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African Journal of Agricultural Research

Full Length Research Paper

Evaluation of morphological and quality characteristics of introduced grape cultivars produced under greenhouse conditions in Kenya

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Grape production in Kenya is low and the country imports approximately 4,000 metric tons of wine every year. Three Chinese table grape cultivars (Jingyan, Jingxiangyu and Jingcui) and two Chinese wine grape cultivars (Beihong and Beifeng) as well as three French hybrid wine grape cultivars (Chenin Blanc, Sauvignon Blanc and Cabernet Sauvignon) were evaluated for fruit morphology (berries and bunches) and quality characteristics (Total Soluble Solids, Titratable Acidity, pH and sensory parameters) in 2018/2019 using International Organization for Vine and Wine descriptors and Economic Co-operation and Development procedure for fruit and vegetables respectively. All vines within the row were planted at a spacing of 0.9 and 1.6 m between the rows in a completely randomized design with three vines per replication and four replications for each cultivar. Collected data were subjected to ANOVA. Jingyan and Jingxiangyu had significantly bigger berries and higher bunch weight than all the other cultivars. The TSS of the grapes cultivars ranged from 16.3 to 25.2 °Brix. Beihong and Beifeng had higher TTA levels of 25.7 and 21.2 g/L respectively. Sensory data showed that Jingyan and Jingxiangyu were the most preferred cultivars. All the cultivars had ideal TSS and pH for winemaking and elaboration.

Key words: Grapes, cultivar, morphology, quality, greenhouse.

INTRODUCTION

Grapes belongs to the genus *Vitis* and family *Vitaceae* and they are believed to have originated from the Caucasian and Caspian regions (FAO, 2017). On a large scale, the genus Vitis is widely used wine and dessert due to their health benefits (Ivanova-Petropulos et al., 2015). Grapes have resveratrol (stilbenes belonging to a non- flavonoid group of phenolic compounds) which has antiviral, anticancer, antiaging, life-prolonging, anti-inflammatory and neuroprotective effects (Kundu and Surh, 2008; Stojanović et al., 2001). Grape also is a rich source of potassium and fibre which improves cardio-vascular health and blood pressure. High potassium

intake is associated with the preservation of bone mineral density, protection against loss of muscle mass and reduced risk of stroke (Ware, 2017). Global consumption of fresh table grapes has been on the rise since 2009/2010 with consumption rising from 15.6 to 20.9 million tons in 2015 (FAS, 2015). In Kenya, grapes are utilized in winemaking, table grapes as well as raisins in the confectionary industry (HCD, 2014). The country spends millions of dollars on importing both fresh and dried grapes as well as wine brands (HCD, 2014). In 2017, Kenya imported 3,000 metric tons of grapes and 4,000 metric tons of wine (KNBS, 2017).

Grapes production in Kenya has been low due to insufficient locally adapted varieties and farmers technical know-how. Additionally, no research has been carried out in this country to understand the crop morphology or breed for locally adapted varieties. Grapes display an array of morphological characteristics which include pigmentation, growth habits, seed shape and flower colour. Morphological characterization is vital for conservation, commercialisation and breeding of new cultivars (Laurentin, 2009; Ocampo et al., 2006; Collard et al., 2005). Table grape quality is determined by the interplay of several metabolites including organic acids (tartaric and malic), total soluble sugars (glucose and fructose) and titratable acidity (Pereira et al., 2006; Dokoozlian, 2000). The composition and content of organic acids and sugars in grape berries determine the wine quality, stability and flavour, as well as the organoleptic quality of table grapes (Shiraishi et al., 2010; Rusjan et al., 2008). Organic acids are responsible for the tart taste in grapes and they influence wine colour, stability and pH. Malic and tartaric acids account for more than 90% of the total acids (Ninio et al., 2003). Sugars (glucose and fructose) in the berry are responsible for the sweetness of table grapes and raisins (Jackson, 2014). Sugars and organic acids are also important in the selection and breeding of new cultivars (Liu et al., 2007). The objective of this study was to evaluate the morphological and quality characteristics of three Chinese table grape cultivars, two Chinese wine grape cultivars and three French hybrid wine grape cultivars as a prerequisite for grapes breeding in Kenya.

MATERIALS AND METHODS

Experimental site

The study was carried out in a greenhouse at JKUAT main campus situated in Juja Sub-County (1°5'35.93"S, 37°0'46.31"E and 1525 m above sea level), 36 km Northeast of Nairobi, Kenya in 2018/2019.

Grape cultivars used for this study

Three Chinese table grape cultivars (Jingyan, Jingxiangyu and Jingcui) and two Chinese wine grapes cultivars (Beihong and Beifeng) introduced from the Institute of Botany, Chinese Academy of Science as well as three French hybrids (Chenin Blanc, Sauvignon Blanc and Cabernet Sauvignon) collected from Yatta

Complex Centre were evaluated for morphological and fruit quality characteristics. The Chinese grape cultivars were introduced and grown for adaptation in Kenya in 2015 while the French hybrids were introduced in 1995.

Experimental design

All vines within the row were planted at a spacing of 0.9 and 1.6 m between the rows in May 2018. The design was completely randomized with three vines per replication and four replications for each cultivar. Training, pruning, watering, fertilization, pest and disease control were carried out as described by Strik (2011).

Fruit morphological analysis

Morphological characteristics that were analysed included the type of flower, berries, bunches and yield. The characteristics were observed and described using the International Organization of Vine and Wine (OIV) descriptors (Table 1) from November 2018 to March 2019. Each characteristics had an OIV code and a number representing their reading. The berries and bunches were morphologically evaluated when the berries attained full veraison (change of skin colour from green to purple for Beihong and Beifeng, red for Jingyan and golden yellow for Jingxiangyu, Chenin Blanc and Sauvignon Blanc. For bunch morphological evaluation, ten bunches per cultivar were selected. For berry morphological evaluation, ten berries per bunch were selected randomly from the ten selected bunches. For yield evaluation, average bunch weight of 10 largest bunches per cultivar was recorded at the time of harvest with the help of a weighing balance and used to estimate the yield (kg) ha^{-1} (OIV, 2009).

Fruit quality analysis

Total soluble solids (TSS)

The TSS was determined as described by OECD (2005). The % brix was determined using handheld refractometer (N1, Atago CO.LTD Tokyo, Japan). Three drops of homogenized grape juice were placed on the prism of the refractometer which had been calibrated and the lid closed. The TSS content was then read on the scale to one decimal place a 20 ± 2°C while held close to the eye. This test was replicated three times. After each reading, the refractometer prism was cleaned with distilled water and dried with soft tissue paper (serviette).

Total titratable acidity (TTA)

The TTA was determined as described by OECD (2005). Thirty berries of each cultivar were crushed using a mortar and pestle. The pulp was then squeezed using a muslin cloth to extract the juice into a beaker after which it was filtered to obtain a homogenized extract using a filter paper. A pipette was used to draw 10 ml of the extract and discharged in a 250 ml beaker. Another clean pipette was used to draw 50 ml of distilled water and added to the juice in the beaker. Three drops of 1% phenolphthalein indicator were then added. The solution was titrated against 0.1N NaOH until a permanent pink colour was achieved. This procedure was replicated three times. The results were expressed as g/L of tartaric acid which is the organic acid in grapes. The following formula was used:

TA g/L = (ml NaOH x N (NaOH) x acid meq. factor x 100)/ ml juice titrated   (1)

Table 1. List of morphological characters used in this study.

Characters	OIV Code No.	Unit of measure
Flower sexual organ	151	N/A
Bunch: length (peduncle excluded)	202	Mm
Bunch width	203	mm
Bunch density	204	N/A
Bunch shape	208	N/A
Bunch: number of wings of the primary bunch	209	N/A
Berry: length	220	Mm
Berry: width	221	Mm
Berry: uniformity of size	222	N/A
Berry: shape	223	N/A
Berry: colour of skin	225	N/A
Berry: firmness of flesh	235	N/A
Berry: ease of detachment from pedicel	240	N/A
Single bunch weight	502	grams
Single Berry weight	503	grams

Source: OIV (2009).

pH

The pH was measured using a pH meter (PHM-2000, TOKYO RIKAKIKAI CO. LTD Tokyo, Japan) at room temperature (23 ± 2°C). The standardization of pH-meter was done with pH buffer solution 4.0, the electrode rinsed in distilled water and then standardized using an alkaline buffer of 7.0. The pH of the grape juice was then measured and the procedure was replicated three times.

Sensory parameters

Sensory evaluation was carried out by 35 untrained panellists (17 males and 18 female) aged 24 to 60 years from the Department of Horticulture and Food Security. Un-deformed mature berries of each of the harvested cultivars were presented to the panellists to rate their preference for sweetness, sourness, crispness, flavour, colour and skin toughness on a 9-point hedonic scale (Jayasena and Cameron, 2008; Lawless and Heymann, 2010). Water was provided to the panellists to rinse their mouth after each sample evaluation under a well-lit room (Santillo et al., 2014).

Statistical analysis

Morphological and fruit quality data were subjected to SPSS Version 25 for windows to assess the analysis of variance (ANOVA) between the cultivars. The difference among the treatments was tested by a multiple mean comparison test (HSD Tukey) at a significance level of $p < 0.05$ (IBM, 2018). Each value of the mean and standard error in the tables represented three replicates of each treatment.

RESULTS AND DISCUSSION

Morphological characteristics

Among the eight selected cultivars for evaluation, six cultivars (Jinyang, Jingxiangyu, Beihong, Beifeng, Chenin Blanc and Sauvignon Blanc) yielded berries (Figure 1). The results of morphological characteristics of Jinyang, Jingxiangyu, Beihong, Beifeng, Chenin Blanc and Sauvignon Blanc are presented in Table 2.

Jingyan and Jingxiangyu had longer bunches compared to the other cultivars. This is an important characteristic since the berries have room for expansion thereby increasing in size and weight. Short bunches tend to have compacted berries which reduces room for berry expansion thereby leading to a smaller/narrow berries as exhibited by Sauvignon Blanc, Chenin Blanc and Beihong. Jingyan and Jingxiangyu showed broad ellipsoid berry shape while the other four cultivars showed globose berry shape. All the cultivars were conical in shape and their berries were uniform in size. These two characteristics make the grapes suitable for commercialization. Salimov et al. (2017), states that berry uniformity is among the most important factors that influence the trade appearance of grapes. Jingyan had red rose colour, Jingxiangyu, Chenin Blanc and Sauvignon Blanc had green-yellow colour while Beihong and Beifeng had blue-black colour. This is as a result of different phenolic compounds within the grape skins. Grapes skin colour is controlled by anthocyanin influences the quality of juice, wine and the market value of table grapes (Liang et al., 2008).

Yield estimates

The estimated yields of the six cultivars are presented in Table 3. Beifeng had three clusters, Beihong had two clusters and the other four cultivars had only one cluster
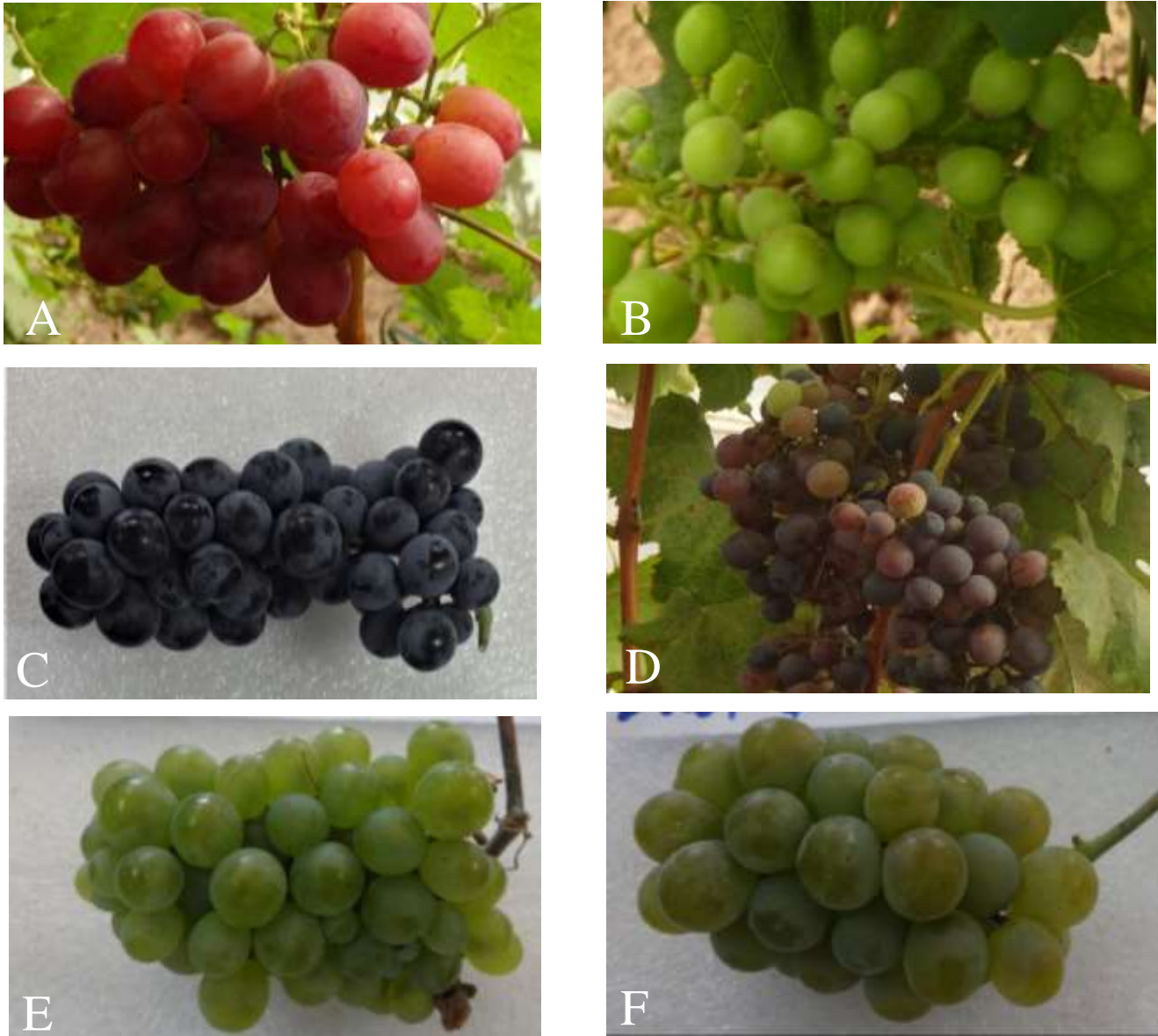
Figure 1. Grapes cultivars used in this study. (A) Jingyan, (B) Jingxiangyu, (C) Beihong, (D) Beifeng, € Chenin Blanc and (F) Sauvignon Blanc.

per vine (Table 3). Berry weight was highest in Jingxiangyu (7.64 g) followed by Jingyan (6.82 g) and lowest in Beifeng (1.41 g). Cluster weight was significantly different with Jingxiangyu having the highest cluster weight (440.8 g) and Beihong, Sauvignon Blanc and Chenin Blanc had the lowest cluster weights (181.3, 154.8 and 145.6 g respectively). Yield (g) per vine was highest in Beifeng (788 g) followed by Jingxiangyu (441 g). When the yield per plant was extrapolated to represent yield per hectare, Beifeng had the highest yield per hectare while Chenin Blanc had the lowest yield hectare. Similarly, Walker et al. (2005), reported that cluster and berry weight influences the overall yield of grapevines.

Principal component analysis

From the results of morphological characteristics, Principal Component Analysis resulted in two principal components (Figure 2) that had Eigenvalues greater than 1 (Table 4). These principal components explained more than 85% of the morphological variability for both subsets. The first principal component comprised characteristics associated with bunch length (OIV, 202), bunch density (OIV, 204), bunch shape (OIV, 208), number of wings of the primary bunch (OIV, 209), berry uniformity of size (OIV, 222), berry shape (OIV, 223), berry firmness of flesh (OIV, 235) and berry ease of detachment from the pedicel (OIV, 240) which accounted

Table 2. Morphological characters of the six grape cultivars used in this study.

Characters/Cultivar	Jingyan	Jingxiangyu	Beifeng	Beihong	Chenin Blanc	Sauvignon Blanc
Flower sexual organ	3:fully developed stamens and gynoecium	3: fully developed stamens and gynoecium	3: fully developed stamens and gynoecium	3: fully developed stamens and gynoecium	3: fully developed stamens and gynoecium	3:fully developed stamens and gynoecium
Bunch length	7: long about 200 mm	7: long about 200 mm	5: medium about 160 mm	5: medium about 160 mm	3: short about 120mm	3: short about 120mm
Bunch width	3: narrow about 80 mm	3: narrow about 80 mm	5: medium about 120 mm	3: narrow about 80 mm	3: narrow about 80 mm	3: narrow about 80 mm
Bunch density	5: medium	5: medium	1: very loose	7: dense	7: dense	7: dense
Bunch shape	2: conical	2: conical	2: conical	2: conical	2: conical	2: conical
Bunch number of wings of the primary bunch	1: absent	1: absent	3: 3 – 4 wings	1: absent	1: absent	1: absent
Berry length	5: medium	5: medium	3: narrow	3: narrow	3: narrow	3: narrow
Berry width	5: medium	5: medium	3: narrow	3: narrow	3: narrow	3: narrow
Berry uniformity of size	2: uniform	2: uniform	2: uniform	2: uniform	2: uniform	2: uniform
Berry shape	3: broad ellipsoid	3: broad ellipsoid	2: globose	2: globose	2: globose	2: globose
Berry colour of skin	2: rose	1: green yellow	6: blue black	6: blue black	1: green yellow	1: green yellow
Berry firmness of flesh	2: slightly firm	2: slightly firm	1: soft	1: soft	1: soft	1: soft
Berry ease of detachment from pedicel	2: easy	3: difficult	2: easy	3: difficult	2: easy	2: easy
Single bunch weight	5: medium: about 500 g	5: medium: about 500 g	3: low: about 300 g	3: low: about 300 g	3: low: about 300 g	3: low: about 300 g
Single berry weight	7: high	7: high	3: low	3: low	1: very low	1: very low

for 66.10% of the variation. The second principal component comprised characteristics associated with bunch width (OIV, 203), single bunch weight (OIV, 502), berry length (OIV, 220), berry width (OIV, 221) and single berry width (OIV, 503) which accounted for 19.87% of the variation.

Fruit qualities

Fruit quality results are presented in Table 5.

Total soluble solids (TSS)

TSS of all the grape cultivars ranged from 16.3 to 25.2% (Table 5) which is greater than the recommended TSS level of 16% for grapes to be considered ripe (FAO, 2007). Jingyan and Jingxiangyu had higher TSS levels (18.4 and 22.0% respectively) as compared to their counterparts produced under open field environment in China which had TSS of 15 to 17% as reported by Jiazi, (2014). The TSS level is a quality trait for grapes that directly affect consumer preference for table grapes. Additionally, wine grapes with high TSS levels are preferred, as it is the TSS level that determines the alcohol content of most wines (Liu et al., 2006). Grapes sugar levels also affect wine quality as it is a substrate for yeast fermentation (Xin et al., 2013). Therefore, Jingyan and

Jingxiangyu are considered suitable for fresh consumption while Beihong, Beifeng, Chenin Blanc and Sauvignon Blanc are considered suitable for wine processing.

Total titratable acidity (TTA)

Based on the results obtained (Table 5), Jingxiangyu, Jingyan and Sauvignon Blanc had ideal TTA levels of 6.32, 7.33 and 7.25 g/L respectively suitable for winemaking. The ideal TTA range for the production of well-balanced wine is 2- 10 g/L (Puckette, 2015). At TTA of 2 g/L, the wine tastes flat and at TTA of 10 g/L, the wine tastes tart. Organic acids are responsible

Table 3. Yield estimates of six grapes cultivars, Jingyan, Jingxiangyu, Beifeng, Beihong, Chenin Blanc and Sauvignon Blanc raised in a greenhouse in Kenya.

Treatment	Cluster no vine⁻¹	Cluster wt. (g)	Berry wt. (g)	Yield (g vine⁻¹)	kg ha⁻¹*
Jingyan	1^c	395.6^b	6.82^b	396^c	2,750
Jingxiangyu	1^c	440.8^a	7.64^a	441^b	3,062
Beihong	2^b	181.3^d	2.45^c	363^c	2,518
Beifeng	3^a	262.8^c	1.46^d	788^a	5,475
Chenin Blanc	1^c	145.6^e	2.51^c	146^d	1,014
Sauvignon Blanc	1^c	154.8^e	2.58^c	155^d	1,076

The data are expressed as means and the treatments mean followed by the same letters in the same column are not significantly different (p≤ 0.05) (Zare et al., 2015).
*Assuming 6944 plants per hectare at 1.6 in row spacing and 0.9 m between rows. Data were not statistically analysed.
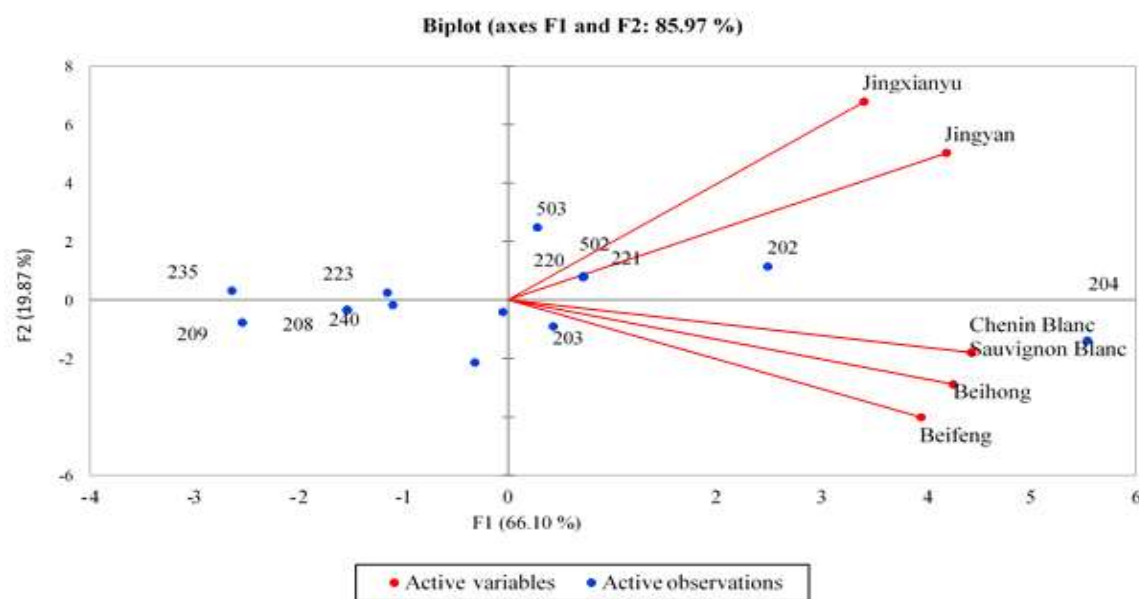
Figure 2. Principal component analyses of the morphological characters evaluated for the six cultivars used in this study.

for the tart taste in grapes and they influence wine colour, stability and pH (Rusjan et al., 2008). Beihong and Beifeng had higher TTA values of 25.7 and 21.2 g/L, respectively. These values are higher than their counterparts cultivated in the field in China with a TTA value range of 6.5- 9.2 g/L (Jiazi, 2014). Therefore, TTA adjustments would be required in order to enhance the stability of the wine made from the two cultivars. Debolt et

Table 4. Estimate of eigenvalues and cumulative variances of the first two principal components (f1, f2) of morphological characters used in this study.

	Eigenvalue	Variability (%)	Cumulative %
F1	3.97	66.10	66.10
F2	1.19	19.87	85.97

Table 5. Fruit quality characteristics of the six grapes cultivars; Jingyan, Jingxiangyu, Beifeng, Beihong, Chenin Blanc and Sauvignon Blanc used in this study.

Treatment	TSS (°Brix)	TTA (g/L)	pH	Sweetness	Sourness	Crispness	Flavour	Skin toughness	Colour	Overall acceptability
Jingyan	18.4±0.18[c]	7.33±0.08[d]	3.15±0.03[d]	6.63±0.37[a]	5.85±0.45[a]	6.74±0.24[a]	6.63±0.31[a]	6.37±0.33[a]	7.15±0.29[a]	6.93±0.33[a]
Jingxiangyu	22.0±0.17[b]	6.32±0.06[e]	3.42±0.02[b]	7.30±0.29[a]	5.59±0.46[ab]	6.63±0.31[ab]	6.04±0.36[a]	6.59±0.32[a]	5.37±0.44[b]	6.81±0.35[a]
Beihong	16.3±0.18[d]	25.7±0.17[a]	3.07±0.02[d]	3.41±0.41[b]	3.89±0.48[b]	4.85±0.37[c]	4.56±0.36[b]	3.89±0.43[bc]	6.33±0.41[ab]	4.04±0.47[c]
Beifeng	18.3±0.09[c]	21.2±0.09[b]	3.28±0.01[c]	3.96±0.39[b]	4.04±0.49[ab]	4.96±0.28[c]	4.22±0.29[b]	4.41±0.32[c]	6.15±0.40[ab]	4.37±0.45[bc]
Chenin Blanc	21.2±0.29[b]	10.50±0.13[c]	3.15±0.01[d]	6.26±0.33[a]	5.26±0.42[ab]	5.41±0.34[bc]	5.96±0.29[a]	5.41±0.35[ab]	4.85±0.41[b]	5.59±0.43[abc]
Sauvignon Blanc	25.23±0.21[a]	7.25±0.03[d]	3.55±0.02[a]	7.33±0.21[a]	4.59±0.49[ab]	5.78±0.25[abc]	6.44±0.29[a]	4.74±0.37[bc]	5.04±0.46[b]	5.93±0.47[ab]

The data are expressed as means ± standard error of the mean and the treatments means followed by the same letters in the same column are not significantly different (p≤ 0.05).

al. (2007), reported that grapes suitability for wine making is dependent on a sufficient and harmonic content of organic acids.

pH

The pH range of all the cultivars ranged from 3.07 to 3.55 (Table 5) which is ideal for winemaking. White wines require a pH range of 3.1 to 3.4 and red wine a pH of 3.5 to 3.6 for quality wine elaboration (MoreFlavor Inc, 2012; Jackson, 2008). A pH value higher than 3.6 is usually undesirable as it causes a low intensity of colour, impairs microbial stability, increases susceptibility to oxidation and raises the spoilage potential of the wine produced (Grapevines, 2010). Thus, the fruits of all wine cultivars that we evaluated under greenhouse conditions in this study namely, Beifeng, Beihong, Chenin Blanc and Sauvignon

Blanc had ideal pH for processing into wine.

Sensory properties

Introduced French hybrid wine grapes (Chenin Blanc and Cabernet Sauvignon) were highly preferred in regards to sweetness compared to the introduced Chinese wine grape cultivars (Beihong and Beifeng). This can be attributed to their high TSS value of more than 20 °Brix. The introduced Chinese table grapes (Jingyan and Jingxiangyu) had no significant difference in regards to sweetness and therefore, their preference was equal. In regards to sourness, Beihong was the sourest while Jingyan was the least sour. The results concur with the overall acceptability where Beihong was the least acceptable cultivar and Jingyan was most acceptable among all the cultivars evaluated. The

sensory quality of grapes greatly depend on the composition and content of acids and sugars and these properties are important factors when selecting new cultivars (Liu et al., 2007). Jingyan was the most preferred cultivar in regards to crispness while Beihong and Beifeng were the least preferred. The results concur with the evaluated morphological traits of berry firmness of fresh for this study where Jingyan was characterized as slightly firm while Beifeng and Beihong as soft (Table 2). Crispness is a major sensory quality characteristic of table grapes according to consumer preference and cultivars with crisp flesh texture are highly considered for table grape breeding (Sato et al., 2006; Sato and Yamada, 2003). The flavour of French hybrid wine grape cultivars was most preferred as compared to the introduced Chinese wine grape cultivars. The introduced Chinese table grape cultivars rated equally with the French hybrid wine grape

cultivars in reference to the flavour. Flavour is one of the most distinct qualities for maintaining a continuous consumer preference in the fresh fruit market of which table grapes must possess (Muñoz-Robredo et al., 2012; Baldwin, 2002). Therefore, French hybrid wine grapes can be considered for the fresh fruit market together with the introduced Chinese table grape cultivars. In reference to the toughness of skin, Jingyan and Jingxiangyu were the most preferred cultivars and Beifeng was the least preferred. Jingyan stood out to be the most preferred cultivar for fruit colour.

Conclusion

This study revealed that Jingyan, Jingxiangyu, Beifeng, Beihong, Chenin Blanc and Sauvignon Blanc had adapted well to greenhouse conditions in Kenya. This is because they were productive under greenhouse conditions, unlike Jingcui and Cabernet Sauvignon which remained vegetative over the entire season. Based on the findings of this study, Jingyan, Jingxiangyu, Beifeng Beihong, Chenin Blanc and Sauvignon Blanc grape cultivars had superior morphological and fruit quality characteristics. All the introduced wine cultivars had ideal quality characteristics for winemaking while the quality characteristics of Jingyan, Jingxiangyu, Chenin Blanc and Sauvignon Blanc revealed that these cultivars are suitable as desserts. These findings will be useful for breeders in the selection of best-performing cultivars for commercialization and/or further research based on high yields and fruit qualities. More research is needed to evaluate the factors hindering Jingcui and Cabernet Sauvignon productivity under greenhouse conditions in Kenya.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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