EVALUATION OF MORPHOLOGICAL CHARACTERISTICS AND YIELD OF INTRODUCED CHINESE & FRENCH GRAPES CULTIVARS IN KENYA

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Evaluation of Morphological Characteristics and Yield of Introduced Chinese & French Grapes Cultivars in Kenya

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DECLARATION

This thesis is my original work and has not been presented for a degree at any other University.

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DEDICATION

To my beloved mother Mrs. Jecinta Wambui Karuru and my sister Ms. Judy Njeri for their unending love, support, and encouragement. God bless you.

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ABSTRACT

Consumption of table and wine grapes (*Vitis vinifera*) in Kenya has increased in the recent past due to increase in the number of urban residents and expatriate communities with higher disposable income. Grapes are a good source of nutritious fruits as well as income for farmers. Grape production in Kenya is low and the country imports approximately 4,000 metric tons of wine every year. The objective of the study was to evaluate the morphological and quality characteristics of eight grape cultivars under greenhouse conditions. 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 season using International Organization for Vine and Wine descriptors and Economic Co-operation and Development procedure for fruit and vegetables. All vines within the row were planted at a spacing of 0.9 m 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 analysis of variance using SPSS to assess mean differences Pearson correlation coefficient among the cultivars. The grapes cultivars varied significantly with respect to morphological characteristics. Jingxianyu and Jingcui took the least number of days to budburst after pruning thus being classified as early bearing cultivars. Chenin Blanc and Cabernet Sauvignon recorded the highest height with respect to shoot length after 12 consecutive weeks from budburst thus being classified as vigorous cultivars. All the grape cultivars produced berries for analysis except Jingcui and Cabernet Sauvignon. Jingyan and Jingxiangyu had significantly bigger berries and higher bunch weight than all the other cultivars. The Total Soluble Solids (TSS) of the grape cultivars ranged from 16.3 to 25.2, with Sauvignon Blanc having the highest and Beihong having the least TSS. The TTA of the grape cultivars ranged from 6.32 – 25.7 g/L, with Beihong recording the highest and Jingxiangyu the least. The grapes cultivars had pH range of 3.07 to 3.55. Sensory data showed that Jingyan and Jingxiangyu were the most preferred cultivars, while Beifeng and Beihong were the least preferred. Jingxiangyu had the highest berry weight (7.64g) and highest cluster weight (440.8g) while Beifeng had the highest yield per vine (778g) translating to 5.7 Tonnes per hectare in a single season. The TTA of Sauvignon Blanc and Chenin Blanc was ideal for making stable wine while that of Beihong and Beifeng would need to be adjusted to be below 12.0g/L. Therefore, the six grape cultivars have potential for commercialization in Kenya under greenhouse conditions. The cultivars that were ideal for dessert (table use/fresh consumption) were Jingyan and Jingxiangyu. The cultivars that were ideal for processing into wine were Jingxiangyu, Jingyan, Sauvignon Blanc and Chenin Blanc. Productivity of all the varieties was not affected by disease and pest since only powdery mildew affected the vines and it was controlled by spraying Wetsulf fungicide therefore making production of grapes in a greenhouse cost-effective. Therefore, the recommendation from this study is to conduct further studies involving greenhouse production in multi-location sites to evaluate the economic viability of growing grapes in the greenhouse.

CHAPTER ONE

INTRODUCTION

1.1. Background

Grapes belongs to the genus *Vitis* and family *Viticeae* with approximately 60 species native to the Northern Hemisphere. It is one of the most important fruit crops in the world in terms of value and total acreage. Domestication of grapes began between 6,000 to 8,000 years ago along the Mediterranean and spread to the rest of the world (This *et al*., 2006). Grapes belong to the Muscadine type (*Vitis rotundifolia*), the American bunch type (*Vitis labrusca*) and the European type (*Vitis vinifera*) (Food & Agriculture Organization (FAO), 2017). *Vitis vinifera* L. accounts for more than 90% annual production around the world due to its large genetic diversity and relatively low chilling requirements to release buds from dormancy (Foreign Agricultural Service (FAS), 2015). The main production regions lie between latitudes 40 and 50° N and latitudes 30 and 40° S, although significant production occurs in the southern hemisphere (Iland *et al*., 2009). Grapes are also produced where climate is moderated by local geographical conditions like mountains, land masses and ocean currents which is a characteristic of the Kenyan climate (Schaffer & Andersen, 2018). Warm dry weather also favors production of table grapes due to reduction of incidences of fungal diseases which can explains the establishment of the oldest wineries in Kenya around Naivasha and Yatta plateau (Schaffer & Andersen, 2018). World grape production in 2018 was 77.8 MT with wine grape contributing to 57%, table grapes 36% and dried grapes 7% (International Organisation of Vine and Wine (OIV), 2019). Africa grape production and export to the EU market represented 3.3% to 3.9% in 2018 with South Africa dominating the largest share ranking 11th in the world (OIV, 2019; Sandrey, 2018).

Grapes are consumed raw as fresh fruits or used to make jam, juices, wine, vinegar, grape seed extracts, grape seed oil and raisins. Grapes also have many health benefits as it provides vitamin B and minerals such as iron, phosphorous and calcium (Natural

Green Farmtech (NGF), 2014). Grape is a source of polyphenol compounds such as resveratrol (stilbenes belonging to a non- flavonoid group of phenolic compounds), especially in red grapes. Resveratrol has numerous beneficial health effects such as antiviral, anticancer, anti-aging, life-prolonging, anti-inflammatory and neuro-protective effects (Kundu & Surh, 2008; Stojanović *et al*., 2001). Grape is a rich source of potassium and fibre which improves cardiovascular 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).

1.2. Problem statement

In Kenya grapes perform well in hot to warm areas, particularly in Yatta, Naivasha, Meru, Machakos and Tharaka Nithi (Robinson, 2015). These areas enjoy cool nights and day temperatures that do not exceed 32°C with volcanic soils that allow good drainage (Manohar *et al*., 2017; Oenotourism, 2019). Hot climates (close to the equator) such as Kenya produce more alcohol with more tannin and less acidity, while cooler climates produce less alcohol with more acidity and tannin in wine (Wu, 2015). Nonetheless, grapes production in Kenya has been slowly decreasing since 2012, with an estimated production of 2,370 metric tons under 236 Ha to 138 metric tons under 46 Ha in 2017 (HCD, 2014; 2017). Consequently, there has been a neglect of the vineyards and now grape production is concentrated around one vineyard (Rift Valley Winery's Vineyard). The low production capacity can be attributed to lack of suitable grape planting materials that are adapted to hot/warm conditions. This can be overcome by introduction of grape breeding programs whose core goal would be to select early ripening, disease resistant, high cold/heat tolerant and high-quality table and wine grapes. In 2017 alone, this country imported 3,000 metric tonnes of grapes and 4,000 metric tonnes of wine (HCD, 2014; Kenya National Bureau of Statistics, 2017). Consequently, Kenya spends millions of dollars on importing both fresh and dried grapes as well as wine brands. Additionally, importing companies suffer an increase in the cost of operation and lacks a competitive advantage. This, therefore, means that Kenya ends up suffering a negative Import - Export trade balance.

1.3. Justification

Grapes major diseases are downy and powdery mildews, which influences the growth, yield and quality of grapes, particularly juice colour, acidity, and sugar levels (Gadoury *et al.*, 2001). According to Prof. Tao, grapes should be grown in greenhouses to avoid pest and disease attacks especially during the rainy season which also ensure two harvests in a year (Mutethya, 2019). Other production aspects such as factors controlling bud burst and berry growth, inflorescence, bud fruitfulness, dormancy, vine nutrition, and vegetative growth are yet to be addressed in Kenyan grape production (Oag, 2001). Introduction of new cultivars will form a model for independent selection and development of new cultivars of grapes which will significantly promote the development of grape production and wine making industry in Kenya. Introduction of new cultivars to Kenya will also bring in a reservoir of diversity that is vital in developing cultivars that are disease and pest resistant as well as better suited to a particular use or region.

Grapes possesses great health benefits as it contains mineral elements such as phosphorous, iron, calcium, vitamin B and phenolic compounds. Polyphenols extracted from grapes are reported to prevent, cardiovascular diseases, type-2 diabetes mellitus and cancer (Nile *et al.*, 2013). Type 2 diabetes and other lifestyle diseases such as cancer, hypertension and cardiovascular diseases are the leading causes of premature deaths in Kenya (Gichinga, 2018). Thus, research to increase production and productivity of grapes in Kenya will go a long way in helping to solve such challenges by making grapes accessible to the local communities.

Over the past decade, there has been an increase in the number of urban residents and expatriate communities with higher disposable income, which has promoted an increase in the overall consumption and sale of grapes and wines. Grape pomace that results from wine making contains phytochemicals that can be used as functional compounds for the food, cosmetic, biopesticide and pharmaceutical industries (Fontana *et al*., 2013).

Kenya is well placed at the equator to make a large impact in the grape production (wine and table) by exploiting its wide range of soils and climate with the idea of earning export currency as well as supplying the growing internal demand. According to Professor Tao, Kenya has the capacity to produce high yields of temperate fruit trees like grapes, plums, peach, pears, and apples if the cultivars and technologies are used (Mutethya, 2019). This initiative will go a long way in reducing unemployment, food, and nutritional insecurity. Additionally, grapes production has a lot of potential to create wealth and employment for the many jobless youth in Kenya.

1.4. Objectives

1.4.1. General objective

To evaluate introduced Chinese and French grape cultivars for improvement towards increased fruit production on Kenya.

1.4.2. Specific objectives

1. To evaluate the morphological characteristics of introduced Chinese and French grapes cultivars cultivated in a greenhouse in Kenya.
2. To determine fruit yield of introduced Chinese and French grapes cultivars cultivated in a greenhouse in Kenya.
3. To determine the fruit quality of introduced Chinese and French grapes cultivars cultivated in a greenhouse in Kenya.

1.5. Hypotheses

1. There is no significant difference in morphological characteristics of introduced Chinese and French grapes cultivars cultivated in a greenhouse in Kenya.
2. There is no difference in fruit yield of introduced Chinese and French grapes cultivars cultivated in a greenhouse in Kenya.
3. There is no significant difference in fruit quality characteristics of introduced Chinese and French grapes cultivars cultivated in a greenhouse in Kenya.

CHAPTER TWO

LITERATURE REVIEW

2.1. Origin and taxonomy of grapes

Grapevine belongs to *Viticeae* family which has 12 genera including *Cissus* (kangaroo vine), *Ampelopsis, Parthenocissus* (Virginia creeper), *Clematicissus, Ampelocissus* and *Vitis* (Creasy & Leroy, 2018). The *Vitis* genus is the most utilized for commercial purposes and consists of two sub-genera: *Muscadinia* and *Euvitis. Muscadinia* has 40 chromosomes and *Euvitis* has 30 chromosomes which makes interbreeding between the two-species impossible (Creasy & Leroy, 2018).

Additionally, *Muscadinia* has smooth bark, fewer berries per cluster, differences in seed shape, simple as opposed to branched tendrils and berries that abscise from the rachis (Creasy & Leroy, 2018). The most common named species in this group are *M. popenoei, M. rotundifolia* and *M. munsoniana. Euvitis* species include *V. labrusca* and *V. vinifera* which are used for raisin production, juices, table consumption and wine production (Creasy & Leroy, 2018). On a large scale, the genus *Vitis* L. is among the most significant crops used to process wine as well as consumed as fresh fruit due to their economic significance and beneficial influences on human health (Ivanova-Petropulos *et al*., 2015).

Taxonomically, the stem is woody; the leaves are alternate, tooth-edged and palmately lobed. All grapevines are perennial, polycarpic and deciduous. The grapevine is mostly tree-climbing although some can have a shrubby growth pattern. Inflorescences opposite the leaves and tendrils also characterize them. Grape is a type of fruit that grows in clusters of 15 to 300 (Liang & Drohojowski, 2008). The variation in the shades of the purple colour of most grape cultivars is brought about by mutation of two regulatory genes of white grapes which turn off the production of anthocyanins (Brouillard *et al*., 2003; Walker *et al*., 2007). The major anthocyanins pigments in grapes which determine the intensity and colour of grape berries include malvidin, petunidin, delphinidin, peonidin and cyanid (Liang *et al*., 2011). The accumulation and synthesis of anthocyanins are influenced by temperature, plant hormones, crop load, nutrition, and light (Buckley, 2006).

Like other plants, grapevines comprise vegetative organs (roots, trunk, shoots, leaves and tendrils) and reproductive organs (cluster with flowers and berries) (Keller, 2015). The flowers are small and greenish in clusters and precede the fruit which varies in colour from green, black, pink, orange, yellow, dark blue and crimson. Most cultivars have a bloom or a whitish powdery coating. The flowers are borne on a flower cluster, or an inflorescence and the main axis is the rachis on which individual flowers attach using a capstem or a pedicel. The cluster is attached to the vine by the peduncle which extends from the shoots to the first branch of the rachis. Nearly all commercial *V. vinifera* cultivars bear hermaphroditic flowers (Dokoozlian, 2000).

2.2. Production of grapes

The world grape production surface area has been stable at >7.45 million hectare (MH) since 1995 with production levels of fresh grapes rising from 55.8 to 75.5 million tons (MT); table grapes from 11.7 to 27.6 MT and dried grapes from 1.0 to 1.3 MT in 2016 (OIV, 2016). China was ranked as the top grape producing country in the world with production levels of 14 MT in 2019 produced under 843,407 Ha (FAO, 2019). China which has also collected and conserved *Vitis* germplasm for more than 60 years in the Institute of Botany, Chinese Academy of Science. The institute has more than 500 accessions grown including 25 wild species, 450 cultivars around the world and 100 accessions originating around China with significant cold resistance (Jiazi, 2014). On the other hand, consumption of table grapes has been on the rise since 1995 rising from 11.7 million tons to 27 million in 2016 while that of dried grapes has increased slowly from 1995 from 1.0 million tons to 1.5 million tons in 2016 (OIV, 2016).
In Africa, the total production surface area has gradually increased from 330,674 ha to 382,838 ha between 1995 and 2016 which is 5.1% of the total world grapes surface area. Within the two decades, the production levels for fresh grapes has increased from 2.6 to 4.8; for table grapes from 1.1 to 2.7 million tons and for dried grapes from 41,637 to 55,345 which is small fraction (<10%) of the world's grape production (OIV, 2016). Ethiopia which lies between latitudes 0 and 10° N produced 5,270 tons of grapes under

2,689 ha in 2016, translating to 0.9 tons/ha which is very low compared to S. Africa and Egypt with production capacity of 17.2 and 22.1 tons respectively (FAO, 2019). The grape cultivars cultivated in Kenya include Merlot, Pinot Noir, Sauvignon Blanc, Chardonnay, Cabernet Sauvignon, Muscat of Alexandria, Office Vine, Golden Muscat, Muscat of Hamburg, Colombard, Chenin Blanc, Shiraz and Dodrelabi (Horticultural Crops Directorate (HCD), 2014). The dry and rainy seasons experienced in Kenya are comparable to those of Yunnan province which is the highest producer of grapes in China (Mutethya, 2019) which translates to the potential Kenya has in production of grapes.

2.3. Grapevine Growth

Several developmental stages occur within grapevine, and this includes dormancy, budburst, bloom, berry set, veraison (colour change or onset of ripening), maturity, and harvest (Creasy & Leroy, 2018).

2.3.1. Dormancy

Grapevines exhibit three main physiological stages related to dormancy, i.e., acclimation, winter dormancy, and de-acclimation. The first stage (acclimation) is experienced when the vine has ripened its berries and shoot growth has ceased. The second stage (winter dormancy) occurs during mid-winter months. The third stage (de-acclimation) is experienced when the vines begin to lose their hardiness by adjusting to warmer temperatures (Creasy & Creasy, 2009). The duration and timing of each of the above stages is subject to variations in seasonal weather, climate, and grape cultivar (Jackson, 2001). Due to the lack of a temperate-zone seasonality forcing the buds to develop before entering dormancy, cultivars with a range of chilling requirements can be tried (Griesbach, 2007).

2.3.2. Method of Breaking Bud Dormancy

Under the tropical conditions, bud rest is achieved by cultural techniques such as desiccation and defoliation followed by pruning, application of budburst chemicals and irrigation to initiate grapevine growth (Griesbach, 2007).

2.3.2.1. Defoliation/desiccation

Defoliation creates an artificial resting period which should be broken later with a chemical spray. In Kenya, defoliation should be done one month after harvest to target a harvesting cycle of 6 to 7 months which means two crops can be achieved per year. Defoliation can be done by hand for a small orchard, but large orchards require chemical defoliation by spraying a mix of 5% urea + 5% $ZnSO_4$; 3-4% Urea; 1% Copper chelate and 0.75% Magnesium chlorate. Desiccation involves withholding irrigation in the dry season following harvest to induce early dormancy (Griesbach, 2007).

2.3.2.2. Chemicals

Prolonged dormancy of grape phloem can be minimized by application of chemicals like hydrogen cyanamide (Dormex) at 5% which causes the buds to open more evenly and at the same time especially under tropical conditions (Griesbach, 2007; Sudawan *et al*., 2016). Other beneficial chemicals include thiourea which mainly influence opening of leaf buds and KNO_3 which primarily affects flower buds. A combination of thiourea (2%) + oil and KNO_3 (10%) + oil, leads to increased yields. Timing of application is critical as vines/trees will not respond if sprayed too early while in dormant state whilst late spraying results to damage of buds that have already budburst (Griesbach, 2007).

2.3.3. Budburst

Budburst is used as a measure of dormancy release and occurs when dormant buds begin to grow from the terminal buds to produce shoots (Kennedy *et al*., 2002; Pletsers *et al*., 2015). Budburst is negatively affected by drought, low carbohydrate storage in vines, frost damage, degree of chilling, and badly timed deficit irrigation in the previous season (Jackson, 2001).

2.3.4. Flowering

As the shoot grow, the formation of undifferentiated primordia takes place within the buds in the leaf axils and develop in either tendrils or flower bunches depending on growing and environmental conditions. As the new primary shoot develops, the flower bunches forms on the opposite and in case it fails to form, a tendril is formed (Kennedy *et al*., 2002).

2.3.5. Fruit set

Flowering is synchronous and quick resulting to an even fruit set with berries setting and ripening uniformly. A normal fruit set will result 20 – 30% of flowers on a bunch yielding into mature berries which is adequate to produce a full bunch. Nonetheless, uneven setting and development of berries (*Millerandage*) may occur which can contribute to failure of grapes to properly develop. This controls the compactness of some cultivars such as Sauvignon Blanc (Hellman, 2003).

2.4. Grapes growth cycle

The seasonality of grapevines is influenced by temperature, stress such as drought, nutrient deficiency or excess status, or infection by pathogens (Keller, 2015). Generally, high temperatures advance grapevine phenology (annual sequence of plant development) and accelerate plant development (Parker *et al*., 2011). The phenology of grapes is controlled by an endogenous clock contained in the plant cells that act autonomously to prevent damages by unfavourable environments (McClung, 2008; McClung & Nakashima, 2001). The clock is driven by self-sustaining oscillators consisting of proteins oscillating with a 24 - hour rhythm in response to the light detected by the phytochromes (Fankhauser & Staiger, 2002; Spalding & Folta, 2005). The annual cycle of a grapevine is divided into a vegetative and reproductive cycle (Keller, 2015).

2.4.1. Vegetative cycle

Shoot growth starts in the distal bud of a vine and its preferential budburst inhibits the growth of the basal buds (Galet, 2000). Grapevine shoot usually grows upwards with variation from erect to droopy growth habits among cultivars (Keller, 2015). The unfolding leaves of many cultivars are reddish before they turn green and have dense hairs. The transient accumulation of anthocyanin pigments and the dense hairs probably protects the developing protochlorophyll from excess light (Liakopoulos *et al*., 2006). The initial growth phase is characterized by strong apical dominance whereby the growing shoot tip suppresses budburst in lateral buds by monopolizing sugar supply for its growth. The relatively sugar-deficient prompt buds are unable to initiate cell division for bud growth (Mason *et al*., 2014). Leaf unfolding and extension of internodes is usually influenced by temperature and day length. Unlike many woody plants, grapevine shoots do not form terminal buds but rather continues to grow if the environmental conditions are favourable (Keller, 2015). The growth cycle of the shoot is completed with leaf senescence associated with the recycling of nutrients from the leaves to the canes and permanent parts of the vine and abscission of leaves (Keller, 2015).

2.4.2. Reproductive cycle

Grapevines propagated from seeds have a vegetative juvenile phase that lasts 2 to 4 years (Keller, 2015). The degree of expression of the gene that controls flowering transition increases gradually during the juvenile stage until it exceeds a threshold that permits the formation of the inflorescence (Bo¨hlenius *et al*., 2006). By contrast, grapevines propagated from cuttings can fruit in the first growing season under optimal conditions. Flower and fruit production require two consecutive growing seasons. Buds formed in the first year give rise to shoots carrying fruits in the second year. Reproductive growth begins with inflorescence induction, flower initiation and flower differentiation (Keller, 2015). Each grape cultivar has different harvest dates depending on its berry health status, maturity, and weather conditions (Fernández & González, 2015).

2.5. Grapes morphology

Grapes display an array of morphological traits which include pigmentation, growth habits, seed shape or flower colour (Collard *et al*., 2005; Ocampo *et al*., 2006). Morphological characterization is vital for conservation, commercialization and breeding of new cultivars (Laurentin, 2009). The morphological characterization is also important in preventing loss of diversity of germplasm. Leaf morphological characterization is one of the most important methods of determining inter-relationship between grapes cultivar (Rodrigues *et al*., 2008). Leaf descriptors are reliable and time-saving (Knezović *et al*., 2017). The morphological characterization has been widely used to study genetic diversity patterns in table grapes (Rusjan, 2013), correlate characteristics of agronomic traits in tomatoes (Ali, 2017) and in the identification of duplicates in papaya germplasm (Asudi *et al*., 2010).

To homogenize identification, characterization and registration of worldwide *Vitis* genera, International Organization of Vine and Wine (OIV) developed standard descriptors that are very important in developing an inventory of grapevine genetic resources with passport, bibliography and photos, primary and secondary descriptors (Lamine *et al*., 2014; OIV, 2009). For quick and precise characterization of grape cultivars, 14 descriptors are recommended for use by OIV as they have demonstrated a good discriminatory power among cultivars and it is easy to score (OIV, 2009). Morphological characteristics using OIV descriptors are normally recorded by DNA or isoenzymes, ampelometry through weighting or measurement, by sensory observations (smell, taste) or visual appraisal (OIV, 2009).

2.6. Grape Maturity Indices

Measurements of titratable acidity, °Brix/acid ratio and soluble solid concentrations are used to determine the proper time to harvest table grapes and predict consumer acceptability (Baiano *et al*., 2012). To determine the technological ripeness (sugar/acidity ratio) and the optimum time to harvest red wine grapes, the skin should have high concentrations of phenolic compounds such as tannins and anthocyanin. The tannin content in the seed peaks at maturity and starts to decrease until physiological maturity and remains stable after that (Jackson, 2014). On the other hand, anthocyanin accumulates from 15 days before maturity, increases during maturity and decrease slightly at the end of maturity period (Jackson, 2014).

2.7. Grapes quality

Table grape quality is determined by the interplay of several metabolites including phenolic compound balance (tannins, flavanols and anthocyanins), organic acids (tartaric and malic), nitrogen compounds (NH_4^+, proteins and amino acids), total soluble sugars (glucose and fructose) and titratable acidity (Dokoozlian, 2000; Pereira *et al*., 2006). Table grapes are required to have a refractometric index (RI) of 16.0°Brix. Berries with a lower RI are acceptable if the sugar/acid ratio is at least equal to (a) 20:1, if the Brix level is greater than or equal to 12.50° and less than 14.0°Brix, or (b) 18:1 if the Brix levels are greater than or equal to 14.0° and less than 16.0°Brix. (FAO, 2007). 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 (Ali *et al*., 2010; Rusjan, 2013). Sugar contents are determined by photosynthetic processes which take place in green berries and leaves (Pavlqušek & Kumšta, 2011). Sugars in the berry are responsible for the sweetness of table grapes and raisins (Jackson, 2014). The main sugars in grape berries are fructose and glucose in most of the genotypes and malic and tartaric acids account for greater than 90% of the total acids (Ninio *et al*., 2003). Sugars and organic acids are also important in the selection and breeding of new cultivars (Liang *et al*., 2008). The phenolic compounds are responsible for the pigmentation of the berries. The red colour associated with red grapes is controlled by anthocyanin and it influences the quality of grape juice, red wine, and the market value of table grapes (Liang & Drohojowski, 2008).

2.8. Factors affecting grape quality characteristics

2.8.1. Mineral nutrition

The nutritional composition of the soil influences the capacity of grape cultivars to absorb minerals from the soil and affects the wine composition of minerals (Fabani *et al*., 2010). Of all the mineral nutrients, Nitrogen is the most influential in its ability to influence the morphology, vine growth, tissue composition and fruit production (Bell & Henschke, 2005). Increased nitrogen availability in the soil to optimal levels enhances photosynthesis which translates to more sugars for growth and fruit ripening. High nitrogen supply favours vegetative growth which leads to dense canopy associated with poor colour, high acidity, and reduced fruit sugars (Keller, 2015). Moderate nitrogen availability maximizes the aroma potential and flavour of white grapes whereas excess nitrogen or deficiency seemingly diminishes the aroma potential (des-Gachons *et al*., 2005). Pigmentation of red grapes during maturity is maximized at low to moderate nitrogen availability and minimized when the vines have high nitrogen status (Hilbert *et al*., 2003).

Grapes grown in cooler climatic regions have low K levels than those grown in warmer climatic regions (Jackson, 2000). Abundant potassium availability in the soil increases the pH of berries due to enhanced potassium uptake and transport to the berries and as a result, the juice and the wine pH are increased (Keller, 2015; Walker & Blackmore, 2012). Cinnamic acid, tannins and anthocyanin derivatives in grape berries are insensitive to P or K supply (Schreiner *et al*., 2014). High amounts of Mg protect the anthocyanin from degradation in cell vacuoles by stabilizing the pigment molecules through the formation of blue anthocyanin-Mg complexes (Sinilal *et al*., 2011). High vine sulfur status due to the foliar application for the control of powdery mildew may increase the concentration of volatile wine thiols (Lacroux *et al*., 2008).

The soil contains several essential mineral elements which are responsible for the growth and development of grapevines consequently affecting the grapevines yield and quality of the berries. The mineral elements involved in cellular and metabolic mechanisms such as chlorophyll synthesis, protein stabilization and enzyme activation include Zn, Ni, Mo, Mn, Fe, Cu and B (Yang *et al*., 2010). Deficiencies in Iron results in leaf chlorosis. Boron affects the size and number of berries, while Zinc improves retention of the bunch (Kamsu-Foguem & Flammang, 2014). The desirable soil nutrients for grapes include 2-3% organic matter, 40-50 ppm Phosphorous (P), 250-300 ppm Potassium (K), 200-250 ppm Magnesium (Mg), 1.5-2.0 ppm Boron (B) and 8-10 ppm Zinc (Z) (Dami, 2005).

2.8.2. CEC and pH

The Cation exchange capacity (CEC) is the measure of the nutrient holding capacity of the soil or its fertility. It is influenced by the amount of organic matter and clay content in the soil. The greater the organic matter and clay content in the soil, the higher the CEC. Soils with high CEC levels have a greater nutrient holding capacity (Brown, 2013). pH is the measure of how acidic or alkaline a soil can be. Nutritional problems in grapevines are usually a result of soil pH. For example, acidic soils with pH< 5.5 results in unavailability of P because it is precipitated by high amounts of free iron and aluminium. High aluminium levels also negatively impact root development by inhibiting cell division at the root tip. An alkaline soil with pH > 8.0 results in unavailability of micronutrients such as copper, iron, manganese, Boron, and zinc (Peterson, 2013). The optimum pH for grapes production and better nutrient balance is in the range of 5.5 to 6.5.

2.8.3. Temperature

Climatic factors play a significant role in the grapes fruit set. Temperatures below 18.3°C or above 37.8°C inhibits pollen tube germination and ovule fertilization (Dokoozlian, 2000). Cold temperatures are associated with incomplete disintegration of the calyptras. Temperature also controls berry acid contents. At the initial stage of berry development, temperature ranges of between 20 to 25°C are suitable for acid synthesis (Dokoozlian, 2000). If the temperature goes beyond 35°C, during berry development, cell elongation and division are reduced resulting in lower yields and smaller berries at harvest (Buckley, 2006). Excessive temperatures delay sugar accumulation, inhibits berry growth, causes berries to shrivel, impedes fruit colouration and may cause abnormal colouration of white berries (Buckley, 2006).

2.8.4. Water

After veraison, mild water deficit is beneficial to grapes quality since it suppresses further vegetative growth which promotes the balance between the fruit ratio and leaf ratio (Jackson, 2014). This concept limits berry enlargement and enhances anthocyanin synthesis. In their study, Romero *et al*., (2015) found that after veraison, the sugar accumulation was higher in non-irrigated versus irrigated berries. Excess water at veraison increases the berry size by double and the concentration of the variables that define grape quality is reduced Jackson, 2014). High rainfall or humidity dilutes the stigmatic fluid and therefore the interference of the germination of pollen grains (Dokoozlian, 2000). Rain and humidity associated with high temperatures favours the development of many diseases associated with bacteria and fungi such as bacterial canker (*Xanthomonas campestris p.v. viticola*), anthracnose (*Elsinoe ampelina*), grapevine downy mildew (*Plasmopara viticola*), dieback (*Botryodiplodia theobromae*), ripe rot (*Colletotrichum* spp.), leaf spot (*Isariopsis clavispora*) and rust (*Phakospsora euvitis*) (Camargo *et al*., 2012).

Low rainfall or controlled water deficit induces the synthesis of abscisic acid (ABA) which triggers stomatal closure. Consequently, the photosynthetic rate and plant growth are reduced (Ferrandino *et al*., 2014; Osakabe *et al*., 2014). Inadequate rainfall to the grapevines affects the berry size and berry tissue (pulp, seeds, and skin) (Gadoury *et al*., 2001). In red wine, water deficit reduces the size of the berries, increases the pulp/skin ration of the berries, and interferes with the concentration of compounds, e.g., phenolic in the grapes (Chaves *et al*., 2010). Phenolics plays a significant role in defining the quality of red wine. For example, they participate directly in red wine bitterness, astringency, ageing capacity, its colour due to anthocyanin and colour stabilization due to procyanidins (Casassa *et al*., 2015; Chaves *et al*., 2010). Low levels of irrigation have been reported to increase the concentration of Cl, K and Na in berries which lead to negative wine considerations such as “soapy,” “sea water like,” or “brackish” wine (Mira de Orduña, 2010). Seasonal drought is a common phenomenon in most of the world’s wine producing countries. An increase in aridity may become a limiting factor in wine quality and production due to water deficit. Grapes subjected to abnormal weather conditions develop physiological disorders such as berry cracking and shattering (Buckley, 2006). To overcome the constraints posed by climate change, greenhouse cultivation is recommended as it reduces the impact of climate change on fruit production (Duan *et al*., 2014).

2.9. Wine quality

Wine quality is difficult to quantify since consumption of wine is dependent on the buyers' preference for taste, colour, aroma, and grape variety (Martínez-Carrasco *et al*., 2006). Nonetheless, different protocols that minimize psychological and physiological factors known to affect human sensory responses have been adopted to evaluate the human perceptions objectively and analytically (Lesschaeve, 2007). Wine characteristics (colour, acidity, flavour, levels of tannin and sweetness) are influenced by the type of grape grown and other conditions such as nutrients, water, warmth, sunlight, climate, weather, winemaking method, chemical and physical composition of the berries (Li *et al*., 2009). On a large scale, the genus *Vitis* is among the most significant crops used to process wine as well as consumed fresh due to their economic significance and beneficial influences on human health (Ivanova-Petropulos *et al*., 2015). Monitoring of physiological and morphological parameters in the grapevine is critical in identifying indicators that can be associated with grape cultivars and wine styles (Nadal & Hunter, 2007).

The grape berry quality primarily determines wine quality, i.e., the levels of chemical constituents including acidity, pH, sugars, phenolic and organic acids (Zerihun *et al*., 2015). Flavanols and flavanols affect the astringency and flavour of wine (Soar *et al*., 2008). It is essential to maintain a balanced state of mean shoot length (LS) and mean shoot weight (WS) to have suitable quality wine grapes (Cortell *et al*., 2005). Grape berry ripeness indices such as colour of seeds, berry skin colour, assimilable nitrogen, general condition of the vine and condition of the fruit are considered as wine quality indicators (Bisson, 2001). The proportion of anthocyanins affect both the colour stability and hue of red wine and thus affect the overall quality of wine (Baiano *et al*., 2015). Anthocyanin concentration is measured by variables such as colour intensity (CI) and total phenolic content (TPC). The seed should also have a hard-outer coating.

This technique is used to minimize the extraction of tannins during the process of making wine (Pourcel *et al*., 2007).

2.10. Factors affecting wine Quality

2.10.1. Temperature

Juice Titratable Acidity and pH declines with increases sunlight exposure to the berries. Berry response to sunlight varies based on cluster location within the canopy. At the same photosynthetically active radiation (PAR) exposure levels, mid-day berry temperatures are 3-4°C higher on the side receiving sunlight exposure compared to the shadowed side (Bergqvist *et al*., 2001).

2.10.2. Skin Solutes: Tannins and Anthocyanins

Tannins and anthocyanins are important phenolic compounds in wine quality. Tannins are generally present in skin, stem, and seeds while anthocyanins are present in grape skin of red varieties. The amounts in wine are affected by environmental conditions and cultural practices during the growing season, and their extraction during fermentation and maceration (Kennedy *et al*., 2006). The concentration of these phenolics is influenced by the size of the berries with wine made from smaller berries having high concentration of both phenolics. Grape skin anthocyanins are on one of the principal measurable variables used to predict wine quality (Francis *et al*., 2005; Ristic *et al*., 2010).

CHAPTER THREE

MATERIALS AND METHODS

3.1. Description of the research area

The study was carried out in a greenhouse at Jomo Kenyatta University of Agriculture and Technology main campus situated in Juja Sub-County (1°5'35.93"S, 37°0'46.31"E and 1525 meters above sea level), 36 kilometres Northeast of Nairobi, Kenya in 2018 and 2019. Production of grapes in a greenhouse is cost-effective since there is minimal ingression of pest and diseases as compared to field production.

3.2. Materials

Eight cultivars were evaluated for morphological and fruit quality characteristics (Table 3.1). The Chinese grape cultivars were sourced from an on-going research project at JKUAT main campus. French hybrid cultivars were collected from Yatta Complex Centre. Jingyan, Jingxiangyu, Jingcui, Beihong and Beifeng were selected for this study due to their high yields, high endurance for transport and good storage qualities, as well as resistance to diseases (Jiazi, 2014). Chenin Blanc, Sauvignon Blanc, and Cabernet Sauvignon were selected for this study due to their adaptability within the Kenyan tropical conditions since 1992 and thus used as reference materials (Gachenge, 2008).

Table 3.1: Grape Cultivars used for the Experiment

Function	Cvs	Source
Table Cultivar	Jingyan, Jingxianyu and Jingcui	CAAS
Wine Cultivar	Beifeng and Beihong	CAAS
Wine Cultivar	Sauvignon Blanc, Cabernet Sauvignon and Chenin Blanc	French Hybrid, Yatta

3.2.1. Preparation of the plant materials

1. Preparation of cuttings: Cuttings of well matured dormant canes with a diameter of ¼ inch with three nodes of 4 inches internodes were obtained from the French hybrids and the Chinese grape cultivars for propagation. The basal cut was made just below the lower bud and the upper cut 2 inches above the top bud.

2. Rooting of the cuttings: They were then planted in a sand trough with the basal part forming the rooting part and put in a greenhouse to develop shoots and leaves in May 2018 (Figure 3.1). The cuttings were watered twice in a week.

3. Potting: After three weeks the cuttings were transferred to potting bags containing soil and allowed to settle for one week after which they were transplanted in the greenhouse (Figure 3.1).

4. High tunnel planting: The soil of the greenhouse was texturally classified as red sandy loam consisting of clay 18.9%, silt 8.2% and sand 69.9%. The chemical properties of the soil were pH 5.9, EC 0.16, available N 117 ppm, available P 41 ppm, and available K 227 ppm. The grapevines were watered twice a week by flooding the beds with water until the soil was saturated. Weeding was done manually once per week to maintain weed free conditions in the greenhouse.

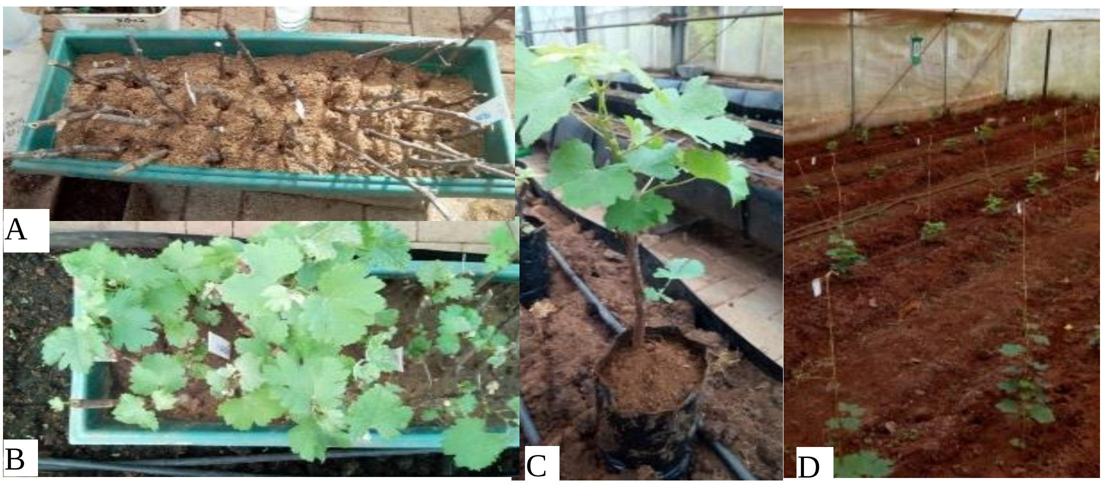


Figure 3.1: Propagation of the plant materials

3.3. Experimental Design

The planting design was completely randomized with 96 rooted cuttings of eight cultivars. The rooted cuttings were distributed in five rows within four replications and each replication contained rooted cuttings of each cultivar as shown in figure 3.2. All the vines were planted at a spacing of 0.9 m and 1.6 m between the rows.

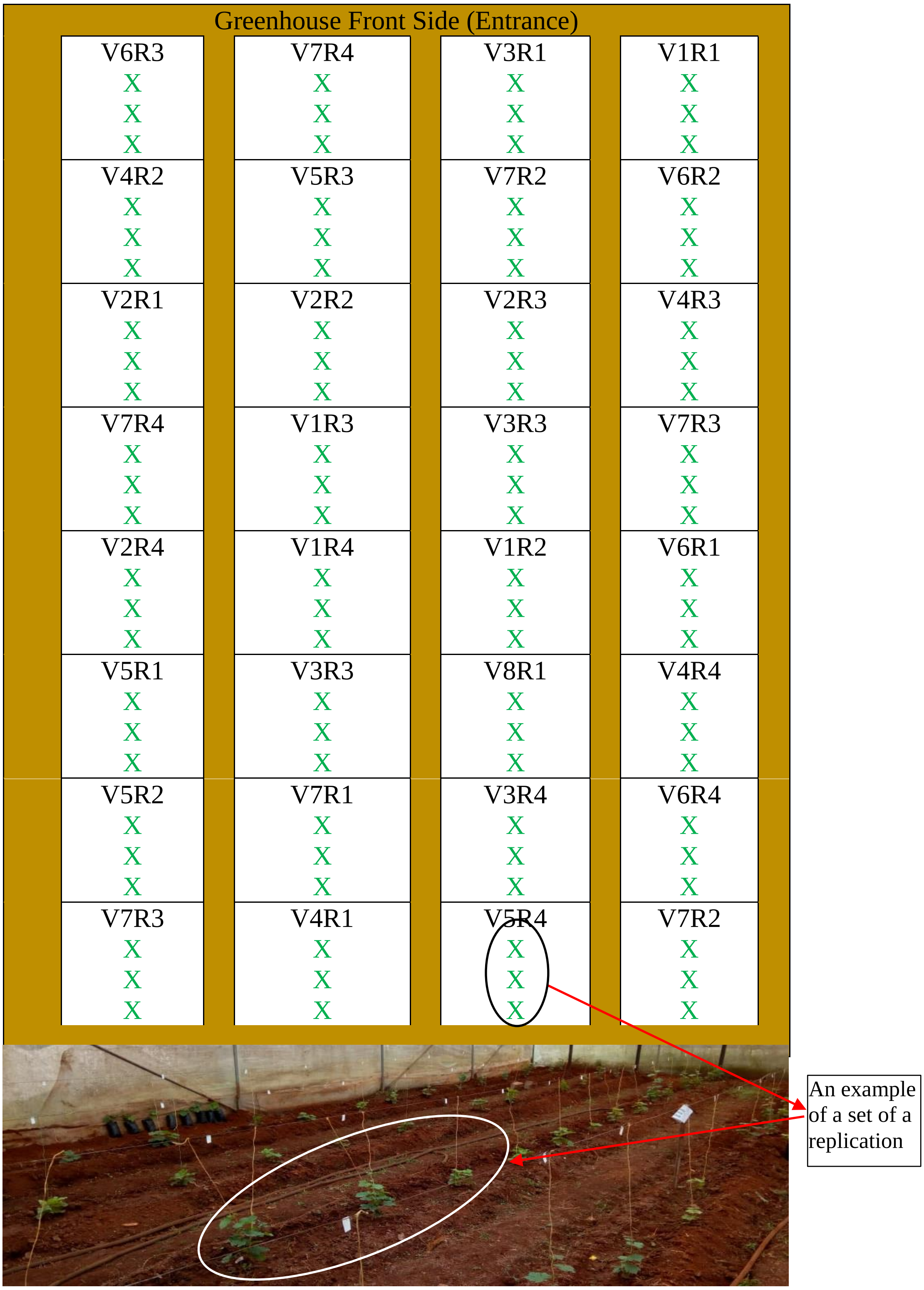


Figure 3.2: A sketch of the randomized planted vines comprising of eight cultivars replicated four times. V: represents the cultivars – 8 cultivars; R: represents the replication – 4 replications; X: represents the vines – 3/cultivar

3.4. Training and maintenance of the grape vines in the greenhouse

After one month of shoot /root development (seedling), the grape seedlings were transplanted in the greenhouse in May 2018. The vines were trained to High Cordon system. During the first season (May – September 2018), straight shoots with eight to ten buds were established for the second growing season (November 2018 – March 2019). Shoot pruning was carried out throughout the two seasons to remove excess lateral growth. Only four node canes per vine were retained for fruiting. Powdery mildew was the only disease that affected the vines, and it was controlled by Wetsulf 8 WP (Sulphur 80% w/w) while mealy bugs were the only pests that infested the vines and they were controlled using Sulban 48 EC (chloropyrifos 48%) both from Osho Chemicals LTD.

3.5. Data collection

Qualitative and quantitative data was collected for two seasons: May to September 2018 and November 2018 to March 2019. The qualitative data included the morphological characteristics of the vines (shoots, leaves, inflorescences, flowers, and the fruits), the pH, Total Titratable Acidity, Total Soluble Solids, and the sensory attributes of the grape berries. The quantitative data included the number of berries per bunch, the number of bunches per vine, the number of days taken to budburst, shoot length and the yield of the cultivars. Data on morphological characteristic, number of days taken to budburst and shoot length was collected once a week and the rest of the data sets were collected after veraison of the grape berries.

3.5.1. Evaluation of morphological characters of different introduced grape cultivars

The morphological characteristics (traits) of the eight grape cultivars were evaluated using a total of 22 morphological characteristics on a weekly basis from June 2018 to March 2019 based on OIV descriptors (OIV, 2009) (Figure 3.3). The morphological descriptors used for the eight cultivars included two shoot descriptors, five leaf descriptors, one inflorescence and flowers descriptors and fourteen fruit descriptors.

Each morphological descriptor had an OIV code and a number representing their reading. The berries and bunches were morphologically evaluated when they attained the veraison stage. In order to evaluate morphological characteristics, ten bunches per cultivar were radomly selected and for evaluation of berry morphological characteristics, berry weight and vine yield ten berries per bunch were selected using simple random method.

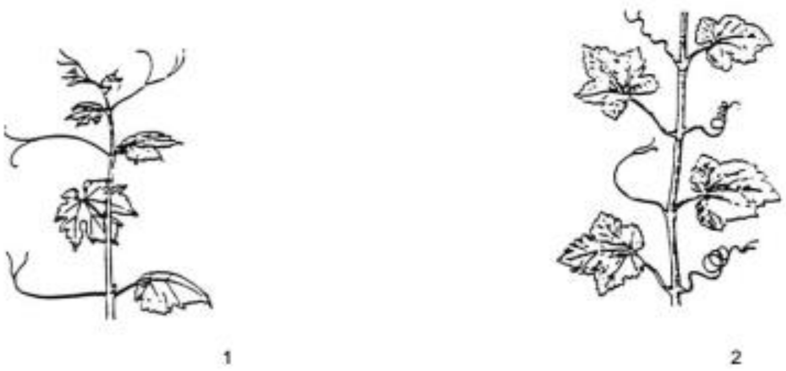
1 Characteristic: Young shoot: opening of the shoot tip — Codes N^{os} OIV 001

Notes:

1	3	5
closed	half open	fully open

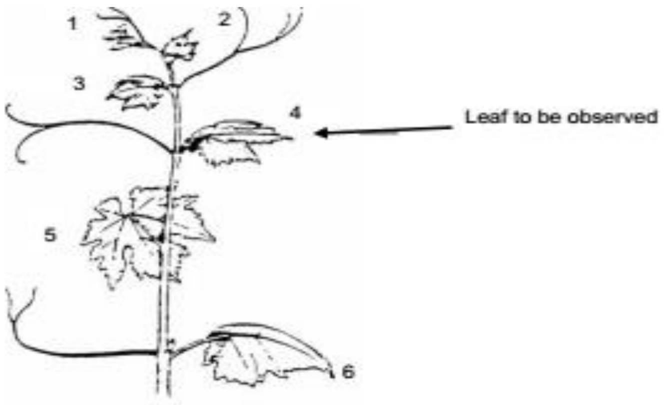
2. Characteristic: Shoot: number of consecutive tendrils — Codes N^{os} OIV 016

1	2
2 or less	3 or more



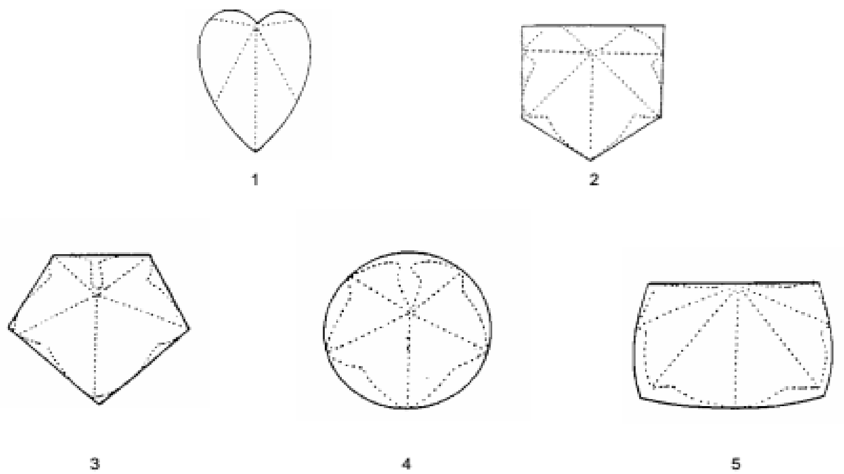
3. Characteristic: Young leaf: color of upper side of blade (4th leaf) | Codes Nos OIV 051*

1	2	3	4
green	yellow	bronze	copper - reddish



4. Characteristic: Mature leaf: shape of blade | Codes Nos OIV 067

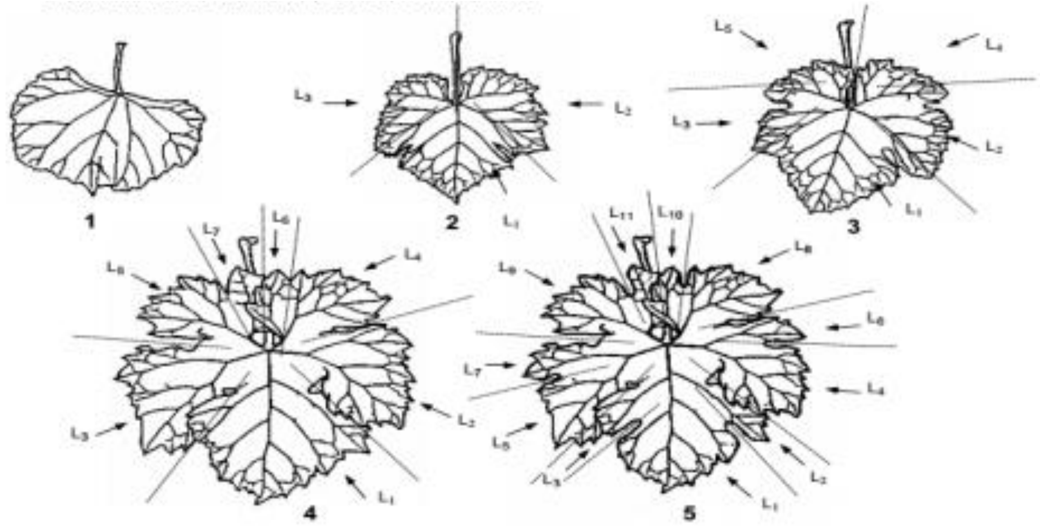
1	2	3	4	5
cordate	wedge-shaped	pentagonal	circular	kidney-shaped



5. Characteristic: Mature leaf: number of lobes

Codes N^{os}
OIV 068

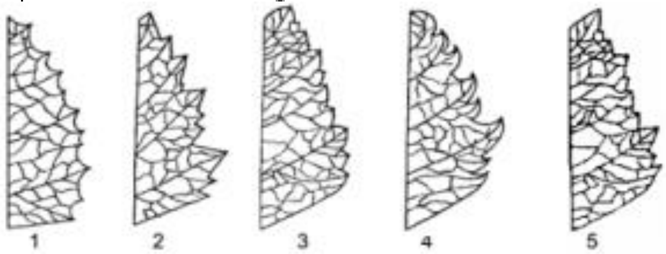
1	2	3	4	5
one (entire leaf)	three	five	seven	more than seven

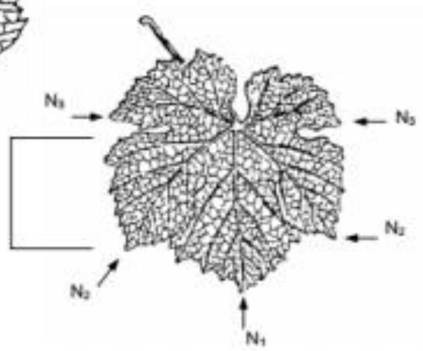


6. Characteristic: Mature leaf: shape of teeth

Codes N^{os}
OIV 076

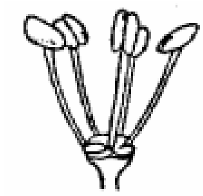
1	2	3	4	5
both sides concave	both sides straight	both sides convex	one side concave, one side convex	mixture between both sides straight (note 2)

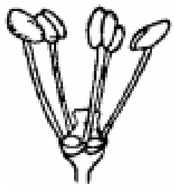




7. Characteristic: Flower: sexual organs — Codes N^{os} OIV 151

1	2	3	4
fully developed stamens and no gynoecium	fully developed stamens and reduced gynoecium	fully developed stamens and fully developed gynoecium	reflexed stamens and fully developed gynoecium


1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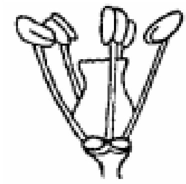
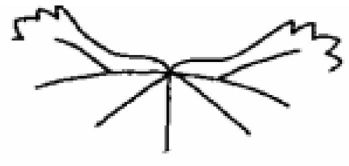

3


4

8. Characteristic: Mature leaf: degree of opening / overlapping of petiole sinus — Codes N^{os} OIV 079

1	3	5	7	9
very wide open	open	closed	overlapped	strongly overlapped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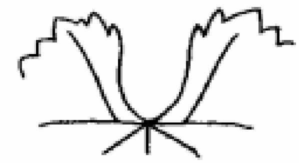
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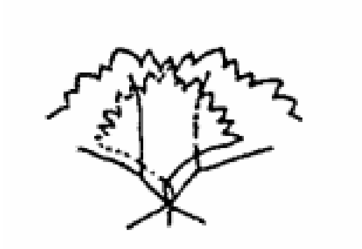
5

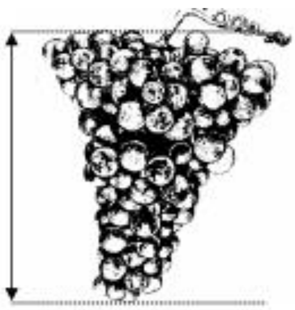

7


9

9. Characteristic: Bunch: length (peduncle excluded) — Codes N^{os} OIV 202

1	3	5	7	9
very short	short	medium	long	very long
up to about 80 mm	about 120 mm	about 160 mm	about 200 mm	about 240 mm and more

Length



10. Characteristic: Bunch: width

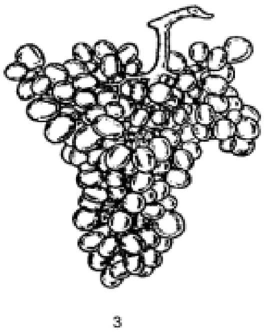
Code N°
OIV 203

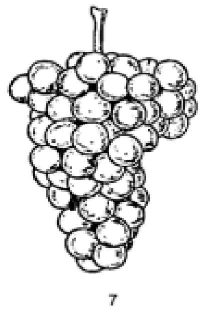
1	3	5	7	9
very narrow	narrow	medium	wide	very wide
up to about 40 mm	about 80 mm	about 120 mm	about 160 mm	about 200 mm and more

11. Characteristic: Bunch: density

Codes N°s
OIV 204

1	3	5	7	9
very loose	loose	medium	dense	very dense

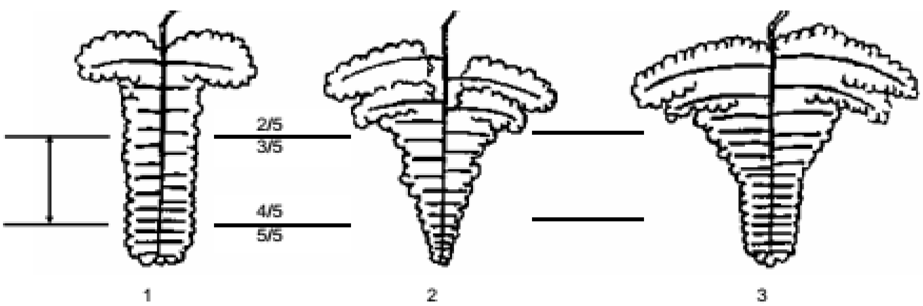




12. Characteristic: Bunch: shape

Code N°
OIV 208

1	2	3
cylindrical	conical	funnel shaped

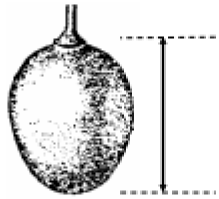


13. Characteristic: Bunch: number of wings of the primary bunch | Code N° OIV 209

1	2	3	4	5
absent	1 - 2 wings	3 - 4 wings	5 - 6 wings	more than 6 wings

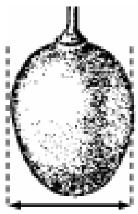
14. Characteristic: Berry: length | Codes N^os OIV 220

1	3	5	7	9
very short	short	medium	long	very long
up to about 8 mm	about 13 mm	about 18 mm	about 23 mm	about 28 mm



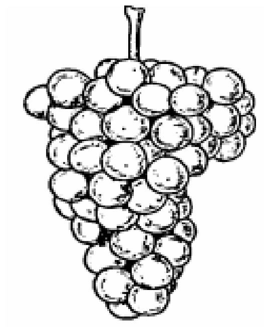
15. Characteristic: Berry: width | Codes N^os OIV 221

1	3	5	7	9
very narrow	narrow	medium	wide	very wide
up to about 8 mm	about 13 mm	about 18 mm	about 23 mm	about 28



16. Characteristic: Berry: uniformity of size

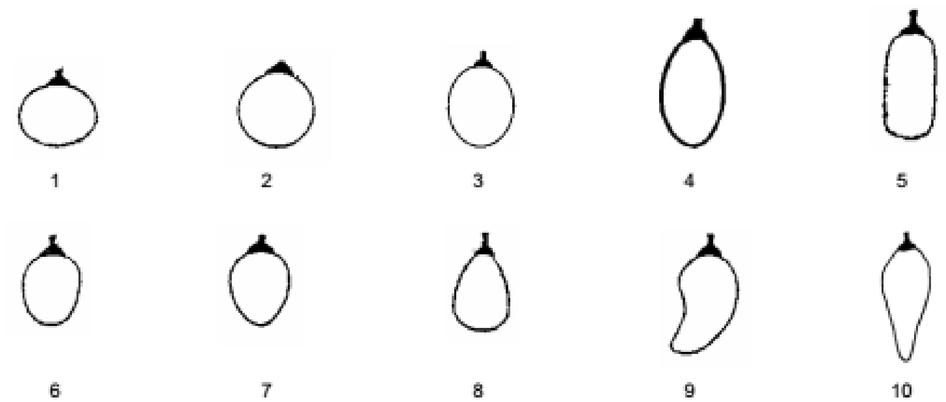
Code N°
OIV 222

1 not uniform	2 uniform
	
1	2

17. Characteristic: Berry: shape

Codes N^{os}
OIV 223

1	2	3	4	5	6	7	8	9	10
obloid	globose	broad ellipsoid	narow ellipsoid	cylindric	obtuse ovoid	ovoid	obovoid	horn shaped	finger shaped



18. Characteristic: Berry: color of skin

Codes N^{os}
OIV 225

1	2	3	4	5	6
green yellow	rose	red	grey	dark red violet	blue black

19. Characteristic: Berry: firmness of flesh

Codes N^{os}
OIV 235

1	2	3
soft	slightly firm	very firm

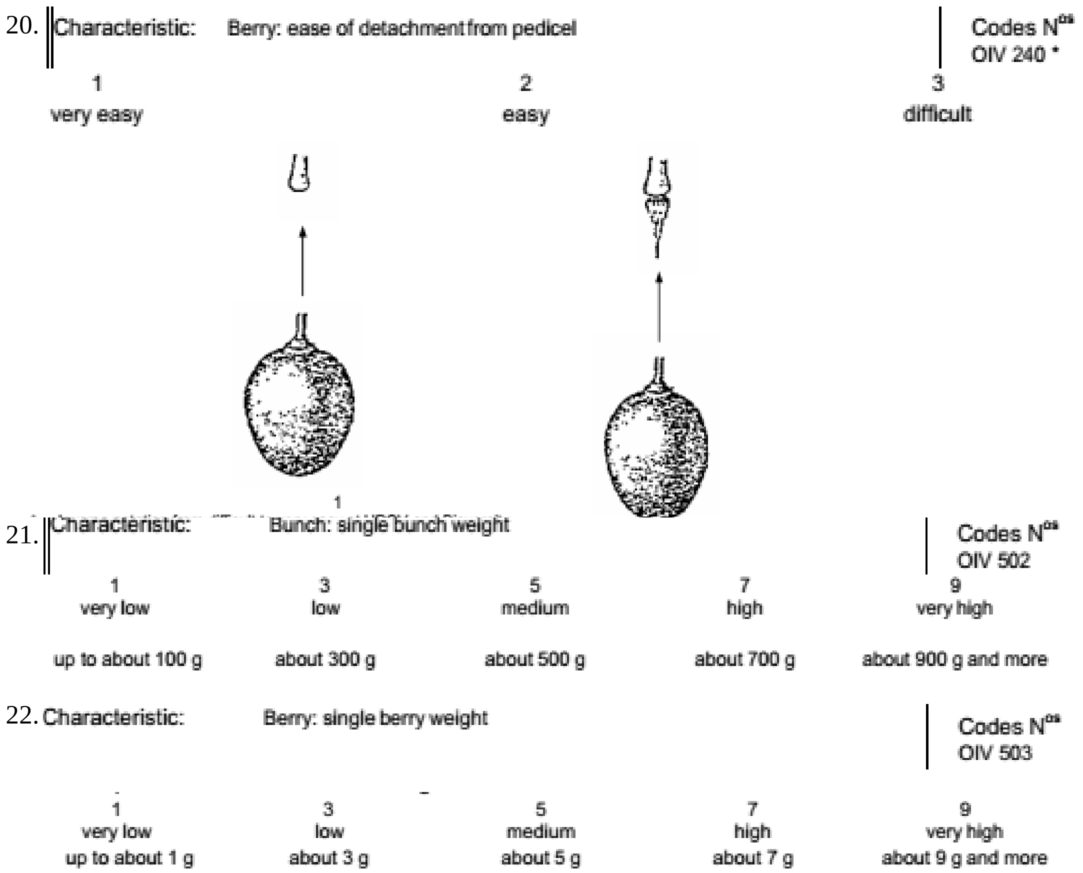


Figure 3.3: Morphological descriptors evaluated for the 8 grape cultivars

3.5.2. Evaluation of growth and yield characteristics of different introduced grape cultivars

3.5.2.1. Days taken for budburst

After the first dormant pruning in September 2018 to establish a permanent trunk, the number of days taken for the buds to break was recorded in each of the cultivars. The objective was to determine the earliness or lateness of the cultivars. Ten canes were tagged per cultivar and data collected when 50% of the terminal buds were in green shoot tip stage.

3.5.2.2. Shoot length (cm)

After the first dormant pruning in September 2018, shoot length was recorded once per week for 12 consecutive weeks. Five shoots were selected randomly for each cultivar and tagged for recording using a string and a ruler. The results were expressed in centimetres.

3.5.2.3.Yield (kg/ha)

The number of bunches borne on the tagged vines in each cultivar was recorded. Each bunch was harvested when ripe and weighed separately. The combined weight of all the bunch from all the 4 replicates was considered as the total yield per cultivar and extrapolated to give yield in kg ha^{-1}.

3.5.3. Evaluation of fruit quality characteristics of different cultivars of introduced grapes.

3.5.3.1. Sample preparation

Three bunches per cultivar were harvested randomly for analysis of fruit physicochemical properties like pH, Total Soluble Solids (TSS) and Total Titratable Acidity (TTA) and sensory parameters. 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 (grape juice) using a filter paper.

3.5.3.2. pH of the Grape Berries

pH of the berries was measured using a pH meter (PHM-2000, TOKYO RIKAKIKAI CO. LTD Tokyo, Japan) at room temperature (23°C ± 2). 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 using the pH meter and the procedure was repeated three times for each cultivar.

3.5.3.3. Total Soluble Solids (TSS or °Brix) of the Grape Berries

The TSS was determined as described by (Organization for Economic Co-operation and Development (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°C ± 2 while held close to the eye. After each reading, the refractometer prism was cleaned with distilled water and dried with soft tissue paper. This test was replicated three times for each cultivar.

3.5.3.4. Total Titratable Acidity of the Grape Berries

The TTA was determined as described by (OECD), 2005). 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 50ml 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 as previously described by (OECD, 2005). The following formula was used:

$$\text{Titratable acidity g/L} = \frac{\text{Acid Factor (0.0075) x Titre of NaOH (ml) x 100 x 10}}{\text{(ml juice)}} \quad (1)$$

3.5.3.5. Sensory Qualities of Grape Berries

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 (Figure 3.4.a) (Jayasena & Cameron, 2008; Lawless & Heymann, 2010). Sensory evaluation was carried out by 35 panellists based on their interest and availability (17 males and 18 female) aged between 24 and 60 years from the Department of Horticulture and Food Security, JKUAT (Figure 3.4.b). Water was provided to the panellists to rinse their mouth after each sample evaluation under a well-lit room (Santillo *et al*., 2014).

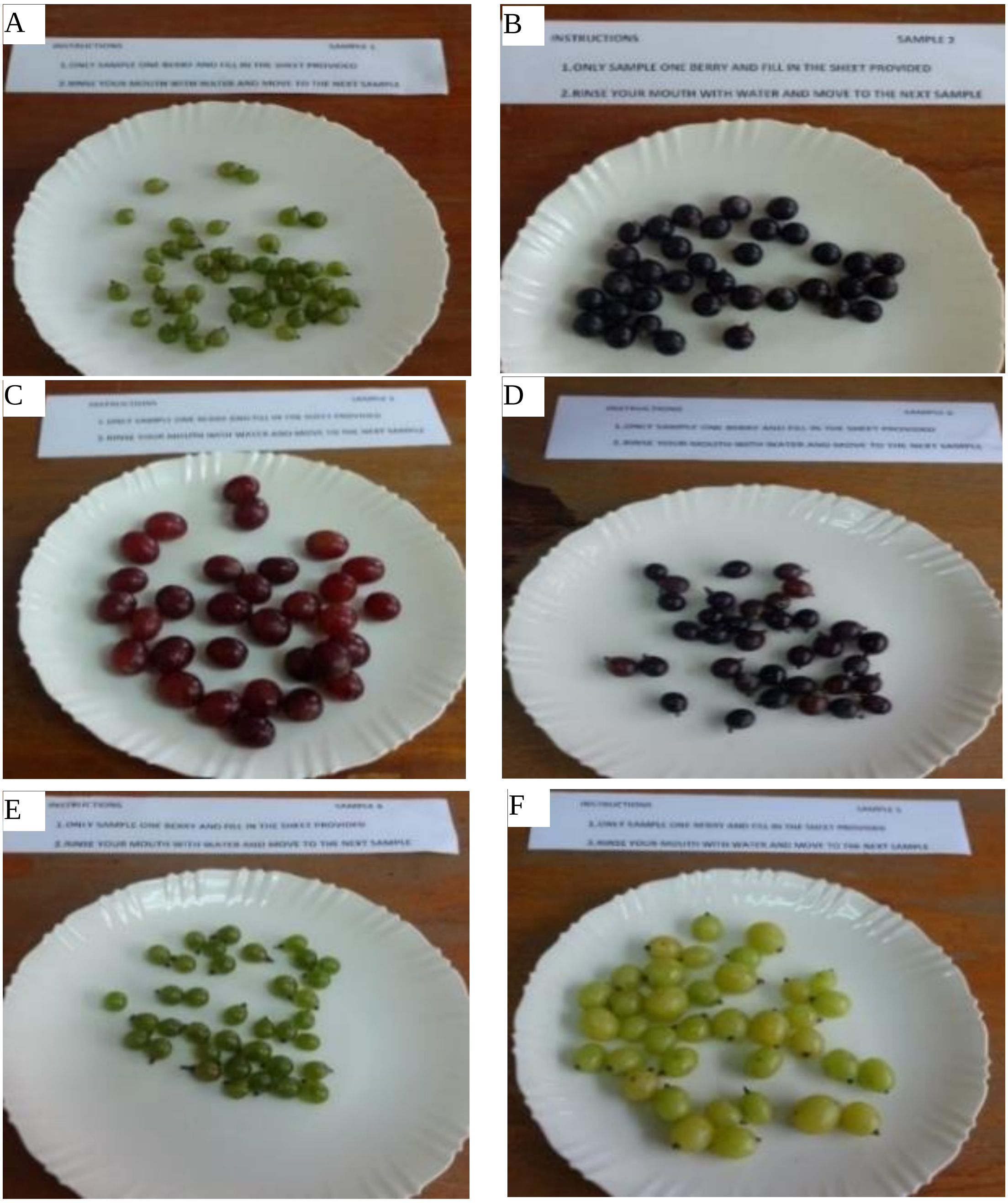


Figure 3.4.a: Grape berries ready for organoleptic testing of the introduced Chinese and French cultivars. A: Chenin Blanc; B: Beifeng; C: Jingyan; D: Beihong; E: Sauvignon Blanc and f: Jingxianyu.

Figure 3.4.b: A panel of JKUAT staffs, belonging to the department of Horticulture and Food Security carrying out organoleptic test of introduced Chinese and French grape cultivars.

3.6. Statistical analysis

Analysis of variance (ANOVA) on days taken for budburst, shoot length, estimated yield parameters and fruit quality data was conducted using SPSS Version 25. The difference among the cultivars 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. Principal Component Analysis was used in the identification of groups, visualization of differences among individuals and the identification of relationships among the cultivars (Martínez-Calvo *et al*., 2008). Pearson's correlation coefficient between the sensory qualities were calculated using XSTAT (Addinsoft, 2019; Jayasena & Cameron, 2008).

CHAPTER FOUR

RESULTS

4.1. Morphological characterisation of different cultivars of introduced grapes

All the cultivars had half-open shoot tip (OIV 001) and two consecutive tendrils (OIV 016) (OIV, 2009). This is a distinctive morphological characteristic of *V. vinifera* grapes. The color of the upper side of the fourth distal leaf from the first unfolded leaf of Chenin Blanc, Sauvignon Blanc, Jingxiangyu and Jingyan cultivars was bronze (OIV, 2009). The copper-reddish color was observed on Cabernet Sauvignon, Jingcui and Beihong cultivar. Beifeng had brown coloration of the lead (OIV 051) (OIV, 2009). Jingxiangyu, Jingcui, Jingyan and Beifeng cultivars had a cordate shape of a leaf, Chenin Blanc and Beihong cultivars had circular, and Cabernet Sauvignon and Sauvignon Blanc cultivars had pentagonal leaf shape (OIV 067) (OIV, 2009). Jingxiangyu, Beifeng, Chenin Blanc and Beihong had three lobes on the leaf, and Jingyan, Jingcui, Cabernet Sauvignon and Sauvignon Blanc had five lobes on the leaves (OIV 068) (OIV, 2009). The shape of teeth on all the cultivars was convex on both sides, except for Jingcui that had straight teeth on both sides of the leaf (OIV 076) (OIV, 2009).The degree of opening/overlapping of petiole sinus was, closed for Sauvignon Blanc, overlapped for Beihong, open for Jingyan, Cabernet Sauvignon, Jingcui, Chenin Blanc, Beifeng and Jingxiangyu (OIV 079) (Table 4.1).

Table 4.1: Morphological description of introduced Chinese and French cultivars

JINGYAN	
Morphological Description Data	
Colour of berry skin	Rose
Variety name	**JINGYAN**
Genus, Species	*VITIS VINIFERA* LINNÉ SUBSP. *VINIFERA*
Country of origin of the variety	China
Use (crop name)	TABLE GRAPE
Holding institution	*Beijing Botanical Garden* *Institute of Botany* *Chinese Academy of Sciences – CAS*

Priority descriptor data			
OIV 004	Young shoot: density of prostrate hairs on the shoot tip	1- none or very low	
OIV 051	Young leaf: colour of upper side of blade (4th leaf)	3- bronze	
OIV 068	Mature leaf: number of lobes	3- five	
OIV 076	Mature leaf: shape of teeth	3- both sides convex	
OIV 079	Mature leaf: degree of opening / overlapping of petiole sinus	3- open	
Bunch / berry descriptor data			
OIV 202	Bunch: length (peduncle excluded)	7 - long (about 200 mm)	
OIV 204	Bunch: density	5- medium	
OIV 502	Bunch: single bunch weight low	5- medium (about 500 g)	
OIV 220	Berry: length	5- medium (about 18 mm and more)	
OIV 221	Berry: width	5-medium (about 18 mm	
OIV 223	Berry: shape	3- broad ellipsoid	
OIV 225	Berry: colour of skin	2- rose	
OIV 503	Berry: single berry weight	7- high (about 7 g)	

JINGXIANGYU	
Morphological Description Data	
Colour of berry skin	Blanc
Variety name	**JINGXIANGYU**
Genus, Species	*VITIS VINIFERA* LINNÉ SUBSP. VINIFERA
Country of origin of the	China
Use (crop name)	TABLE GRAPE
Holding institution	*Beijing Botanical Garden* *Institute of Botany* *Chinese Academy of Sciences – CAS*

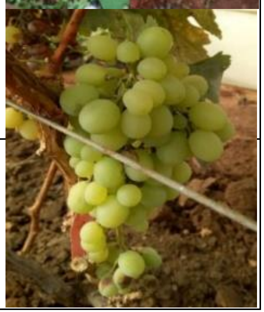
Priority descriptor data

OIV 004	Young shoot: density of prostrate hairs on the shoot tip	1- none or very low
OIV 051	Young leaf: colour of upper side of blade (4th leaf)	2- bronze
OIV 068	Mature leaf: number of lobes	2- three
OIV 076	Mature leaf: shape of teeth	3- both sides convex
OIV 079	Mature leaf: degree of opening / overlapping of petiole sinus	3- open

Bunch / berry descriptor data

OIV 202	Bunch: length (peduncle excluded)	7 - long (about 200 mm)
OIV 204	Bunch: density	5- medium
OIV 502	Bunch: single bunch weight low	5- medium (about 500 g)
OIV 220	Berry: length	5- medium (about 18 mm and more)
OIV 221	Berry: width	5- medium (about 18 mm and more)
OIV 223	Berry: shape	3- broad ellipsoid
OIV 225	Berry: colour of skin	1- green, yellow
OIV 503	Berry: single berry weight	7- high (about 7 g)



JINGCUI	
Morphological Description Data	
Colour of berry skin	Blanc
Variety name	**JINGCUI**
Genus, Species	*VITIS VINIFERA* LINNÉ SUBSP. VINIFERA
Country of origin of the	China
Use (crop name)	TABLE GRAPE
Holding institution	*Beijing Botanical Garden* *Institute of Botany* *Chinese Academy of Sciences – CAS*
Priority descriptor data	

OIV 004	Young shoot: density of prostrate hairs on the shoot tip	1- none or very low	
OIV 051	Young leaf: colour of upper side of blade (4th leaf)	4- copper-reddish	
OIV 068	Mature leaf: number of	3- five	
OIV 076	Mature leaf: shape of teeth	2- both sides straight	
OIV 079	Mature leaf: degree of opening / overlapping of petiole sinus	1- very wide open	

BEIHONG	
Morphological Description Data	
Colour of berry skin	Noir
Variety name	**BEIHONG**
Genus, Species	*VITIS* INTERSPECIFIC CROSSING
Country of origin of the	China
Use (crop name)	TABLE GRAPE/WINE GRAPE
Holding institution	*United States Department of Agriculture (USDA), Agricultural Research Service (ARS)* *Plant Genetic Resources Unit, Cornell University*

Priority descriptor data

OIV 004	Young shoot: density of prostrate hairs on the shoot tip	7- high
OIV 051	Young leaf: colour of upper side of blade (4th	2- bronze
OIV 068	Mature leaf: number of	2- three
OIV 076	Mature leaf: shape of teeth	3- both sides convex
OIV 079	Mature leaf: degree of opening / overlapping of petiole sinus	5- closed

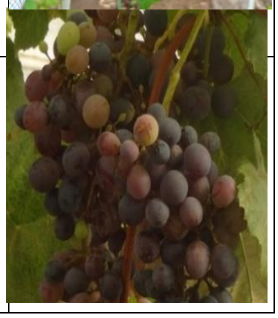
Bunch / berry descriptor data

OIV 202	Bunch: length (peduncle excluded)	1-very short (up to about 160 mm)
OIV 204	Bunch: density	7- dense
OIV 502	Bunch: single bunch weight low	3- low (about 300 g)
OIV 220	Berry: length	3- short (about 13 mm)
OIV 221	Berry: width	3- narrow (about 13
OIV 223	Berry: shape	2- globose
OIV 225	Berry: colour of skin	6- blue black
OIV 503	Berry: single berry weight	3- low (about 3 g)

BEIFENG	
Morphological Description Data	
Colour of berry skin	Noir
Variety name	**BEIFENG**
Genus, Species	*VITIS* INTERSPECIFIC CROSSING
Country of origin of the variety	China
Use (crop name)	WINE GRAPE
Holding institution	*Beijing Botanical Garden* *Institute of Botany* *Chinese Academy of Sciences – CAS*

Priority descriptor data		
OIV 004	Young shoot: density of prostrate hairs on the shoot tip	7 – high
OIV 051	Young leaf: colour of upper side of blade (4th	2- yellow
OIV 068	Mature leaf: number of lobes	2- three
OIV 076	Mature leaf: shape of teeth	3- both sides convex
OIV 079	Mature leaf: degree of opening / overlapping of petiole sinus	3- open
Bunch / berry descriptor data		
OIV 202	Bunch: length (peduncle excluded)	1-very short (up to about 160 mm)
OIV 204	Bunch: density	1- very loose
OIV 502	Bunch: single bunch weight low	3- low (about 300 g)
OIV 220	Berry: length	3- short (about 13 mm)
OIV 221	Berry: width	3- narrow (about 13
OIV 223	Berry: shape	2- globose
OIV 225	Berry: colour of skin	6- blue black
OIV 503	Berry: single berry weight	3- low (about 3 g)



CABERNET SAUVIGNON	
Morphological Description Data	
Colour of berry skin	Noir
Variety name	**CABERNET SAUVIGNON**
Genus, Species	*VITIS VINIFERA* LINNÉ SUBSP. VINIFERA
Country of origin of the	France
Use (crop name)	WINE GRAPE
Holding institution	*INRA*

Priority descriptor data

OIV 004	Young shoot: density of prostrate hairs on the shoot tip	7- high	
OIV 051	Young leaf: colour of upper side of blade (4th	4- copper - reddish	
OIV 068	Mature leaf: number of	3- five	
OIV 076	Mature leaf: shape of teeth	3- both sides	
OIV 079	Mature leaf: degree of opening / overlapping of petiole sinus	3- open	 

SAUVIGNON BLANC			
Morphological Description Data			
Colour of berry skin	BLANC		
Variety name	**SAUVIGNON BLANC**		
Genus, Species	*VITIS VINIFERA* LINNÉ SUBSP. VINIFERA		
Country of origin of the variety	France		
Use (crop name)	WINE GRAPE		
Holding institution	*I.N.R.A UMR 1287 EGFV*		
Priority descriptor data			
OIV 004	Young shoot: density of prostrate hairs on the shoot tip	7- high	
OIV 051	Young leaf: colour of upper side of blade (4th leaf)	3- bronze	
OIV 068	Mature leaf: number of	3- five	
OIV 076	Mature leaf: shape of	3- both sides convex	
OIV 079	Mature leaf: degree of opening / overlapping of petiole sinus	3- open	
Bunch / berry descriptor data			
OIV 202	Bunch: length (peduncle excluded)	3 -short (about 120 mm)	
OIV 204	Bunch: density	7- dense	
OIV 502	Bunch: single bunch weight low	3- low (about 300 g)	
OIV 220	Berry: length	3- short (about 13	
OIV 221	Berry: width	3- narrow (about 13 mm)	
OIV 223	Berry: shape	2- globose	
OIV 225	Berry: colour of skin	1- green, yellow	
OIV 503	Berry: single berry weight	1- very low (up to about 1 g)	

CHENIN BLANC	
Morphological Description Data	
Colour of berry skin	Green
Variety name	**CHENIN BLANC**
Genus, Species	*VITIS VINIFERA* LINNÉ SUBSP. VINIFERA
Country of origin of the	France
Use (crop name)	WINE GRAPE
Holding institution	*INRA*

Priority descriptor data

OIV 004	Young shoot: density of prostrate hairs on the shoot tip	7- high
OIV 051	Young leaf: colour of upper side of blade (4th leaf)	3- bronze
OIV 068	Mature leaf: number of lobes	2- three
OIV 076	Mature leaf: shape of teeth	3- both sides convex
OIV 079	Mature leaf: degree of opening / overlapping of petiole sinus	3- open

Bunch / berry descriptor data

OIV 202	Bunch: length (peduncle excluded)	3 -short (about 120 mm)
OIV 204	Bunch: density	7- dense
OIV 502	Bunch: single bunch	3- low (about 300 g)
OIV 220	Berry: length	3- short (about 13
OIV 221	Berry: width	3- narrow (about 13 mm)
OIV 223	Berry: shape	2- globose
OIV 225	Berry: colour of skin	1- green, yellow
OIV 503	Berry: single berry weight	1- very low (up to about 1 g)

4.2. Principal Component Analysis of the morphological characteristics

Principal Component Analysis of growth and yield of the different cultivars resulted in two principal components (Figure 4.1) that had Eigenvalues greater than 1. 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 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.

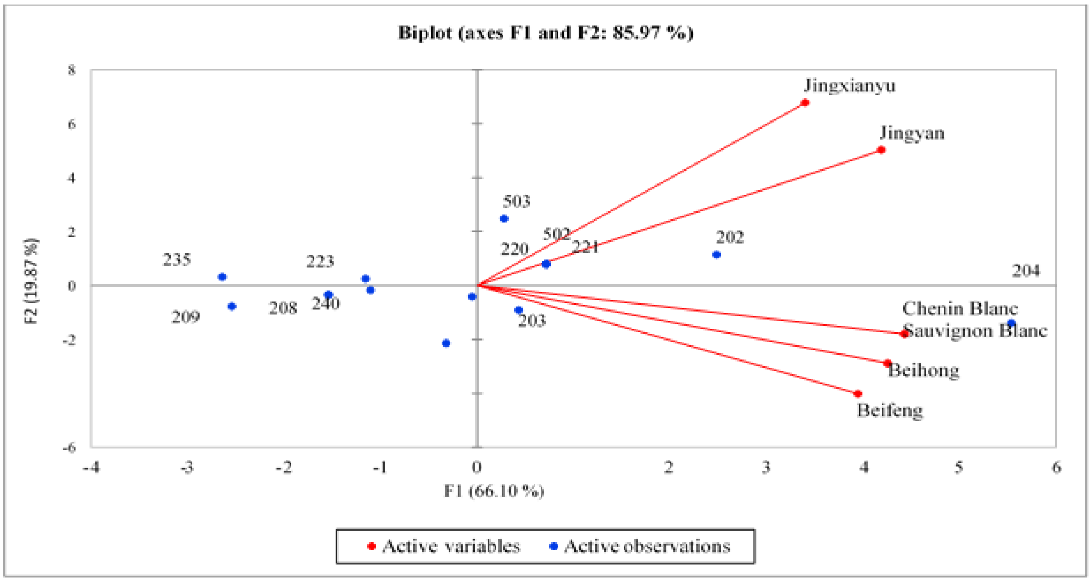


Figure 4.1: Principal component analyses of the fruit morphological characteristics evaluated for the introduced grape cultivars

4.3. Evaluation of growth and yield of different cultivars of introduced grapes

4.3.1. Growth and Fruit Characteristics of Introduced Chinese and French Grape Cultivars

Jingxiangyu and Jingcui took less days (6 – 7 days) to budburst while Beihong took the longest (18 -19 days) time to budburst (Table 4.2). Cabernet Sauvignon and Jingcui cultivar did not flower and therefore no analysis was conducted. Jingyan, Jingxianyu, Beifeng, Beihong, Chenin Blanc and Sauvignon Blanc had hermaphrodite flowers which yielded berries for analysis (Figure 4.2 and 4.3).

Beifeng had three clusters, Beihong had two clusters and the other four cultivars had only one cluster per vine. Berry weight was highest in Jingxiangyu (7.64 g) followed by Jingyan (6.82 g) and lowest in Beifeng (1.46 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 g, 154.8 g, and 145.6 g respectively) (Table 4.3).

Table 4.2: Number of days to budburst and shoot length of introduced grape cultivars cultivated in a greenhouse at JKUAT

Treatment	Budburst Days	Shoot Length
Jingyan	8.8±0.42bc	29.72±2.66ab
Beifeng	12.4±0.48d	31.30±2.53ab
Jingxiangyu	6.9±0.38a	23.47±1.80a
Jingcui	6.9±0.31a	32.25±2.32ab
Beihong	19.2±0.33e	30.16±2.29ab
Cabernet Sauvignon	13.3±0.52d	34.59±2.74b
Chenin Blanc	8.2±0.33ab	36.74±2.58b
Sauvignon Blanc	10.3±0.30c	33.66±2.43ab
P Value	< 0.001	< 0.01

Table 4.3: Yields of introduced Chinese and French Grape Cultivars cultivated in a greenhouse at JKUAT

Treatment	Cluster no/vine	Cluster wt. (g)	Berry wt. (g)	Yield (g/vine)	Estimated Kg/ha*
Jingyan	1c	395.6b	6.82b	396c	2,750
Beifeng	3a	262.8c	1.46d	788a	5,475
Jingxiangyu	1c	440.8a	7.64a	441b	3,062
Beihong	2b	181.3d	2.45c	363c	2,518
Chenin Blanc	1c	145.6e	2.51c	146d	1,014
Sauvignon Blanc	1c	154.8e	2.58c	155d	1,076
Jingcui	-	-	-	-	-
Cabernet Sauvignon	-	-	-	-	-
P Value	< 0.01	< 0.01	< 0.01	< 0.01	

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). Statistical Software SPSS V. 25.

Kg/ha* Extrapolated yield to represent yield/ha [(10,000 ÷ sq. meter/vine) × Yield (g/vine) ÷ 1,000]

Figure 4.2: Inflorescence characteristics of Jingyan, Jingxianyu, Chenin Blanc, Sauvignon Blanc, Beifeng and Beihong cultivated in a greenhouse at JKUAT

Figure 4.3: Grape berries for Jingyan, Jingxianyu, Chenin Blanc, Sauvignon Blanc, Beifeng and Beihong cultivated in a greenhouse at JKUAT

4.4. Evaluation of fruit quality characteristics of different cultivars of introduced grapes.

TSS of all the grape cultivars ranged from 16.3 to 25.2%. Jingxiangyu, Jingyan, Sauvignon Blanc and Chenin Blanc had ideal TTA levels of 6.32, 7.33, 7.25 g/L and 10 g/L respectively suitable for winemaking. The pH range of all the cultivars ranged from 3.07 to 3.55 (Table 4.4), which is ideal for winemaking. The panellists preferred French hybrid wine grapes (Chenin Blanc and Sauvignon Blanc) in regard 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 (Table 4.5).

Table 4.4: Physiochemical characteristics of the fruits of six different cultivars of the introduced grape cultivars

Treatment	TSS (°Brix)	TTA (g/L)	pH
Jingyan	18.4±0.18c	7.33±0.08d	3.15±0.03d
Jingxiangyu	22.0±0.17b	6.32±0.06e	3.42±0.02b
Beihong	16.3±0.18d	25.7±0.17a	3.07±0.02d
Beifeng	18.3±0.09c	21.2±0.09b	3.28±0.01c
Chenin Blanc	21.2±0.29b	10.50±0.13c	3.15±0.01d
Sauvignon Blanc	25.23±0.21a	7.25±0.03d	3.55±0.02a
Jingcui	-	-	-
Cabernet Sauvignon	-	-	-
P Value	< 0.001	< 0.001	< 0.001

The data are expressed as means ± standard error of the mean. The treatments mean followed by the same letters in the same column are not significantly different ($p \leq 0.05$). Statistical Software SPSS V. 25.

Table 4.5: Sensory characteristics of the fruits of six different cultivars of the introduced grape cultivars

Treatment	Sweetness (TSS/°Brix)	Sourness	Crispness	Flavour	Skin Toughness	Colour	Overall Acceptability
Jingyan	6.63±0.37a	5.85±0.45a	6.74±0.24a	6.63±0.31a	6.37±0.33a	7.15±0.29a	6.93±0.33a
Jingxiangyu	7.30±0.29a	5.59±0.46ab	6.63±0.31ab	6.04±0.36a	6.59±0.32a	5.37±0.44b	6.81±0.35a
Beihong	3.41±0.41b	3.89±0.48b	4.85±0.37c	4.56±0.36b	3.89±0.43bc	6.33±0.41ab	4.04±0.47c
Beifeng	3.96±0.39b	4.04±0.49ab	4.96±0.28c	4.22±0.29b	4.41±0.32c	6.15±0.40ab	4.37±0.45bc
Chenin Blanc	6.26±0.33a	5.26±0.42ab	5.41±0.34bc	5.96±0.29a	5.41±0.35ab	4.85±0.41b	5.59±0.43abc
Sauvignon Blanc	7.33±0.21a	4.59±0.49ab	5.78±0.25abc	6.44±0.29a	4.74±0.37bc	5.04±0.46b	5.93±0.47ab
Jingcui	-	-	-	-	-	-	-
Cabernet Sauvignon	-	-	-	-	-	-	-
P Value	< 0.001	< 0.007	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

The data are expressed as means ± standard error of the mean. The treatments mean followed by the same letters in the same column are not significantly different (p≤ 0.05). Statistical Software SPSS V. 25.

CHAPTER FIVE

DISCUSSION

5.1. Morphological characters of different cultivars of introduced grapes

Productivity of all the cultivars was not affected by disease and pests since only powdery mildew affected the vines and it was controlled by spraying Wetsulf fungicide. All the cultivars had half-open shoot tip (OIV 001). This is a distinctive characteristic that differentiates *V. vinifera* species from other *Vitis*. İşçi and Altındişli, (2017) obtained similar results and concluded that all their grapes accessions were *V. vinifera* among them being Cabernet Sauvignon. Jingyan and Jingxiangyu showed broad ellipsoid berry shape while the other four cultivars showed globose berry shape. Salimov *et al*., (2017), states that berry uniformity of grapes is among the most important factors that influence consumer acceptability of grapes. All the berries that were harvested from the fruitful cultivars were conical in shape and their berries were uniform in size which makes them suitable for commercialization. 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 because of different phenolic compounds within the grape skins. Grapes skin colour influences the quality of juice, wine, and the market value of table grapes (Liang & Drohojowski, 2008).

5.2.Growth and Fruit Characteristics of Introduced Chinese and French Grape Cultivars

5.2.1. Days taken for budburst

Time taken for grapevine to burst their buds is used as an index to classify the grapes as either early, mid or late cultivars (Jiazi, 2014). Early cultivars mean earlier flowering and fruit ripening. Jingcui and Jingxiangyu are thus considered early bearing cultivars, Jingyan, Chenin Blanc, Beifeng, Sauvignon Blanc and Cabernet Sauvignon are mid bearing cultivars and Beihong are late bearing cultivars.

The beginning of productive growth and production in grapes is marked by bud burst. It is a variety character, and it is a response of vine to the prevailing environmental conditions such as temperature. Woody plants initiate bud dormancy to endure extreme events such as heat, cold and drought, which are characterized by obstructed metabolic and respiratory activities, apprehended cell division and inhibited growth (Arora *et al*., 2003). Therefore, their adoption to seasonal environmental changes during dormancy ensures simultaneous blooming and survival under extreme environments ultimately improving fruit production under the conditions (Khalil-Ur-Rehman *et al*., 2017). Bud dormancy was overcome by severe defoliation followed by pruning of the vines after the first season (May – September 2018) leaving only 3 – 4 primary buds for next season fruiting accompanied desiccation for a period of 1 month.

5.2.2. Shoot length

There was significant difference in shoot length between the cultivars. The shoot length was highest in Chenin Blanc and Cabernet Sauvignon while the least shoot length was in Jingxiangyu cultivar. Therefore, Chenin Blanc and Cabernet Sauvignon are considered highly vigorous and Jingxiangyu less vigorous. Fruit and wine quality is influenced by the balance between the vegetative growth of a vine and the number of fruits on a given vine often called "vine balance" (Walter-Peterson, 2011). Low and highly vigorous vines are considered to affect grape yield negatively. From the results obtained on yield, Chenin Blanc had the lowest yield which is a direct correlation with its vigorous nature. On the other hand, Jingxiangyu was the second high yielder (3T/Ha) which is a direct correlation with its less vigorous nature. Vine balance is achieved when vegetative growth (vigour) and fruiting load are in equilibrium and this can be judged by the shoot length (Fredes *et al,* 2010). Excess canopy shading affects the fruitfulness of the vine since the penetration of sunlight is blocked and low canopy results to decreased assimilate production from the leaves which does not meet the demand of the clusters

5.2.3. Yield estimates

Yield (g) per vine was highest in Beifeng (788 g) followed by Jingxiangyu (441 g). Difference in bunch weight in different cultivars is attributed to inherent characters of the cultivar, berry size and difference in the number of berries per bunch (Havinal *et al*., 2008; Walker *et al*., 2000). When the yield per plant was extrapolated to represent yield per hectare, Beifeng had the highest yield (5.4T/Ha) while Chenin Blanc had the lowest yield (1.0T/Ha). Unlike production of grapes in the temperate climate where production occurs once a year during the spring-summer season, production of grapes in the greenhouse under the tropical climate occurred twice in a year. This was attributed to overcoming factors such as winter dormancy that affect grape production in the temperate climate. The grape yield/cane depends on the fruitfulness of the vine which constitutes the cluster number and the weight per cane (Fredes *et al*., 2010).

5.3. Evaluation of fruit quality characteristics of different cultivars of introduced grapes.

5.3.1. Total Soluble Solids of the grape berries

Wine grapes with high °Brix levels are preferred as it is the TSS level that determines the alcohol content of most wines (Liu *et al*., 2006). The fruit qualities of grapes revealed that Sauvignon Blanc had the highest TSS levels (25.23°Brix) and Beihong recorded the least TSS levels (16.3 °Brix). The TSS level is a quality trait for grapes that directly affect consumer preference for table grapes. Additionally, wine grapes with high °Brix 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). 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). Among the French Hybrids, Sauvignon Blanc had TSS of 25.23% which was higher compared to Chenin Blanc which had TSS of 21.2%. Jingyan, Jingxiangyu, Beihong, Beifeng, Chenin Blanc and Sauvignon Blanc are therefore considered suitable for fresh consumption as well as wine processing since their TSS was greater than the recommended TSS level of 16°Brix for grapes to be considered ripe (FAO, 2007).

5.3.2. Total Titratable Acidity of the grape berries

The ideal TTA range to produce 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 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 25.7g/L and 21.2g/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). According to KS EAS 138:2014, still table wine should have a TTA of 4 – 12 g/L (Kenya Bureau of Standards, 2015). Therefore, TTA adjustments would be required to enhance the stability of the wine made from the Beihong and Beifeng. Grapes suitability for winemaking is dependent on a sufficient and harmonic content of organic acids (Debolt *et al*., 2007).

5.3.3. pH of the grape berries

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 (Jackson, 2008; MoreFlavor Inc, 2012). 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).

5.3.4. Sensory properties of the grape berries

The introduced Chinese table grapes (Jingyan and Jingxiangyu) had no significant difference regarding sweetness and therefore, their preference was equal. In regard 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. Liu *et al.,* (2007), states that 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.

Jingyan was the most preferred cultivar in regard to crispness while Beihong and Beifeng were the least preferred. The results concur with the evaluated morphological traits of berry firmness of fresh where Jingyan was characterized as slightly firm while Beifeng and Beihong as soft. 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 & 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 (Baldwin, 2002; Muñoz-Robredo *et al*., 2012). Determination of organoleptic qualities of any product plays a big role in its development and marketing (Dzung *et al*., 2003). 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. In reference to colour, Jingyan stood out to be the most preferred cultivar.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1. Conclusion

The viticulture and wine industry are new in Kenya compared to other African countries such as Tunisia, Algeria, Morocco, and South Africa. Kenya being close to the equator provides suitable environment for grapes that require hot climates to thrive such as Sauvignon Blanc. Nonetheless, the viticulture industry does not have breeding programs for developing new cultivars adapted to the Kenyan conditions. Different morphological traits and organoleptic quality attributes were put into consideration in the selection of adaptable introduced grape cultivars. The evaluation of the morphological characteristics highlighted Chenin Blanc and Cabernet Sauvignon as vigorous; Jingxianyu and Jingcui as early bearing cultivars and Jingxiangyu, Jingyan and Beifeng as high yielders. Based on yield results, Beifeng recorded the highest number of clusters compared to the other cultivars. Jingxiangyu and Jingyan recorded the highest berry weight, and the least was in Beifeng. The evaluation of quality characteristics highlighted Jingxiangyu, Jingyan, Sauvignon Blanc and Chenin Blanc to have desired qualities for wine making and Jingxiangyu and Jingyan to have desired qualities for dessert.

From the results of the study, the introduced grape cultivars proved to be of commercial importance and thus there is a need for the development of a grape breeding programme that bring in a reservoir of grape diversity that is critical in developing new cultivars that are high yielding, bearing fruits early and with better quality characteristics. Jingyan and Jingxianyu should be considered for first adoption since they performed best in respect to yield and TSS.

6.2. Recommendations

Kenya being located at the Equator possesses a greater chance of having two growing seasons unlike the temperate regions that only experience one production season due to the cold effects of winter. There is thus a need to adopt introduced grape germplasm to develop new cultivars that will contribute to establishment of wineries to process grapes into wine and increased table grape production in Kenya. The government should then enhance sensitization to establish vineyards in the selected areas of Kenya.

There is also a need for the production of planting materials for the best Jingyan and Jingxianyu. Consequently, smallholder grape farmers will have access to affordable high-quality planting materials. In doing so, Kenya will stand a better chance in reducing unemployment, food and nutritional insecurity and create wealth for the country through export of grapes and its related products, vinegar, jam, grape juice, wine, raisins, jelly, and grape seed oil and grape seed extract.

From the results of this study, Jingcui and Cabernet Sauvignon did not produce flowers that could yield berries for evaluation and analysis under greenhouse conditions. Therefore, the recommendation is to conduct more studies on the influence of budburst chemicals e.g., Dormex to the productivity of Jingcui and Cabernet Sauvignon or reject them and keep them as germplasm.

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APPENDICES

Appendix I: Sensory quality Questionnaire

Gender: Male (   )   Female (   )

You are receiving coded samples of grapes. Please rate how much you liked or disliked the same using the scale below:

1. Disliked extremely 2. Disliked very much 3. Disliked moderately 4. Disliked slightly 5. Neither liked nor disliked 6. Liked slightly 7. Liked moderately 8. Liked very much 9. Liked extremely

Sample No.	Sweetness	Sourness	Crispness	Flavour	Toughness of skin	Colour	Overall Acceptability
1							
2							
3							
4							

Comments:………………………………………………………………………………

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Appendix II: ANOVA of yield for the introduced Chinese and French grape cultivars

		S.S	df	M.S	F	Sig.
Cluster weight	Between Groups	332901.38	5	66580.28	2643.11	0.00
	Within Groups	453.42	18	25.19		
	Total	333354.80	23			
Berry weight	Between Groups	125.76	5	25.15	213.10	0.00
	Within Groups	2.13	18	0.12		
	Total	127.88	23			
Yield (kg)/vine	Between Groups	633140.34	5	126628.07	2680.53	0.00
	Within Groups	850.32	18	47.24		
	Total	633990.66	23			

Appendix III: ANOVA of TSS, TTA and pH for the introduced Chinese and French grape cultivars

		S.S	df	M.S	F	Sig.
TSS	Between Groups	160.947	5	32.189	388.864	0.000
	Within Groups	0.993	12	0.083		
	Total	161.940	17			
TTA	Between Groups	1030.107	5	206.021	6424.783	0.000
	Within Groups	0.385	12	0.032		
	Total	1030.492	17			
pH	Between Groups	0.509	5	0.102	71.051	0.000
	Within Groups	0.017	12	0.001		
	Total	0.526	17			

Appendix IV: Pearson Coefficient of sensory parameters for the introduced Chinese and French grape cultivars

		S.S	df	M.S	F	Sig.
Sweetness	Between Groups	537.681	5	107.536	33.980	0.000
	Within Groups	645.600	204	3.165		
	Total	1183.281	209			
Sourness	Between Groups	101.338	5	20.268	3.296	0.007
	Within Groups	1254.286	204	6.148		
	Total	1355.624	209			
Crispness	Between Groups	114.557	5	22.911	9.446	0.000
	Within Groups	494.800	204	2.425		
	Total	609.357	209			
Berry flavor	Between Groups	164.743	5	32.949	11.723	0.000
	Within Groups	573.371	204	2.811		
	Total	738.114	209			
Skin toughness	Between Groups	228.438	5	45.688	13.855	0.000
	Within Groups	672.686	204	3.297		
	Total	901.124	209			
Color of berry	Between Groups	159.752	5	31.950	7.412	0.000
	Within Groups	879.371	204	4.311		
	Total	1039.124	209			
Overall acceptability	Between Groups	246.367	5	49.273	11.734	0.000
	Within Groups	856.629	204	4.199		
	Total	1102.995	209			