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Multivariate analysis of colored and white grape grown under semi-arid tropical conditions of Peninsular India

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ABSTRACT: Thirteen grape varieties (Eight colored and five white) were evaluated during 2007-2009 under semi-arid tropical conditions of Peninsular India for 17 agro-morphological traits. Red varieties were vigorous as they have recorded more summer and winter pruning weight. Based on bud burst, most of the red varieties were early and medium types except Ruby red. The mean number of canes per vine and shoot length was higher for red varieties than white varieties with more variation for cane diameter. Red varieties have also produced longer shoots than white varieties. Vigorous varieties such Chenin Blanc and Shiraz have produced comparatively shorter shoots than less vigorous varieties. White grape varieties have recorded more number of leaves (16.96) in comparison to red varieties (16.64). However, range for number of leaves was high for red varieties (13.83) than white varieties (6.84). The mean leaf area (cm2) was high for red varieties (74.1) than white varieties (60.06) with range of 66.2 and 28.72, respectively. Red varieties were early in flowering in comparison to white varieties. Pearson correlation indicated highly significant correlation between days to 50 % flowering and heat unit requirement ($r = 0.93$) and it also had significant correlation against days to bud burst ($r = 0.79$), berry diameter ($r = 0.60$), mean bunch weight ($r = 0.58$), hundred berry weight ($r = 0.49$) and mean bunch length ($r = 0.44$).The prinicipal component analysis (PCA) revealed that, first PC explained 32.94 % variance through phenological and yield attributes. Second PC contributed for 19.71 % variance through fruit yield and berries per bunch. Third PC explained 14.85 % variance through summer, winter pruning weight and number of leaves. Cluster analysis suggested grouping of varieties in to five clusters. Cluster III found to be diverse as it represented both red (Gulabi and Bangalore blue) and white varieties (Symphony and Sauvignon Blanc) of grape and it is the largest (total four varieties) among the five clusters. The genetic advance as per cent of mean was high for mean bunch weight (108.69 %) and winter pruning weight (86.06 %) followed by summer pruning weight (83.11 %). Mean bunch weight (99.90 %), days to bud burst (99.24 %) and hundred berry weight (98.85 %) are the important traits in grape which have expressed high heritability signifying high potential for improvement of grape through selection.
Key words: *Vitis vinifera,* principal component, total Sugar, tss: ta ratio, cluster analysis

INTRODUCTION

The grape was one of the first fruit crop to be cultivated by man to produce table fruits, dry fruits, juice and wine (Frederique Pelsy et al. 2010). Grape (*Vitis vinifera*) L. belongs to family Rutaceae and reported to be originated in Middle East. The archaeological evidence revealed that cultivation of domesticated grape (*Vitis vinifera* subsps *vinifera* began 6,000 - 8,000 in the near east from its wild progenitor *Vitis vinifera* subsps *sylvestris* (Mc Govern 2003). The genus *Vitis* comprises of three natural groups based on geographical locations viz., North American, Eurasian and Asiatic. American and Asiatic groups have 25-30 species whereas, Eurasian has only one species i.e. *vinifera* which has contributed for advancement of grape cultivation throughout the world. Grape is one of the world's most widely grown fruit crops in relatively warm temperature-zone climates and not so well adapted to sub-tropical or tropical areas although special management allows dessert grapes to be harvested 2-4 times per year in tropical countries such as Thailand and Indonesia (Jackson & Looney 1999).There are three distinct regions of grape cultivation in India viz., temperate (Jammu and Kashmir, and Himachal Pradesh), sub-tropical (Punjab, Haryana, Rajasthan and western Uttar Pradesh) and tropical (Andhra Pradesh, Maharashtra, Karnataka and Tamil Nadu). The 94 % of grape production in India comes from tropical region (Chadha 2008) as the state of Maharashtra occupies highest area (71.5 %) and contributes 80 % of the country's production followed by Karnataka and Andhra Pradesh as these two states constitute the southern part of Peninsular India (Karibasappa et al. 2006).

The grape vine has deep roots and is drought tolerant although irrigation is necessary in some production areas. It is also tolerant of many soil types provided they are deep and well drained. Over-fertilization, especially with nitrogen can lead to too vigorous growth (which may adversely affect wine quality).Pruning weight is important criteria in grape to determine and distinguish vigorous, non-vigorous varieties. Several studies have proved that high yielding clines produced large pruning weight with high vigorous growth of the vine and vice- versa (Smith 1996; Havinal et al. 2008; Ratnacharyulu 2010; Benz et al.2006; Shellie 2007). Beside pruning weight, number of canes produced by wine after pruning will also determines the vigour of vine. Sprouting buds on spur is varietal character and response of vine to prevailing environmental conditions (temperature). Time taken for bud burst is an index to classify grape varieties as early, medium and late. Previous report (Lingaraj 1965) suggested wide variation in bud burst among different grape cultivars (Shinde and Patil, 1978). Number of leaves and leaf area per cane are two important traits which enhances the net photosynthesis in grape. Several authors reported wide variation in leaf area per cane (Chadha and Randhawa 1974; Kadu et al. 2007) resulting in different yielding ability of the plant. Fruits of grape vine are botanically called as "Berries" and a cluster of berries on main rachis and secondary rachis are referred to as "Bunches". Bunch and berry attributes include bunch weight, bunch length, number of berries, diameter of berry and 100 berry weight which contribute to the yield of vines. Each berry consists of a multi-layered pericarp and may contain up to four seeds, although a number of cultivars for fresh consumption are seedless. The cells of grape berries are tightly packed with an internal gas volume of about 1.2 ml/100 g (Zosangliana & Narasimham 1993). The pericarp can be divided into the exocarp (skin), mesocarp (pulp) and endocarp. The pulp makes up most of the berry weight and cells are highly vacuolated, containing high levels of sugars and other soluble compounds. The seeds contain high levels of tannins (5-8%), oil (10–20%) and phyto-hormones (Winkler et al. 1974). The pericarp contains plastids throughout berry developmental though their morphology changes at around anthesis and lipid-like globules form within berry (Hardie et al. 1996). The concept of heat unit requirement can be effectively used for determining the optimum time of harvest (Jacob, 1950). The use of heat summation data as the harvest index was suggested by several workers in different crops. As early as 1940, Winkler and Williams reported that the grape harvesting date can be determined by calculating the approximate heat summation from date of pruning to harvest. The time required for grapes to reach maturity is determined by the total amount of heat received from full bloom to ripening, which is expressed in terms of degree days (Thakur et al. 2008).

Since the dawn of civilization, the fermented product of grapes, wine, has probably been an important way of consuming grapes (McGovern et al. 1995). Due to its rich constitution, grape juice is considered a differentiated beverage with positive energetic, nutritional and bioactive effects (Rizzon and Miele 1995; Mazarotto 2005). Grape juice is a rich source of flavonoids and other phenolics and supplementing the grape in human diet has positive health benefit (Lima et al. 2014) such as improvement of the endothelial function, increase of the serum antioxidant capacity, protection of LDLs against oxidation, decrease of native plasma protein oxidation, and reduction of platelet aggregation, has also been reported (Chou et al. 2001: Alberto et al. 2004). Wines have always been considered as safe and healthful drink, an important adjunct to the diet and moderate quantity of wine consumption has been found to lower the mortality from heart diseases (Delin and Lee 1991). It also provides calories and vitamins, since the wines are not distilled they have more nutrients like vitamins, minerals and sugars than the distilled beverages like beer, brandy and whisky. In addition to this, several therapeutic and medicinal values are found to associate with wines. The existence of alcohol and anti-oxidants in wine reduce a variety of human ailments especially the cardio vascular diseases (Joshi and Sharma 2004). Wines contain antioxidants. The anti-microbial activity found with wines is an added advantage.

Carey et al. (2008a), demonstrated effect of climatic conditions viz., topography, climate, substrate and soil (Carey et al. 2008a) representing agriculture practices of the site. Climate, soil and topography affect phenology, growth, yield, berry composition and wine-related parameters for Cabernet-Sauvignon (Carey et al. 2008b).Climate, and particularly insolation, has a significant impact on vine photosynthesis and, consequently, on the synthesis of phenolic compounds. Temperature also influences the accumulation of colour in berry skins.

Rainwater availability affects vine vigour, production and indirectly affects the accumulation of sugars, acids and phenolic compounds in berries (Zamora 2003; Gonzalez et al. 2012).Therefore; performance of particular species varies depending upon agro-climatic conditions. Particular variety performs better under certain set of agro-climatic conditions and may not perform well similarly under another set of agro-climatic conditions. No scientific investigation has so far been made to find out suitable grape varieties for commercial cultivation in Andhra Pradesh, an important state of grape growing in India, although a few such studies were made in Maharashtra (Patil et al. 2007; Havinal et al. 2008, Karibasappa and Adsule 2008), Punjab (Thakur et al. 2008), Karnataka (Chikkasubbanna 1982 ; Suresh et al. 1985; Patil and Patil 2008) and West Bengal (Ghosh et al. 2008).This necessitates performance studies of different varieties/hybrids to select better performing variety in terms of agro-morphological traits under semi-arid tropical conditons of peninsular India.

MATERIALS AND METHODS

The present experiment was conducted at Grape Research Station, Rajendrangar, Department of Horticulture, College of Agriculture, Acharya N G Ranga Agriculture University, Hyderabad, Telangana State, India. The grape produced during 2007-08 and 2008-09 were used in the present study.

The experimental site was located at 18^{o}.45' North latitude and 77^{o}.85' East longitude at an altitude of 542.6 meters above mean sea level. It falls under arid sub-tropical climatic zone having an average annual rainfall of 800 mm. The Meteorological data was collected once in a week from the Meteorological Observatory situated at Agricultural Research Institute, Rajendranagar, Hyderabad, Telangana State, India during the crop season from 2007-08 to 2008-09 and are furnished in fig 1 and 2.

The weekly mean minimum and maximum temperature for the crop period i.e. from foundation pruning to end of harvest during the first year 2007-08 ranged from 17.00c and 31.10c with an average temperature of 240c and mean relative humidity ranged from 36 to 84 % with a rainfall of 1.6 mm during the crop period, while during the second year 2008-09, it ranged from 16.30c and 30.70c with an average temperature of 23.50c and mean relative humidity ranged from 38 to 82 % with a rainfall of 9.3 mm during the crop period. The experiment involved thirteen wine grape varieties of which eight colored and five white were evaluated for various agro-morphological traits. The colored varieties were Zinfandel, Cabernet Sauvignon, Shiraz, Ruby Red, Pusa Navrang, Bangalore Blue, Athens and Gulabi. Whereas, Symphony, Chenin Blanc, Sauvignon Blanc, Thompson Seedless and Italia were the white varieties. The varieties selected for the study were five years old grown on own roots, planted at 14 ft x 7 ft spacing and trained on an overhead bower. The soil of the vineyard is texturally classified as red sandy loam consisting sand 69.9 %, silt 8.2 % and clay 18.9 %. The chemical properties of these soils are pH 6.2, EC 0.16 dSm-1, Organic carbon 1.60%, available N 350.0 kg ha-1, available P 123.0 kg ha-1, available K 680.0 kg ha-1, Iron 35.50 mg kg-1, Manganese 6.50 mg kg-1, Copper 8.20 mg kg-1 and Zinc 1.8 mg kg-1. Well rotten Farm yard manure @10kg per vine was applied twice before each pruning. A fertilizer dose of 500 kg N + 500 kg P2O5 + 1000 kg K2O per hectare was applied at April and October pruning in splits according to the stages of vine as per the standard package of practice. Irrigation was provided through drip irrigation system. Two drippers each of 8 litres per hour discharge capacity were placed on either side of each vine 60 cm distance from the main trunk. Weeding was done by both manually and mechanically so as to maintain weed free conditions in the orchard. All the vines were pruned twice in a year viz., foundation pruning during March- April leaving one or two buds to develop vegetative canopy and fore pruning was carried out during October-November in both the years (2007-08 and 2008-09) leaving 4-10 buds for fruiting depending on the variety.

Data recording for agro-morphological traits

Randomly five healthy plants were selected and subjected to record following agro-morphological traits.

Pruning weight

The fresh weight of the pruned canes at the time of October pruning was measured with the help of a weighing balance (Tulaman, H.T. 500 series). Three groups of vine vigour viz., low, medium and high were designated on the basis of pruning weight as follows. a. Low vigour- Pruning weight less than 0.2 kg; b. Medium vigour - Pruning weight 0.2 kg to 0.4 kg; High vigour - Pruning weight more than 0.4 kg (Havinal et al. 2008).

Days taken for bud burst after pruning

The number of days taken for bud sprouting from pruning was recorded in each treatment after the winter (October) pruning to know earliness or lateness of the variety. After October pruning, ten canes on each vine of each cultivar were tagged and observed for recording the days required for sprouting.

Number of canes

The number of canes retained per vine after the October pruning was recorded.

Cane diameter (mm)

Mean cane diameter was recorded with vernier calipers by selecting ten canes randomly in each variety and expressed in millimeters.

Shoot length (cm)

Shoot length was recorded by selecting five shoots randomly from tagged canes and was expressed in centimeters.

Number of leaves per cane: Number of leaves per cane was recorded by counting the number of leaves per ten canes per vine.

Leaf area (cm2)

Leaf area was measured with the help of an Electronic leaf area meter(LI-3100, Lincoln, Nerbraska USA) by selecting five leaves randomly from tagged canes and was expressed in square centimeters.

Days taken for 50 % flowering

After October pruning, ten canes on each vine of each cultivar were tagged and observed for recording the days required for 50% flowering and to know the variety with early flowering trait.

Average number of bunches per vine

The mean bunch number was worked out on the basis of observations from a composite sample of ten canes chosen at random from every vine of each variety.

Mean bunch weight (g)

The mean bunch weight was worked out on the basis of observations from a composite sample of ten bunches chosen at random from every vine of each variety and expressed in grams.

Mean bunch length (cm

The mean length of the bunches was derived by averaging the length of ten bunches randomly selected from each variety and expressed in centimeters.

Average number of berries per bunch

Number of berries per bunch was recorded by counting the number of fruits per five bunches per vine and averaged.

Hundred berry weight (g)

From each treatment hundred berries were randomly selected at harvest and their mean weight was recorded in grams.

Berry diameter (mm)

Mean berry diameter was recorded with the help of Vernier calipers at harvest by selecting ten berries randomly in each variety and was expressed in millimeters.

Fruit yield (kg/vine)

The number of bunches borne on the labeled spurs in each treatment was noted and weighed. The combined weight of these bunches was considered as the total yield per treatment and expressed in kilograms.

Number of Heat Units required for fruit ripening

The Heat units or degree days were calculated from the day of October pruning to harvest by using the following formula described by Rai et al. (2002).

$DD = (T\ max + T\ min)/2 - Tb$

T max & T min are the maximum and minimum temperatures respectively.

Tb- is the base temperature below which fruit growth is arrested.

The mean daily temperature was calculated from the maximum and minimum temperatures and the base temperature of 10^{o}c was subtracted from this. The remaining temperature thus obtained is called 'Heat Unit' (HU), which is summed up over the period from October pruning to harvest to get heat unit required for maturity of grapes.

The base temperature for grape is taken as 10^{o}C (Brar et al.1992).

On the basis of heat unit requirements, the maturity period was categorized in to three groups as

Early – Heat unit requirement less than 1700 degree -days

Medium – Heat unit requirement 1700- 1900 degree - days

Late – Heat unit requirement more than 1900 degree days

Statistical analysis

The data for two consecutive years was pooled and mean were calculated for 17 agro-morphological traits viz., SPU: Summer pruning weight (kg/vine); WPW: Winter pruning weight (kg/vine); DBB: Days taken for bud break; NCV: Number of canes per vine; CDM: Cane diameter (mm); SLT: Shoot length (cm); NLV: Number of leaves per vine; LAR: Leaf area (cm2); DFL: Days to 50 % flowering; NBV:Number of bunches per vine; MBW: Mean bunch weight (g); MBL: Mean bunch length (cm); NBB:Number of berries per bunch; HBW:Hundred berry weight (g);BDM:Berry diameter (mm); FRY: Fruit Yield (kg/vine); HUR: Heat Unit requirement for Randomized Block Design as per the procedure outlined by Panse and Sukhatme (1967). Principal component analysis, phenotypic coefficient of variation (PCV), Genotypic coefficient of variation (GCV), Heritability, Genetic Advance and Genetic Advance as per cent mean was worked out using XLSTAT Version 2014.2.05 (Addinsoft SARL, France). The grape agro-morphological data underwent multidimensional scaling and Agglomerative Hierarchical Cluster (AHC) analyses using XLSTAT Version 2014.2.05 (Addinsoft SARL, France; Marco et al. 2010; Susan et al. 2010; Trent et al. 2013).

RESULTS AND DISCUSSION

Though, grape originated in temperate region (Giovanni Zecca et al. 2012) but it has been extended successfully to tropical and sub-tropical regions of the globe. The agro-morphological traits vary significantly with varying agro-climatic conditions. Variation in climatic factor viz., temperature, humidity, rainfall and its distribution greatly affect the growth and yield of grape. The prevailing climatic factors in the Deccan plateau of southern India where wide range of varieties are being grown for wine production. Therefore, selection of suitable variety under semi-arid tropical conditions of south India for their growth performance and yield assumes significant (Patil et al. 2007).

Anova

The analysis of variance was presented in table 1 and found significant for summer pruning weight (kg/vine), Days taken for bud break, number of canes per vines, cane diameter (mm), shoot length, number of leaves, leaf area, days to 50 % flowering, number of bunches per vine, mean bunch weight, mean bunch length, number of berries per bunch, hundred berry weight, berry diameter and fruit yield at 0.01 Probability. However, winter pruning weight was significant at 0.05 Probability. The heat unit requirement found to be non-significant at both level of probability. The highest Coefficient of variation was recorded by winter pruning weight (22.55 %) followed by summer pruning weight (14.02 %). The lowest Coefficient of variation (1.61 %) was recorded by mean bunch weight (g) followed by days taken for bud burst (2.47 %).

Agro-morphological traits

The comparison of white and red grape varieties for different agro-morphological traits has been presented in Table 2. The pruning weight considered as in-direct measure of the vigour of the vine in grape. The red grape varieties have recorded higher mean (3.30 Kg/vine) summer pruning weight in comparison to white varieties (2.4 Kg/vine), with range of 4.2 Kg/vine for red varieties and 1.79 Kg/vine for white varieties, indicating more variation for summer pruning weight among red varieties than white varieties. The mean winter pruning weight was high for red varieties (1.45 Kg/vine) than white ones (1.09 Kg/vine) with range of 2.3 Kg/vine for red varieties and 1.02 Kg/vine for white varieties, indicating more variation for winter pruning weight among red varieties. Red varieties may be considered as more vigorous than white varieties as they recorded more summer as well as winter pruning weights. (Shikhamany 1983; Fawzi et al. 1984; Satisha and Shikhamany 1999; Benz et al. 2006). The amount of pruning weight depends upon the vigour of the vine, as highly vigorous varieties produce more pruning weight than less and medium vigorous varieties. Among red varieties, Shiraz and Italia among white may be considered as vigorous varieties based on their respective pruning weights. Generally speaking, both red and white varieties have recorded more summer pruning weight than winter pruning weight. Smith (1996) reported that high yielding clones produced larger pruning weights and vice versa.

Apart from pruning weight, number of canes and cane diameter is another criteria in deciding vigorous nature of the vine. Cane regulation is important technique as cane thinning in wine grapes induced a canopy microclimate that was less favourable to the development of fungal diseases. The mean number of canes per vine was higher for red varieties (42.3) than white varieties (40.8). The range for number of canes per vine was 20.32 for red varieties and 21.00 for white varieties. Shiraz (54.93) among red and Chenin Blanc (53.9) among white varieties recorded highest number of canes per vine. Varieties producing more number of canes per vine may be considered as vigorous. Therefore, regulation of canes in grape cultivar affects the growth, yield and quality of grapes for wine production. While, pruning for fruit, more number of canes per vine are retained on vigorous vines and less are retained on less vigorous ones. Hence, cane regulation should be considered as technical cultural practices suitable for modification of grapevine physiology and plant production towards a defined goal (Mattii and Ferrini 2005). However, vine regulation at 20 -24 canes per vine produce good quality grapes for preparing fine quality wine (Patil et al. 2012). Grape vines with more canes bear heavy crop and results in delayed maturity under unfavourable weather conditions. The mean cane diameter recorded by red varieties (15.51 mm) and white varieties (15.39 mm) with range of 7.11 mm and 4.77 mm, respectively. More variation was observed among red varieties for cane diameter than the white varieties. Ruby red (among red varieties) and Itaila (among white varieties) recorded high cane diameter. Hence, Shiraz, Chenin Blanc, Italia and Ruby red may be considered as highly vigorous varieties which strengthen our present finding that high pruning weight may result in more number of canes giving rise to more vigorous vines. Generally, length of the shoot depends upon the vigour of the variety and extent of pruning (Havinal et al. 2008). The mean shoot length recorded by red varieties (66.95 cm) and white varieties (67.18 cm) with range of 18.5 cm and 13.35 cm, respectively. Red varieties have produced longer shoots than white varieties. Vigorous varieties such Chenin Blanc and Shiraz have produced comparatively shorter shoots than less vigorous varieties. This may be due to number of buds retained on the cane after pruning.

Leaves are the site of photosynthesis, more number of leaves enhances the rate of photosynthesis leading to increase in the grape yield. White grape varieties have recorded more number of leaves (16.96) compared to red varieties (16.64). However, range for number of leaves was high for red varieties (13.83) than white varieties (6.84) indicating more variation for number of leaves among red varieties. Ruby red (23.66) among red varieties and Sauvignon Blanc and Chenin Blanc (18.67 & 18.5) among white varieties have recorded higher number of leaves. Such variation among the colored and white varieties for leaf number may be attributed to difference in number of canes and vigour of the vine and also the inherent varietal character. The mean leaf area (cm^2) was high for red varieties (74.1) than white varieties (60.06) with range of 66.2 cm^2 and 28.72 cm^2, respectively. Such, high variation among the red and white varieties for leaf area may be attributed to varietal character. It is evident from data that varieties having less number of leaves have recorded higher leaf area and vice versa this might be due to translocation of more nutrients to the leaf growth which ultimately resulted in higher leaf area (Kadu et al. 2007; Shirsath 1965; Chadha and Randhawa 1974). The increased leaf area results in highest active photosynthesis rate which helps to store more carbohydrate in the sink, bunch (Somkumar et al. 2013). However, report suggest that leaf area with a range of 7 to 14 cm^2 /gm is necessary to achieve ripening of grape berries (Stanely 2001).

Phenological traits

Bud burst is a varietal character as it marks the beginning of seasonal growth and it is strongly influenced by temperature. Days taken for bud burst vary from variety to variety and climatic conditions. The time taken for bud burst is taken as an index to classify the grape varieties as early, mid and late varieties There was no much difference for mean number of days taken for bud burst as red varieties took 13.65 days and white varieties took 13.73 for bud bust. However, variation was observed for range values as red varieties took 11.7 days and white varieties 8.1 days for bud burst indicating more variation among red varieties for bud burst than white ones. Pusa Navrang, Bangalore Blue and Chenin Blanc were the earliest ones to show bud break requiring less than 10 days. Whereas, Ruby Red took more than 20 days for bud break. Based on this, the varieties can be classified in to early (Pusa Navrang Bangalore, Chenin Blanc and Gulabi), mid (Sauvignon Blanc, Symphony, Shiraz, Zinfandel, Italia and Cabernet Sauvignon) and late (Ruby Red, Thompson Seedless and Athens) bursting varieties (Bharat 1997; Mandelli et al. 2003). It is evident that most of the red varieties were early and medium types except Ruby red. Flowering is considered as transition phase in plant growth cycle. Early flowering is desirable trait in grape which depends upon climatic condition particularly temperature. The red varieties of grape took less mean number of days (34.92) to 50 % flowering than white varieties (36.15), with range of 18.04 and 18.12 days, respectively. There was less variation for range values for days to 50 % flowering. Flowering data indicates that red varieties earlier in flowering in comparison to white varieties. However, Chenin Blanc and Italia found to be early and late bearing types irrespective of color of the variety. Flowering is special trait, polygenic in expression and environment plays critical role. Bright warm weather induces early flowering than rainy and cool weather (Weaver 1976). Flowering helps in assessing the maturity and early harvesting of berries in one or two pickings which reduces cost of harvesting. It also helps to overcome the incidence of diseases which quite oftenly coincides with early rains especially under north Indian conditions. Under tropical conditions of Bangalore (Peninsular India), Gulabi and Bangalore Blue varieties require 47.0 and 33.5 days respectively to reach 50% flowering. Jawanda et al. (1965) reported range for 50 % flowering from 33.5 to 47.0 days and several other researchers reported variation in flowering behavior of different grape varieties under varying climatic conditions (Bharat 1997; Sumbli 1970; Prasad 1971; Negi et al.1974; Huang and Lu 2000).

Yield and associated traits

The number of bunches per vine is an important yield attribute in grape. The mean number of bunches per vine were high for red varieties (69.84) than white varieties (62.82) with range of 52.05 and 76.53, respectively. The white varieties have recorded high variation for number of bunches per vine than red varieties. Among red varieties, Shiraz and Chenin Blanc among white varieties recorded highest bunches. A wide range in number of bunches was reported by several workers 9.30 to 33.43 (Kadu et al. 2007); 17.35 to 93.10 (Karibasappa and Adsule 2008); 58.33 to 142.00 (Ratnacharyulu 2010); 131 to 162 (Walker et al. 2000). The increased number of bunches per vine increases the grape yield per vine with an increment in carbohydrate content in the berries to the maximum extent (Somkumar et al. 2013).Bunch weight is another important yield attribute. The heavier the bunch, more will be the grape yield. The mean bunch weight was high for white varieties (195 g) than red varieties (120.9 g) with range of 233.2 g and 66.84 g, respectively. More variation was observed among white varieties for mean bunch weight in comparison to red varieties. Athens (red variety) and Italia (white variety) have recorded high mean bunch weight. Earlier reports suggest high variation for bunch weight ranging from 44.9 to 436.1 g in different cultivars by Daulta et al. (1972). Sharma et al. (1993) observed a wide range of bunch weight from 230 to 575g in six different cultivars of grape. Richard et al. (1999) recorded bunch weight ranging from 88 to 310 g in 5 cultivars of grape. The bunch weight also differed in cultivars of grape viz., Cabernet Franc (147.7 g), Ugni Blanc (135.6g), Chenin Blanc (132.8g) as reported by Havinal et al (2008). The differences in the bunch weight in different varieties may be attributed to inherent genetic character of the variety, difference in number of canes, number of berries per bunch and berry size and also vine canopy size where the high bunch weight was observed in the varieties which had large canopy size (Walker et al. 2000; Havinal et al. 2008). The mean bunch length was high for white varieties (11.74 cm) in comparison to red varieties (9.78 cm) with a range of 11.24 cm and 4.77 cm, respectively. The white varieties have recorded more variation for mean bunch length in grape. Among colored varieties, Shiraz and Thompson seedless among the white varieties have recorded highest mean bunch length. Similar finding regarding bunch length were reported by Joshi 1961; Shirsath 1965; Kashyap et al. 1988; Shanmugavelu 1989). The mean number of berries per bunch was high for white varieties (65.27) in comparison to red varieties (59.55) with a range of 38.34 and 55.34, respectively. High variation was observed among the red varieties for number of berries per bunch in grape. Pusa Navrang (colored variety) and Thompson seedless (white varieties) have recorded highest number of berries per bunch. The difference in the number of berries per bunch may be attributed to the difference in the size of the berry and diameter of the berry. These results are in agreement with the findings of and Kadu et al. (2007) and Ratnacharyulu (2010). The mean hundred berry weight was high for white varieties (282.2 g) in comparison to red varieties (210.4 g) with range of 215.7 g and 158.00 g, respectively. White varieties have recorded more variation among them for hundred berry weight. Gulabi (red variety) and Italia (white variety) have recorded highest hundred berry weight. Based on the hundred berry weight, the varieties can be classified as high berry weight varieties (Italia, Thompson Seedless, Gulabi Bangalore Blue and Athens) and lowest berry weight varieties (Pusa Navrang, Cabernet Sauvignon, Shiraz and Chenin Blanc) while the remaining varieties (Symphony, Sauvignon Blanc, Zinfandel and Ruby Red) fall in medium berry weight category. The variation in the berry weight might be due to variation in the diameter of the berries and also due to number of berries per bunch. Wide range of hundred berry weight was reported by several workers , 45 to 398 g (Daulta et al. 1972); 104 to 275 g (Ram Kumar et al. 2002); 106 to 403 (Ratnacharyulu 2010); 110 to 160 g (Richard et al. 1999); 130 to 480 g (Thakur et al. 2008); 150 to 300 g (Ghosh et al. 2008).The mean berry diameter was high for red varieties (13.96 mm) in comparison to white varieties (13.78 mm) with range of 5.76 mm and 5.79 mm, respectively. The variation was more among white varieties for berry diameter in grape. Highest berry diameter was recorded by Gulabi (16.51 mm) among red varieties and Italia (17.94 mm) among variety. The high berry diameter may be due to presence less number of berries in a bunch, if more berries are present in the bunch may lead to less diameter of the grape berries. Several workers reported a wide range of berry diameter ranging from 10 mm(Cabernet Sauvignon) to 19 mm (Bangalore Purple). Kadu et al. (2007); 10.0 mm (Ruby Red) to 20.7 mm (Cardinal) reported by (Thakur et al. 2008).The results are in agreement with the reports of Richard et al. (1999); Ratnacharyulu (2010). The mean fruit yield was highest for white varieties (10.74 Kg/vine) in comparison to red varieties (8.52 Kg/vine) with a range of 12.31 Kg/vine and 8.54 Kg/vine, respectively. There was more variation among white varieties for fruit yield of grape. The highest fruit yield (13.48 Kg/vine) was recorded by Shiraz among red varieties and Chenin Blanc (16.82 Kg/vine) among white varieties. Based yielding ability, varieties can be classified as high yielders ranging from 16.81 to 10.78 kg/vine (Chenin Blanc, Italia, Shiraz, Thompson Seedless and Pusa Navrang) ; medium yielders ranging from 9.91 to 7.31 kg/vine (Zinfandel, Athens, Cabernet Sauvignon and Symphony); and low yielders ranging from 6.74 to 4.51 kg/vine (Ruby Red ,Bangalore Blue, Gulabi and Sauvignon Blanc). Pusa Navrang yielded 21.5 kg/vine at Lucknow, whereas at Hyderabad it yields 10.78 kg/vine. This difference may be due to variation in the prevailing climatic conditions at both locations. The climatic conditions at Lucknow come under sub-tropical zone whereas Hyderabad climatic conditions come under semi-arid tropical zone. Thus, it is clear that the prevailing climate of the location has a substantial bearing on yield. The yield potential of a grape variety is inherent subject to adoption to varying agro-climatic conditions of different locations. The ultimate objective of the grape grower is to harvest the high yield, which is the most important factor from commercial point of view. Yield is variable among the different varieties of grape and is genetically inherent. However, it depends on the age of the plant, nutrition, cultural practices adopted, pest and disease incidence and finally climatic conditions of cultivated area. Yield also varies from year to year in the same variety and also when grown at different locations. These facts have been brought about clearly in the present investigation. Wide range of yield among different varieties of grape screened at different location has been reported from India and abroad (Daulta et al. 1972; Thatai et al. 1987; Kadu 2002; Ramkumar et al.2002; Ghosh et al. 2008; Shellie 2007; Karibasappa and Adsule 2008; Havinal et al. 2008 and Ratnacharyulu 2010) which support the results of the present study at Hyderabad. The difference in the yield per vine in different grape cultivars might be due to differences in weight of the bunch, number of bunches, weight of the berries and age of the vines besides their successful adoption to the varying agro-climatic conditions under which they are cultivated (Thatai et al. 1987; Havinal et al. 2008).

Heat unit requirement

Optimum stage of maturity of fruits is an important factor that influences the quality of wine. The stage of maturity can be judged by heat summation, besides others like days for bud burst and days for anthesis, colour of the stem, transparency of the berries and TSS etc. Hence, heat unit requirement for maturity in different cultivars was worked out based on the base temperature of grape under semi-arid conditions of Hyderabad. The heat unit requirement was high for white varieties (1,950) in comparison to red varieties (1,916) with a range of 443.35 and 393.72, respectively. The white varieties have recorded more variation for heat unit requirement. The highest heat unit requirement was recorded by Ruby Red (2,119.97) among red varieties and Italia (2,207) among white varieties. Varieties exhibit inherent differences in their heat unit requirement. Each variety has a specific heat summation requirement which however, varies under the influence of climatic condition and time. This has been observed to be true in the present study. According to Bammi (1968) most of the grape growing areas in India received heat units of 4000 to 4800 degree days in grape from the start of growth to maturity of berries. The requirements of heat units also differed with earliness or lateness of the variety. Makhija et al. (1984) observed that early maturing varieties (Pearl of Csaba) required 1600 degree days, mid-season variety (Black Muscat) required 2080 degree days and late season variety (Alam Wick) required 2250 degree days under Delhi conditions and concluded that early maturing varieties required less heat units than the late maturing varieties. Similar observations was made by Thakur et al. 2008. The requirement of heat units differs from place to place for the same variety. Bangalore Blue required 3562 degree days to attain maturity at Coimbatore (Palaniswamy et al. 1965) whereas it required 1815.79 heat units at Hyderabad in the present study. The heat unit requirement in case of Italia varied from 1727-1840 degree days in different months over a base temperature of 12^{o}C in Brazil (Murakami et al., 2002). In Egypt, Thompson Seedless required 8566 and 12591 heat units for the start and the end of the bud break whereas it required 2040.16 heat units in the present investigation at Hyderabad. In the present study, heat unit requirement in different cultivars of grape varied from 1726.24 to 2207.46 degree days having recorded maximum by the variety Italia and minimum by the variety Pusa Navrang respectively. Based on this data, varieties can be classified as early maturing (Pusa Navrang, Chenin Blanc, Symphony and Sauvignon Blanc), mid maturing (Gulabi, Bangalore Blue, Shiraz and Zinfandel) while late maturing varieties (Cabernet Sauvignon, Athens, Thompson Seedless, Ruby Red and Italia). The variation in heat unit requirements among the different grape varieties was attributed to the variation in the date of maturity (Thakur et al. 2008). The variation in the heat unit requirement with the variation in the date of maturity was also reported in Ber (Singh et al. 1998); Mango (Shinde et al. 2001) and Litchi (Rai et al. 2002).

Correlation studies

Pearson correlation coefficient was depicted in fig 1 to the association between growth and yield parameters. Summer pruning had positive significant correlation against winter pruning (r = 0.88) and cane diameter (r = 0.73).Whereas, winter pruning weight positively correlated against collar diameter (r = 0.55). Reynolds et al. 1994a, 1994b, 1994c reported that wine quality did not decrease with increase in crop load (yield to pruning weight ratio). Kliewer and Dokoozlian 2000; Kliewer and Weaver 1971) found high correlation between crop yield and pruning weight as well leaf area to crop weight. The number of days to bud burst had high positive correlation against days to 50 % flowering (r = 0.79) and heat unit requirement (r = 0.78) followed by number of leaves (r = 0.54) and mean bunch weight (r = 0.41). Such positive signification correlation among phenological and associated traits would be very handy for the breeders to select early grape varieties. Lesser the number of days taken for bud burst may result in early flowering as confirmed from signification positive correlation among days to bud burst, 50 % flowering and heat unit requirement. It also exhibited positive association with mean bunch length, number of berries per bunches, shoot length, 100 berry weight and berry diameter. This indicates selection of grape varieties based on phenological traits also aids in indirect selection of yield associated traits due to their positive association.

High significant positive correlation was recorded between number of canes per vine and number of bunches per vine (r = 0.87), and it also positively correlated against number of leaves per vine (r = 0.45) and fruit yield per vine (r = 0.45).The association between number of canes and fruit yield in grape was linearly correlated (Tafazoli 1977) as the number of canes per vine increases there is increase in the fruit yield of grape varieties through number of leaves and number of bunches. Hence, retention of more canes per vine would be the best technical cultural management practice to enhances the grape yield in semi-arid tropical conditions. However, under un-unfavorable climatic conditions also more number of canes per vine yields heavy crop but leads to delayed maturity (Tafazoli 1977). Cane diameter had positive significant correlation against summer pruning (r = 0.73), winter pruning (r = 0.55), leaf area (cm^2 ; r = 0.51) and hundred berry weight (r = 0.48). Thicker canes were more productive compared to thinner canes due to better bud burst and high fruit set in grapes (Bowed and Kliewer 1990). It also had positive association with days to 50 % flowering, mean bunch weight, mean bunch length, berry diameter, hear unit requirement. Such correlation between cane diameter and 100 berry weight might have contributed through mean bunch weight and bunch length, an important yield attributes in grape. The shoot length was not significantly correlated against none of the traits under study however, it has positive association with days to bud burst, number of leaves per vine, days to 50 % flowering. This indicates higher the shoot length more will be the number of leaves.

Number of leaves had significant correlation against days to bud burst (r = 0.54) and summer pruning weight and number of canes per vine. Leaf area (cm^2) had significant positive correlation against cane diameter (cm; r = 0.51) and found positively associated with summer and winter pruning. Correlation between pruning weight and leaf area (Smart et al. 1985) may sever as practical indicator for assimilate availability for the grape (Naor et al. 2002). Larger the leaf area more will be the photosynthesis which results in more pruning weight ultimately leading to more vigorous vines. Naor et al. 2002 reported strong correlation between reciprocal of the ratio of leaf area to fruit weight and the ratio of fruit weight to pruning weight, which provides biological rationale for relationship between crop load and wine quality. Among all the traits under study, highly significant correlation was recorded between days to 50 % flowering and heat unit requirement (r = 0.93) and it also had significant correlation against days to bud burst (r = 0.79), berry diameter (r = 0.60), mean bunch weight (r = 0.58), hundred berry weight (r = 0.49) and mean bunch length (r = 0.44).This association between days to 50 % flowering and heat unit requirement indicates selection may be done for earliness based on either days to 50 % flowering or heat unit requirement. The heat requirement may be more scientific and accurate method to categories earliness in grape varieties (Brar et al. 1992). High significant correlation was recorded between number of bunches per vine and number of canes per vine (r = 0.87) and fruit yield (r = 0.50). Mean bunch weight (g) recorded highly significant correlation against mean bunch length (cm; r = 0.92) followed by hundred berry weight (r = 0.73), heat unit requirement (r = 0.62), number of berries per bunches (r = 0.59), days to 50 % flowering (r = 0.58), fruit yield (r = 0.50) and days to bud burst (r = 0.41). Mean bunch weight considered to be an important trait contributes towards fruit yield and quality of grape. Selection based on bunch weight may result in selection of high yielding vines (Branislava Sivcevi et al. 2011).

Mean bunch length (cm) was significantly correlated against number of berries per bunch (r = 0.73), fruit yield (r = 0.64), hundred berry weight (r = 0.50) and heat unit requirement (r = 0.45). Number of berries per bunch had significant correlation with fruit yield (r = 0.71). Whereas, hundred berry weight (g) had significant association with berry diameter (r = 0.66) and heat unit requirement (r = 0.54). Lastly, berry diameter was significantly correlated against heat unit requirement (r = 0.69). Selection of vines based berry weight may result in selection of large berries and *vice-versa* and also helps to determine the earliness of the variety based on size of the berries due to their positive correlation between berry weight, berry diameter and heat unit requirement. Similar findings were reported in grape by Taleb Abu Zahra (2010)

Principal component studies

The principal component analysis revealed the differences among the varieties studied. Thumb rule as suggested by Johnson and Wichern (1988) was used to decide the importance of traits in different components which suggested use of square root of the standard deviation of the Eigen value for the respective principal component as significant or important. The Eigen values represent the variance of the principal component and cumulative per cent of the Eigen values indicates the percent contribution to the total variance attributable to each principal component. The scree plot explains Eigen value, variance in each component as well cumulative per cent of variance by the different principal components. The Eigen value higher than one accounted for 67.15 % of variance which is also the cumulative per cent of variance explained by the first three principal components. The heat unit requirement was significant and exerted high influence in first PC followed by days to 50 % flowering, mean bunch weight, hundred berry weight, berry diameter, days to bud burst, mean bunch length and cane diameter which accounts for 32.94 % variance. Fruit yield significantly dominated the second PC followed by number of berries per bunch representing 19.71 % variance whereas, summer pruning weight, winter pruning weight and numbers of leaves per vine were dominant growth traits in third PC which accounting for 14.85 % variance. The scatter plot was generated for red and white grape varieties for the first two principal components from a principal component analysis of 17 agro-morphological traits were depicted in fig (2). It was revealed that there was no clear distribution pattern separating color and white grape varieties except in the first quadrant where two white varieties Thompson seedless and Italia have got separated and in fourth quadrant three red varieties viz., Gulabi, Athens and Ruby red have been grouped. Such separation of white and colored varieties may be due to distinct and diverse nature of the varieties for different agro-morphological traits. The remaining two quadrant were assembly of white and red grape varieties (Kadu et al. 2007; Joslyn and Amerine 1964).

Cluster Analysis

The Agglomerative hierarchical cluster analysis was performed based on similarity and unweighted pair-group average. The dendrogram (Fig 3) enabled relatively good comparison of different grape varieties and also demonstrated that agro-morphological traits of grape are comparable. Clustering helps to find out association between red and white grape varieties (Patel 1994) as such classification based on agro-morphological traits would be ideal for the breeder to select the parents for taking up sound breeding involving diverse parents. The distribution pattern of different grape varieties in to different clusters was not based on similar geographical origin/collection/colour. Cluster I represented red varieties viz., Zinfandel, Ruby red and Athens. The variety (Zinfandel) recorded highest number of canes per vine and other two varieties Ruby red recorded high summer pruning weight whereas, Athens has high winter pruning weight, as higher the pruning weight, more vigorous will be the grape vine and low pruning weight results in non-vigorous nature of the grape vine. The cluster I recorded highest cluster mean for summer pruning weight (3.50 Kg/vine). Hence, cluster I may be considered as vigorous as it accommodated varieties which have scored highest value for summer and winter pruning weight. Thus, Athens and Ruby red may be considered as vigorous varieties based on their pruning weight (Shikhamany 1983; Fawzi et al. 1984; Satisha and Shikhamany 1999; Benz et al. 2006). Cluster II also encompasses two red varieties viz., Cabernet Sauvignon and Pusa Navrang. The latter may be considered as superior variety in terms of number of bunches per vine an important yield contributing trait in grape. Cluster III found to be diverse as it represented both red (Gulabi and Bangalore blue) and white varieties (Symphony and Sauvignon Blanc) of grape and it is the largest (total four varieties) among the five clusters under study. The cluster III recorded highest mean for leaf area and also early bud burst mean was recorded. Cluster IV accommodated one red and (Shiraz) white variety (Chenin Blanc) each which are well adapted and superior in terms of berry yield (Kg/vine). The cluster IV recorded highest cluster mean for winter pruning weight (1.77 kg/vine), number of canes per vine (54.41), number of berries per vine (105.76), fruit yield per vine (15.14 kg/vine). This cluster may be considered as important from economic and breeding point of view, as it recorded highest cluster mean for yield and yield attributes. Cluster V represents two white varieties (Thompsons seedless and Italia).Cluster V recorded highest cluster mean for cane diameter (71.13), shoot length (68.44), mean bunch weight (319.70),mean bunch length (17.45) number of berries per bunch (80.80), hundred berry weight (368.67) and berry diameter (15.58). This cluster recorded highest mean for most of the yielding attributing traits. Crosses involving cluster IV with cluster I and V having favorable attributes such vigorous vine, traits contributing to yield and yield attributes may help to evolve varieties with broader genetic base with better yield and adaptability to semi-arid tropical conditions of peninsular India. Further, grape breeder should focus on the stable yield, good quality grapes which can yield fine quality of wine upon processing and adaptability to particular soil and climatic conditions that are characteristics of particular geographical region and climatic condition (Alleweldt 1970).

GCV, PCV, Heritability and Genetic Advance studies

Analysis of phenotypic and genotypic variability identifies nature and extent of variation that can be attributed to different causes, sensitive nature of the crop to environmental influences, heritability of the traits and genetic advance that can be realized in practical crop improvement programme evolving varieties to various environmental conditions. Perusal of the data in table () shows differences between phenotypic coefficient of variation and genotypic coefficient of variation for all the agro-morphological traits under study. This indicates presence of greater environmental influence on expression of all these traits and selection may not be effective in the improvement grape. The grape varieties under study have higher phenotypic coefficient of variation than corresponding genotypic coefficient of variation indicating the dominance of environment over genotype in expression of traits under study. However, there was narrow difference between PCV and GCV for traits viz., days to bud burst, days to 50 % flowering, mean bunch weight, hundred berry weight, berry diameter and fruit yield. This indicates less influence of environment and more contribution from genotype on expression of these traits. The high degree of difference between GCV and PCV was observed for winter pruning weight (5.18) followed by summer pruning weight, number of leaves per vine and heat unit requirement indicates dominance of environment on the expression of these traits. The estimation of GCV itself does not helps to determine the extent of heritable variation. Therefore, estimation of heritability indicates effectiveness with which selection may be expected to exploit the genetic variability. The observed variability among the grape varieties for different agro morphological traits is combined estimation of genetic as well as environmental causes, where genetic variability alone is heritable. The genetic variability is heritable from generation to generation. Hence, heritability and genetic advance is a useful tool for breeders in determining the direction and magnitude of selection. The yield and yield attributes are polygenic in nature and are subjected to different degree of non-heritable variation (Lush 1940; Sivcev et al. 2000). The effective selection depends upon genetic variability and the extent to which variation is heritable. Therefore, heritable is an indication of magnitude of inheritance of quantitative traits, whereas, genetic advance aids in formulating suitable selection procedure. Therefore, heritability along with genetic advance plays crucial role in determining the effective of selection (Johnson et al. 1955). Heritability estimates gives a measure of transmission of characters from one generation to the next and the consistency in the performance of progeny in succeeding generations and depends mainly on the magnitude of heritable portion of variation. Heritability estimates of quantitative characters play an important role in expressing the reliability of variance value as a selection guideline to the plant breeder during the succeeding generations. Mean bunch weight (99.90 %), days to bud burst (99.24 %) and hundred berry (98.85 %) are the important traits in grape which have expressed high heritability signifying high potential for improvement of grape through selection. The heritability will be more effective and meaningful when accompanied by genetic advance and genetic advance as per cent of mean (Johnson 1955). The genetic advance as per cent of mean was high for mean bunch weight (108.69 %) and winter pruning weight (86.06 %) followed by summer pruning weight (83.11 %). The mean bunch weight, an important yield attribute has high heritability and high genetic advance as per cent mean, indicating that mean bunch weight in grape was under the strong influence of additive gene action (Panse 1957) and hence simple selection of grape varieties based on their performance in semi-arid tropical environment would be more effective.

CONCLUSION

Based on agro morphological traits it was found that among red varieties, Shiraz and Italia among white may be considered as vigorous varieties based on their respective pruning weights. Based on bud burst, the varieties can be classified in to early (Pusa Navrang Bangalore, Chenin Blanc and Gulabi), mid (Sauvignon Blanc, Symphony, Shiraz, Zinfandel, Italia and Cabernet Sauvignon) and late (Ruby Red, Thompson Seedless and Athens) bursting varieties. However, Chenin Blanc, Italia, Shiraz, Thompson Seedless and Pusa Navrang considered to high yielders and suitable for cultivation under semi-arid tropical conditions.

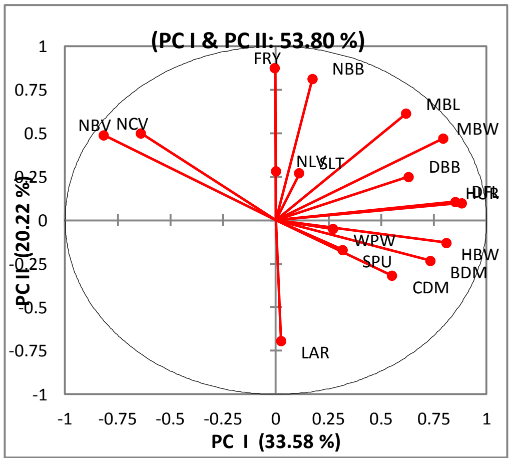

Figure 1. Principal component biplot for colored and white grape varieties using 17 agro-morphological traits

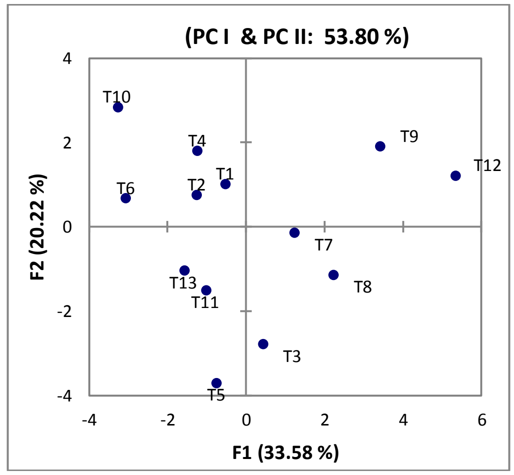

Figure 2. Scatter plot for colored and white grape based on 17 agro-morphological traits

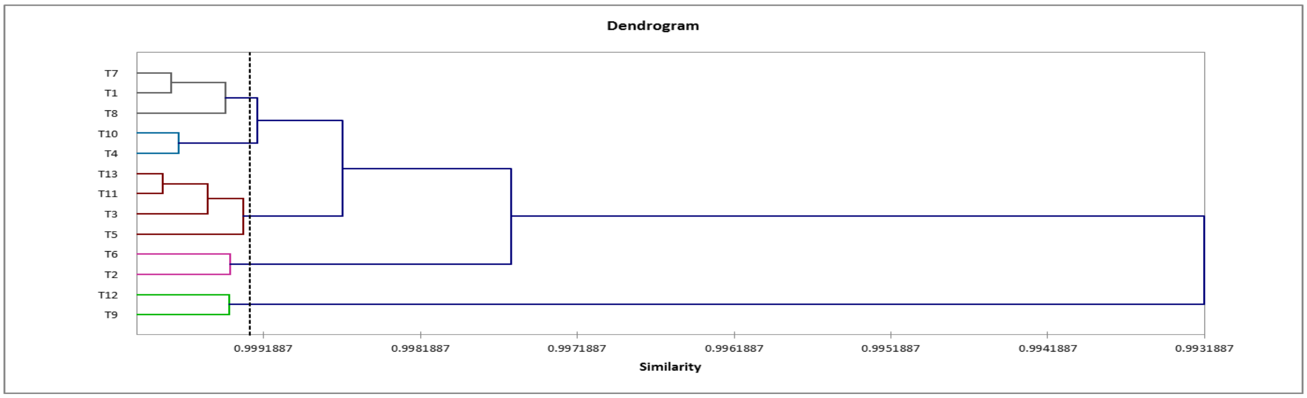

Figure 3. Hierarchical clustering of colored and white varieties of grape grown under semi-arid tropical conditions

Table 1. ANOVA for Agro-morphological traits of Grape

	C.D.	SE(m)	SE(d)	C.V.	P value
SPU	0.914	0.293	0.415	14.03	0.004
WPW	0.653	0.21	0.296	22.55	0.030
DBB	0.746	0.24	0.339	2.476	0.001
NCV	5.109	1.64	2.319	5.56	0.005
CDM	1.68	0.539	0.762	4.929	0.002
SLT	6.118	1.964	2.777	4.142	0.001
NLV	3.953	1.269	1.794	10.7	0.008
LAR	9.39	3.014	4.262	6.204	0.001
DFL	2.625	0.843	1.192	3.367	0.002
NBV	12.49	4.008	5.668	8.441	0.001
MBW	5.313	1.706	2.412	1.615	0.001
MBL	1.998	0.641	0.907	8.61	0.001
NBB	8.9	2.857	4.04	6.542	0.001
HBW	18.19	5.838	8.257	3.469	0.001
BDM	1.382	0.444	0.627	4.515	0.001
FRY	1.581	0.507	0.718	7.652	0.001
HUR	197.5	63.38	89.63	4.645	0.076

SPU: Summer pruning weight (kg/vine); WPW: Winter pruning weight (kg/vine); DBB: Days taken for bud break; NCV: Number of canes per vine; CDM: Cane diameter (mm); SLT: Shoot length (cm); NLV: Number of leaves per vine; LAR: Leaf area (cm2); DFL: Days to 50 % flowering; NBV:Number of bunches per vine; MBW: Mean bunch weight (g); MBL: Mean bunch length (cm); NBB:Number of berries per bunch; HBW:Hundred berry weight (g);BDM:Berry diameter (mm); FRY: Fruit Yield (kg/vine); HUR: Heat Unit requirement

Table 2.Pooled data for range and mean values for colored and white grape varieties for different agro-morphological traits

	SPU	WPW	DBB	NCV	CDM	SLT	NLV	LAR	DFL	NBV	MBW	MBL	NBB	HBW	BDM	HUR	FRY
Treatments																	
T 1 (Zinfandel)	1.03	0.46	15.17	38.00	10.94	65.33	14.5	46.3	36.33	70.47	149.3	10.77	67.83	218.1	15.28	9.91	1,907.37
T 2 (Cabernet Sauvignon)	1.78	0.88	15.87	47.95	12.66	72.66	14	59.37	38.23	87.75	88.06	9.03	65.33	135.2	14.03	7.72	2,031.64
T 3 (Gulabi)	3.11	1.4	10.1	35.03	16.73	77	12.83	66.5	35.93	45.7	89.6	7.56	31.73	281.2	16.51	4.945	1,881.68
T 4 (Shiraz)	4.94	2.76	14.00	54.93	15.47	65.5	21.5	61.53	34.55	97.75	127.6	12.33	63.77	187.7	11.63	13.48	1,859.70
T 5 (Bangalore blue)	3.41	1.64	8.49	34.61	16.88	53.33	9.83	112.5	27.63	54.83	104.9	8.865	39.95	275.6	13.65	6.03	1,815.79
T 6 (Pusa Navrang)	2.63	0.91	8.15	44.26	16.35	61.97	14.5	82.57	25.36	95.53	116.2	11.08	87.17	123.2	10.75	10.78	1,726.25
T 7 (Athens)	5.23	2.215	16.22	44.35	16.95	79.17	22.33	72.13	37.98	60.48	154.9	9.5	57.43	251.4	14.63	8.61	1,989.73
T 8 (Ruby Red)	4.26	1.33	21.22	39.11	18.15	60.67	23.66	91.95	43.4	46.27	136.6	9.115	63.21	210.8	15.22	6.745	2,119.97
Mean	3.3	1.45	13.65	42.3	15.51	66.95	16.64	74.1	34.92	69.84	120.9	9.78	59.55	210.4	13.96	8.52	1,916.51
Range	4.2	2.3	11.7	20.32	7.11	18.5	13.83	66.2	18.04	52.05	66.84	4.77	55.34	158	5.76	8.54	393.72
T 9 (Thompson seedless)	1.94	1.165	17.95	32.91	15.67	75.13	18	70.93	43.57	37.27	307.8	17.9	82.75	323.1	13.25	11.53	2,040.17
T 10 (Chenin Blanc)	2.03	0.78	9.85	53.9	13.83	69.34	18.5	42.21	26.25	113.8	138.3	10.1	69.35	198.5	12.15	16.82	1,764.12
T 11 (Sauvignon Blanc)	2.23	0.645	11.57	42.03	14.51	65.33	18.67	64.78	38.03	51.6	98.83	6.665	44.41	233.3	12.23	4.51	1,926.52
T 12 (Italia)	3.73	1.665	15.37	34.4	18.6	61.78	11.83	51.47	44.37	38.75	331.6	17	78.85	414.2	17.94	13.53	2,207.47
T 13 (Symphony)	2.11	1.23	13.97	40.73	14.38	64.34	17.83	70.93	28.55	72.72	98.38	7.045	51.03	241.7	13.38	7.315	1,816.30
Mean	2.4	1.09	13.73	40.8	15.39	67.18	16.96	60.06	36.15	62.82	195	11.74	65.27	282.2	13.78	10.74	1,950.91
Range	1.79	1.02	8.1	21	4.77	13.35	6.84	28.72	18.12	76.53	233.2	11.24	38.34	215.7	5.79	12.31	443.35
Grand Mean	2.95	1.31	13.68	41.7	15.46	67.03	16.76	68.7	35.39	67.14	149.4	10.53	61.75	238	13.89	9.37	1,929.74

Table 3. Genetic parameters for colored and white grape varieties grown under semi-arid tropical conditions

Traits	PCV	GCV	Heritability (%)	GA	GA (as % mean)
SPU	44.745	42.489	90.174	2.458	83.117
WPW	51.629	46.442	80.918	1.131	86.06
DBB	28.424	28.316	99.241	7.952	58.11
NCV	17.719	16.824	90.152	13.725	32.907
CDM	14.487	13.623	88.424	4.082	26.389
SLT	11.331	10.547	86.64	13.558	20.223
NLV	26.417	24.152	83.587	7.626	45.487
LAR	28.009	27.313	95.094	37.697	54.868
DFL	18.862	18.56	96.814	13.316	37.619
NBV	37.504	36.542	94.934	49.247	73.345
MBW	52.815	52.79	99.906	162.38	108.697
MBL	33.437	32.309	93.37	6.775	64.313
NBB	27.264	26.468	94.243	32.686	52.93
HBW	32.362	32.175	98.85	156.831	65.898
BDM	14.885	14.184	90.799	3.868	27.841
HUR	8.057	6.584	66.774	213.878	11.083
FRY	39.947	39.208	96.331	7.434	79.272

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