under different set of environmental conditions (Kingston & Van Epenhuijsen, 1989). Similarly, the meso- and macro-climactic differences may exit, when the same variety is cultivated under different, but comparable climatic conditions. However, these differences are more evident in higher altitude and can clearly be attributed to the differences in the solar radiation intensity.

The pH of these varieties ranged from 3.80 to 3.96. The pH values of 'Black Prince, 'Gold', 'Dehkani', 'King's Early' and 'Anab-e-Shahi' were at par among each other (3.92-3.96) and significantly higher than 'Shamas Guru (3.81) and 'Cardinal' (3.80) (Table II). Similalry, Amerine *et al*. (1967) also reported that the pH of grapes at maturity varied from approximately 3.1 to 3.9. The level of the pH of grapes is a very important factor in relation to flavour and resistance to spoilage (Amerine, 1973). At harvest the SSC of berries exhibited significant differences raging from 19.6% for 'King's Early' to 23.5% for 'Black Prince' (Table II). SSC values for 'Dehkani', 'King's Early', 'Anab-e-

**Fig. 1: The average temperature, rainfall and relative humidity of Faisalabad, during February to August, 2009**

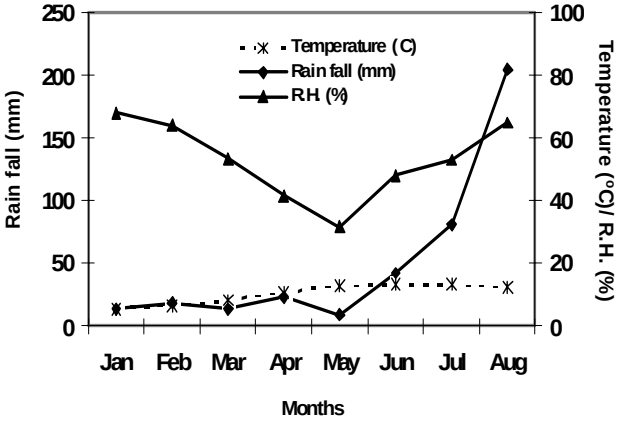



**Fig. 2: Phenological characteristics of seven grapes varieties grown under the agro-climatic conditions of Faisalabad. Vertical bars indicate ± SE of means. Any two means not sharing same letter differ significantly at 5% level of probability, n = 3 replicates**

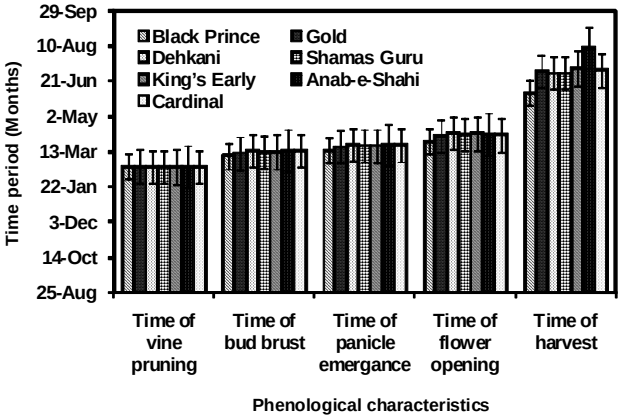



**Fig. 3: Time from bud burst to harvest for seven grapes varieties grown under the agro-climatic conditions of Faisalabad. Vertical bars indicate ± SE of means. Any two means not sharing same letter differ significantly at 5% level of probability, n = 3 replicates**

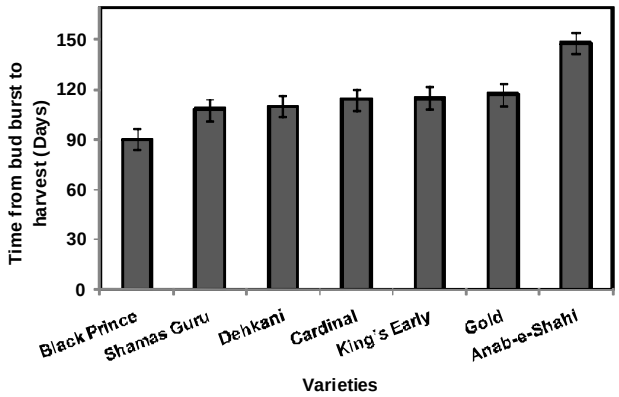
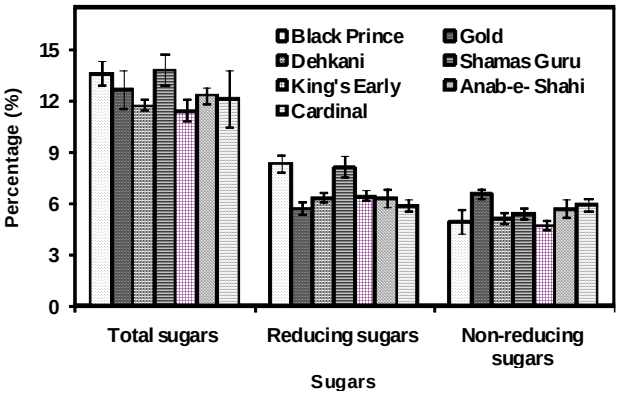



**Fig. 4: Sugar percentage of seven grapes varieties grown under the agro-climatic conditions of Faisalabad. Vertical bars indicate ± SE of means. Any two means not sharing same letter differ significantly at 5% level of probability, n = 3 replicates.**




Shahi', remained lower than all other varieties. Varieties with black colour and large to medium berry size show more SSC. The range of TA of these seven varieties varied from 0.24% to 0.33%, which is less than that reported by Johnson and Carroll (1973), who indicated 1.24% TA on an expressed juice fraction. Low TA have been found in grapes grown in subtropical climatic conditions as compared to temperate climates due to high temperatures during berry maturity and ripening (Poudel *et al*., 2009). The TA of the grapes is inversely related to the pH value, as TA of grapes increased their pH value decreased. Kliewer (1971) found reduction in the TA in the warmer regions. In addition the reduction in acidity is also brought about through a dilution effect caused by increased fruit size as reported by Johnson and Carroll (1973). All varieties showed low TA due to high temperature under the agro-climatic conditions of Faisalabad than temperate zone varieties. The SSC:TA ratio of the berries differed significantly for all the varieties evaluated (Table II). 'Black Prince' exhibited highest (99.3) and 'Cardinal' lowest (60) SSC:TA ratio. The higher SSC:TA ratio of 'Black Price' may be ascribed to the higher SSC and lower TA values. SSC: TA of medium to small berry size varieties was better than that of large size varieties. SSC: TA ratio is a flavour quality index commonly applied to not only grapes, but other fruit products (Flora, 1977). The contents of ascorbic acid were highest in variety 'Cardinal' (23.3 mg 100 $g^{-1}$) followed by 'Anab-e-Shahi' (21.1 mg 100 $g^{-1}$) and 'Gold' (20 mg 100 $g^{-1}$). However, level of ascorbic acid in 'Gold', 'Anab-e-Shahi' and 'Cardinal' were at par with respect to each other (Table II).

The amounts of total, reducing and non-reducing sugars were significantly different in the varieties evaluated (Fig. 4). The range of total sugars was from 11.44 to 13.60%. Highest total sugars (13.8%) were recorded in 'Shamas Guru' followed by 'Black Prince'

(13.6%) and 'Gold' (12.7%). Among all varieties assayed, the 'Black Prince' had the highest reducing sugars (8.36%), while 'Gold' with lowest reducing sugars (5.73%). The percentage of non-reducing sugars was highest (6.6%) in 'Gold' and lowest (4.8%) in 'King's Early'. Similarly, Tang (1978) have noted variation in concentration of SSC, pH, TA and sugars worked amongst various European, American and French grapes varieties. Earlier large differences have also been reported between grapes harvested from cool compared with hot regions (Mira de Orduna, 2010). Grape growers tend to wait longer for ripeness in temperate climatic zones because berry sugar content increases slowly, but under subtropical conditions acids convert rapidly into sugars due to high temperature and growers had not to wait for longer period. Under warmer climates like the semi-arid region of Faisalabad the berry attained maturity earlier and got less accumulation of colour pigments and sugars with comparatively poor aroma and taste as compared to cooler regions. As the temperature rises the late maturing cultivars are at risk of being crushed at high temperature and oxidation losses. Undue delay in the harvest results in quantitative and qualitative loss. When, an exotic table grape germplasm is introduced, it is essentially important to evaluate and/or select a variety suitable for the local environmental conditions. The pheno-physiological (bud burst, berry growth & development, berry size, numbers of berry per bunch, time of maturity & ripening) and biochemical (SSC, TA, sugars, amino acids, organic acids, phenolic compounds & total antioxidants) attributes of table grapes varieties have been reported to vary with change in the site, locality, topography and environment (Artes-Hdez *et al.,* 2003; Shiraishi *et al.,* 2010). Our results demonstrate that commercially important fruit traits such as berry ripening time, berry weight and SSC fluctuate due to environmental variation and must be tested in a new set of climatic condition to ensure the better adaptability of new varieties.

## CONCLUSION

The above mentioned findings indicated that considering the important characteristics, the 'Black Prince' is the best variety having large berry size, loose bunch, attractive black color and better sugar: acid ratio. While, 'Gold' also exhibited acceptable berry quality, but it is late maturing so it cannot be cultivated under the agro- climatic conditions of Faisalabad. 'Shamas Guru' and 'Cardinal' are rejected due to small bunch size. 'Dehkani', 'King's Early' and 'Anab-e-Shahi' are late maturing varieties and have very compact bunch prone to fungal attack. Hence, 'Black Prince' being an early maturing variety with excellent berry quality can be successfully cultivated under the agro-climatic conditions of Faisalabad.

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