

**ANALYSIS OF APPLE CULTIVARS AND THEIR MANAGEMENT OPTIONS FOR
OPTIMUM YIELD IN THE KIGEZI HIGHLANDS OF UGANDA**

BY

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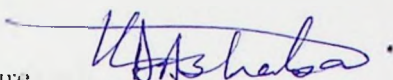
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**RESEARCH DISSERTATION SUBMITTED TO THE DEPARTMENT OF FORESTRY
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MAKERERE UNIVERSITY**

OCTOBER, 2018

DECLARATION

I, Ashaba Denis do hereby declare that this research work is original and has never been published or presented to any institution for an award of any academic qualification.

Signature 

Date..... 24/10/2018

DEDICATION

This work is dedicated to every person who supported me in any way as I pursued this course.

God bless you all,

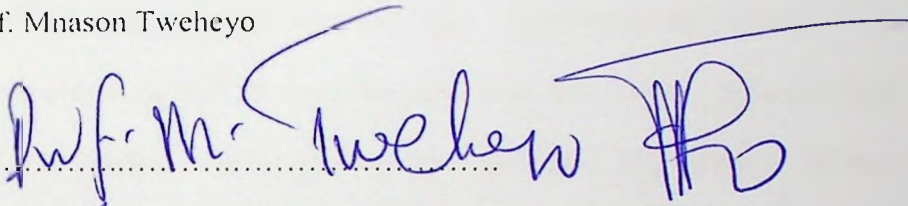
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APPROVAL

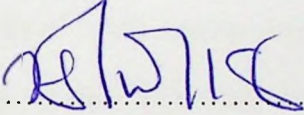
The Dissertation titled "*Analysis of apple cultivars and their management options for optimum yield in the Kigezi highlands of Uganda*" has been written under our supervision and guidance and thereby recommend it for submission to the School of Graduate Studies of Makerere University in partial fulfilment of a Master of Science Degree in Agro Forestry of Makerere University

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Signature.....

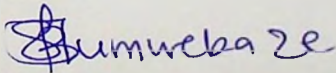


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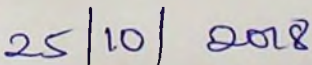


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Date.....



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LIST OF ACRONYMS

ICRAF	International Centre for Research in Agroforestry
NARO	National Agriculture Research Organization
WTO	World Trade Organization
CIAMD	Centre for International Agricultural Marketing and Development
FAO	Food and Agricultural Organization
FAOSTAT	Food and Agricultural Organization Statics Division
AFRENA	Agroforestry Research Network for Africa

ABSTRACT

Apple growing was introduced in Kigezi highlands to eradicate rural poverty by transforming subsistence farming into commercial agro-enterprise of high value crops. The initiative was supported by the government of Uganda for improving household incomes among communities in south Western Uganda. Studies have showed a high potential of the Kigezi region to produce deciduous fruits. However, the yield potential of the introduced apple cultivars has never been realized with some farmers having variations in yields from similar pieces of land. This disparity in yield elicited a lot of concern which necessitated research to maximize yield among farmers in South western Uganda. The aim of the study was therefore to improve orchard management practices for optimal apple yield. This study was conducted to assess the performance of different apple cultivars in relation to orchard location, compare yield with management practises and identify challenges facing apple fruit growers in Kigezi region.

The study was conducted in Kigezi region with the largest number of apple orchards in Uganda dating back over 10 years. A cross sectional survey of farmers' orchards and station orchards was used. A total of 54 farmers and 3 on-station orchards were selected. From these orchards, 20 apple trees per farmer or station were randomly selected. Results showed that higher yields were generally realized when farmers planted apples on the slopes compared to other sites. Furthermore, yields were higher when farmers used 30% pruning, growth facilitation, defoliation at 10 days, bending and staking after 1 year and practising fruit thinning. These results call for measures and policies for more agricultural extension service provision that will enhance good management practises for better yields in apples.

CHAPTER ONE

INTRODUCTION

1.1 Back ground to the study

Apples originate from temperate regions of the world (Janick *et al.*, 1996) and account for 50% of the world's deciduous fruit tree production (Janick *et al.*, 1996). They have been domesticated for more than 5000 years in the areas of their origin (Lewis and Martin, 2005). The main ancestor of apples *M. Sieversii* is believed to be from Tianshan at the boundary between Western China and the former Soviet Union to the edge of the Caspian Sea (Morgan and Richards, 1993). This area could also be the origin of the cultivated *Malus domestica* (Janick *et al.*, 1996). Cultivation of apples seems to have been practised by Romans and Greeks and during their invasions and travels they might have spread it to Europe and Asia (Janick *et al.*, 1996). Later cultivation concentrated around the medieval monasteries. Until the latter half of the 20th century, most of the Worlds' apple cultivars were chance seedlings selected by fruit growers (Janick *et al.*, 1996)

The most planted apple trees (*Malus domestica* Borkh) are temperate trees belonging to family *Rosaceae* and genus *Malus*. The genus *Malus* has 25-30 species and several subspecies many of which are cultivated as ornamental trees for their blossom and attractive fruits (Janick *et al.*, 1996). Apple trees are a high breed mixture of four wild apple variety species namely: *M. sylvestris*, *M. pumilla*, *M. dasyphylla* and *M. sieversii* that occurs in a cool and sub-tropical climate areas (Saver, 1993).

Apples contain high soluble fibre, antioxidant chemicals and unsaturated fatty acids (Oswald, 2002). Apples can be processed into sauce, slices, juice and are floured for pastries, cakes, tarts and pies (Janick *et al.*, 1996). The pulp can be processed into candles and used as a source of pectin. The juice can be consumed fresh either natural or fermented into alcoholic beverages such as cider or wine distilled into brandy or transformed into vinegar. Apple fruits have also been associated with high income and employment with an annual gross global income of about \$ 657.7millionUSD (CIAMD, 2002; WTO, 2004). They are an important crop both for consumption and commercialization.

Apple is one of the most popular fruit trees in the world and China is the leading apple producer in the world. It accounts for annual production of approximately 39.7 million tonnes of fresh apple fruit harvested on 2.41 million ha of land (FAO, 2016; Na, & Fu-suo, 2016). The European Union (EU) and the United States are the 2nd and 3rd largest world producers of apples (FAO, 2016). The major producing countries in Africa include South Africa (649,218 tonnes), Morocco (466,437 tonnes), Egypt (436,931 tonnes), Algeria 364,750 tonnes and Tunisia (96,000 tonnes) contributing 1.43% of the World production (FAOSTAT, 2013).

In Uganda, the apple industry started in 1999 when the Forestry Resources Research Institute (FORRI) and Kawanda Agricultural Research Institute (KARI) initiated trials in the highlands of South-Western Uganda, with the aim of offering farmers an alternative source of income (ICRAF, 2003b). Over the last 7 years, temperate fruit types namely apples, pears, peaches, nectarines, plums, grapes and figs were introduced in Uganda (Namirembe *et al.*, 2006). At present, apple production lies with small-holder family farmers in the highlands of South-Western Uganda. Although apple enterprise has become a gainful cash crop for the people of South-Western

Uganda, its production in South Western Highlands Agro-ecological Zone (SWHAEZ) and Uganda at large is still at a subsistence level (Aheisibwe et al., 2017). The enterprise has over the years seen increasing investments in production, purchase and distribution of apple seedlings to farmers across the SWHAEZ in order to foster adoption of apple growing for income generation. Nonetheless, the country has continued to rely on importation of the fruits from Kenya and South-Africa to meet the increasing domestic demand for apples. Uganda imports over 15,000 tons of apples every year (MAAIF, 2012). Evidence available indicates that Uganda roughly spends over 73 billion shillings each year importing apple fruits without considering juices and other concentrates (MAAIF, 2012). Additionally, performance of apples has continued to fall both in terms of production and profitability as most farmers continue to abandon their orchards (Aheisibwe et al., 2017). However, it remains unclear to which factors influence optimum yield performance of the different apple cultivars in the south western highlands of Kigezi. Therefore, this study analysed the factors that influenced yield performance of different apple cultivars in order to come up with management options for optimum yield.

1.2 Statement of the problem

Uganda imports over 15,000 tons of apples every year to try to satisfy the growing demand (MAAIF, 2012). Apple fruit growing was introduced in the Kigezi Highlands in 1999 (ICRAF, 2005). Few varieties were introduced in 1999 and nine more varieties introduced in 2000. On station research and performance was well monitored. After station trials were done and released to the field, on-farm research was not conducted. This created challenge on management and farm yield reduced compared to on- station fields. There is no information and consistent plan for management of apple trees for optimum yield in Uganda. Due to this, some farmers in

Uganda can harvest three tones while others one tone of fruits and others much less a year per acre (Turyomurugyendo *et al.*, 2004, Turyomurugyendo and Kakuru, 2006).

There is lack of information on the variation of fruit yields among various apple cultivars. Related to yield there is also limited information on timing of silvicultural practices such as bending and staking of branches, pruning, defoliation, fruit thinning and management of pests and diseases. This study therefore analyzed different orchard management options in order to advise farmers on best practices for different cultivar yields. Thus the management options of apple orchards for optimum yield has not been evaluated and documented. It is hoped that after the study, farmers will access this information in order to improve their orchards for maximum yield.

1.3 Objectives of the study

The overall objective of this study was to examine the factors influencing performance of the different apple cultivars in order to come up with the best management option for optimum yield.

1.3.1 Specific objectives

The specific objectives of the study included:

1. To explore the influence of orchard location (valleys, hillsides and hill tops) on apple yield performance in Kigezi Highlands.
2. To find out how orchard management practices affects apple yield performance of the different apple cultivars in Kigezi Highlands.
3. To assess the effect of farm characteristics and orchard management practices on apple yield performance in Kigezi Highlands

4. To examine any other challenges facing farmers in production of apples in Kigezi Highlands.

1.4 Research questions

The study addressed the following specific questions:

1. Are there significant differences in yield performance of apple fruits between farmers in different orchard locations?
2. How does orchard management practices influence yield performance of the different apple cultivars in Kigezi Highlands?
3. What are the effects of farm characteristics and orchard management practices on apple yield performance in Kigezi Highlands?
4. What other challenges are faced by farmers in production of apples in Kigezi Highlands?

1.5 Justification of the study

This study seeks to analyse cultivars and management options for optimum yield of apple orchards in the Kigezi highlands. The agronomic practices, farmer innovations, , fruit yields on variety basis will be documented. This will provide base-line information on adoption of recommended agronomic and silvicultural practices for apple orchard management, as well as provide information on current apple yield in the region. Secondly, this will contribute to development of better apple orchard management practices for improved yields from farmers' orchards. Standardised apple orchard management is likely to stimulate apple productivity in Kigezi and hence increased household incomes and consumption of fruits among highland communities. This will further improve the nutritional status of vulnerable groups such as children, lactating mothers, sick and elderly people.

The findings of this study will also improve capacity of agricultural extension workers, policy makers, politicians and development planners in support for the development of apple growing particularly in Kigezi and Uganda in general. Dissemination of the findings to farmers will encourage rehabilitation of abandoned apple orchards to productive status and promote adoption. The study will stimulate adoption of technologies for large scale production of apple fruit growing in the country as well as identify opportunities for further research and inform interventions in apple production in Uganda.

CHAPTER TWO: LITERATURE REVIEW

2.1 Origin and distribution of apples

Apples spread in its wild state in most countries of Europe and is believed to have originated from the Asiatic centre, the origin of cultivated plants (Janick *et al.*, 1996). Apples are temperate fruit trees which originate from regions with marked seasons of winter, spring, autumn and summer. These deciduous plants shed (lose) leaves/foilage naturally due to chilling effect of temperate winters that induce dormancy. These extreme cold conditions favourably stress apple trees and induce them to immobilize food in dormancy to be used during flowering growth. The climax of the dormancy period is the beginning of vegetative growth in which buds breaking to flowering especially at the beginning of summer. Winter is also crucial in the control of orchard pests and diseases whose life cycles are interrupted because most vegetative plant parts like leaves are lost (defoliated naturally) and terminal and lateral buds are dormant thus providing no food and habitat for their survival (Russell and Franzel, 2004). However, apples have been successfully introduced in the tropics.

In Africa, leading temperate fruit producers are mainly in South Africa, Egypt, Tunisia, Morocco and Algeria. Tropical areas lack marked winter and summer but in some areas especially highlands, apple fruit growing have been adapted due to cold climate, analogous to temperate regions. Despite lack of this chilling winter, tropics offer suitable conditions for continuous vegetative growth without undergoing foliage-shedding and dormancy unless induced by manual defoliation. Manual defoliation offers orchard managers opportunity to manipulate growth cycles and achieve two harvest seasons in a year under tropical conditions unlike in temperate regions

(Chemining'wa *et al.*, 2005). However, continuous tree growth presents persistent pests and disease problems compared to temperate regions.

Apple varieties vary in size from a little larger than a cherry to as large as a grape fruit. Apples are fat, sodium and cholesterol free, are a source of fibre pectin, essential vitamins and one apple has five grams of fibre and about 80 calories (Lewis and Martin, 2005). Apple growing is no longer considered as a luxury but a necessity for sustaining human nutritional needs (Musana *et al.*, 2006).

2.2 Apple production in Uganda

In 1999, the International Centre for Research in Agroforestry (ICRAF) started apple demonstration trials in the Kigezi highlands of Kabale in its agroforestry activities (ICRAF, 2003b). Apple growing was introduced in Kigezi highlands to eradicate rural poverty by transforming subsistence farming into commercial agro-enterprise of high value crops. The initiative was supported by the government of Uganda for improving household incomes among communities in south Western Uganda (Chemining'wa, *et al.*, 2005).

Four varieties of apples namely Anna, Golden Dorset, Rome Beauty, and Winter Banana were planted on-station in Bugongi, Kalengyere and Kachwekano stations, Kabale District by AFRENA- Uganda project in conjunction with National Agriculture Research Organization (NARO) and Kawanda Agricultural Research Institute (Namirembe *et al.*, 2006). Nine more varieties were introduced in 2000 for further evaluation on-station. Following on-station trials with good fruit yields, two varieties that had promising yields were taken for on-farm trials (Chemining'wa *et al.*, 2005; Turyomurugyendo and Kakuru, 2006).

The initial performance of the apple fruits on-station and on-farm elicited lots of enthusiasm and interest from farmers and leaders. This resulted into considerable investment in the enterprise by farmers and local governments in Kigezi to purchase and distribute fruit tree seedlings for planting (Chemining'wa *et al.*, 2005; Turyomurugyendo *et al.*, 2004; Turyomurugyendo and Kakuru, 2006). According to AFRENA, (2001) the location and altitude of Kigezi highlands offered a promising temperate like climatic conditions at 1500-2400 m above sea level which is suitable for temperate fruits. The enterprise has over the years seen increasing investments in production, purchase and distribution of apple seedlings to farmers across the highland agro-ecological zones in order to foster adoption of apple growing for income generation.

Apples among many tropical fruits have a high market in Uganda (ICRAF, 2003a; Ssemwanga, 2003). The consumption of apples is mainly in urban centres but of recent has moved to rural areas.

The continued importation and the increase in quantities and varieties indicate a ready local market for apples. Over 115,000 million USD worth of apples have been imported annually to try to satisfy this growing demand (World Agro forestry Centre, 2003). Imported apples are expensive and most local people cannot afford them. It is assumed that locally produced apples would be more affordable to local people. There is also a ready local market in Kigezi and in surrounding areas. In these areas, traders already have knowledge of and are willing to stock local apples. For example, most supermarkets in Kigezi demand for the local apples claiming that local apples are sold better than the imported ones due to lower prices, and that they taste better. However, the competitive edge of locally produced apples can be gauged on their ability to command a stable market share and even substitute imports at the national markets. The biggest challenge to date is the limited quantities and the inconsistent deliveries from local

orchards due to low and unreliable apple production caused by unstandardized orchard management practices

2.3 Taxonomy and Botany of apples

Apples belong to Kingdom: *Plantae*, phylum: *Magnoliophyta*, Class: *Magnoliopsida*, Order: *Rosales*, Family: *Rosaceae*, Subfamily: *Maloideae*, Genus: *Malus*, Species: *Malus domestica*. *Malus domestica* is a hybrid mixture of four wild apple species of *M. sylvestris*, *M. pumilla*, *M. dasycarpa*, and *M. sieversii* that occur in the cool and sub-tropical climate (Saver, 1993). The genus *Malus* has 30-35 species with more than 5600 horticultural forms classified on time of maturation, colour, size, flavour or state of consumption (Kochhar, 1996).

An apple tree is a slow standing tree that reaches a height 12.5 metres high, under cultivation leaves are simple, dull green in colour and clustered on short shoots. Flowers blossom and leaf buds occur in terminal cymes on spurs borne on rapid growing shoots (Zobel *et al.*, 1982). Flowers have numerous stamens in 3 whorl and inferior ovary, apple flowers are insect pollinated. The fruit is a pome, spherical green to yellow red skin in colours with a fresh apocarp and edible endocarp (Kozlowisky *et al.*, 1997).

2.4 Ecology of apple production

Apple trees are indifferent to all soils provided they are fairly fertile, deep and well drained with small quantities of lime and slightly acidic (Kochhar, 1986). The best pH range is between 6-6.5, but soils with pH values below 5 may be limed before planting (Griesbach, 1992). However they can tolerate an array of alkaline conditions such as the alkaline soils in Yakima and Columbia Basin where apples do well (Roper, 1998). Apples in poorly drained soils, for example in clay soils in low lying areas, succumb to anaerobiosis and or phytophthora root rot especially

if water remains in the root zone (Parker, 1997; Andersen and Crocker, 2000). According to Chemining'wa *et al.*, (2005), the soils in Kigezi are acidic to slightly acidic loams, reddish brown clay loams, humus loams and yellowish red clay loams with generally a good nutrient supply, and with natural fertility and good drainage (Nair, 1984). These soils are generally suitable for apple production except for the poorly drained soils of the bottom lands and the heavy clays.

Apples grow well on an altitude of (1500m to 2900m) above sea level in highland areas (Notodimedjo *et al.*, 2005). According to Bal. (1997) altitude influences regular fruit bearing and colour development in apple cultivars. Apples and other temperate fruit grow well in regions with hot dry summers and cold wet regions with pronounced periodicity. Many apple varieties grown need many hours of coldness to break dormancy and initiate flowering (Griesbach, 2007). Insufficient breaking of dormancy results in slow or no bud development thus affecting flowering. Temperatures below 7.2°C provide the required chilling units for some apple cultivars to break dormancy.

2.5 Propagation of apples

Desired root stocks are propagated on by grafting, seed stratification in moist sand at 2°C in a fridge to enhance rapid germination. When seedlings (rootstocks) attain pencil like and stick thickness (ICRAF, 2003b) are grafted. Grafting is done on rootstocks because they are tolerant to diseases. Apples are grafted to enhance early fruiting, to produce quality fruits, to control the tree size and height for easy harvesting (ICRAF, 2003b).

2.6 Management of apple orchards

2.6.1 Tree management

Young apple trees require training to obtain a tree with lateral branches almost perpendicular to the trunk and radially spaced around a central leader to encourage branching. The trees have to be pruned to remove diseased, dead, weak branches and water suckers. Pruning is done to give the tree a desired shape (ICRAF, 2004). Pruning also opens up the tree so that light can get to all plant parts, and enable development of flower buds into flowers and flowers into fruits. It also enables fruits to ripen and obtain an even colour. The practices of tree training and pruning are important for maintaining high apple tree production. Tree management is an important practice in apple production. Fruit thinning and the removal of excess flowers from the inflorescence is an important management practice to avoid overcrowding of fruits. Thinning of fruits improves their size and quality, thereby increasing the marketable fruits.

2.6.2. Tree training and pruning

The objectives of tree training and pruning are to develop and maintain small, conical shaped (Christmas tree shape) trees that are capable of early production of large crops of high quality fruit (Edwin, 2014). Trees are pruned to help maintain a balance between vegetative and reproductive growth throughout the tree and to maintain desired tree shape and size with an open tree canopy that allows penetration of sunlight, fungicides and pesticides. The practices of training and pruning are not easily separated because the training of a young tree will determine how the tree will be pruned as it matures. Sunlight is critical to tree growth and cropping. Pruning can alter light interception and its utilization by the tree. Sunlight is the sole source of energy for plant growth. Green leaves intercept light energy and convert it to chemical energy

through the process of photosynthesis. Photosynthetic products (carbohydrates) are required for vegetative growth, fruit set, fruit growth, fruit colour, and flower bud initiation and development.

Pruning tends to encourage vegetative growth, which is antagonistic towards flower bud formation. Additionally, pruning encourages flower buds development which leads to formation of future flower. Pruning usually improves fruit quality by improving light distribution throughout the tree and by reducing the number of fruits per tree (Heinicke, 1964). Fruits on pruned trees tend to be larger than on non-pruned trees because there are fewer fruits competing for carbohydrates. Therefore, to encourage fruiting, young trees should be pruned judiciously. To improve fruit quality and reduce over cropping, mature trees should be pruned annually.

In order to help the apple tree to produce high quality fruits, annual training and pruning are required. Training is the process of selecting limbs that will eventually support the weight of the fruits– the skeleton of the tree (Heinicke, 1964). Training and pruning a tree can be difficult if you do not know what you are doing and in some cases you can do more harm than good. When training an apple tree it is important to select limbs that have wide crotch angles. Limbs with narrow attachments to the trunk are not as strong those limbs that attach almost perpendicular to the trunk. Narrow crotch angles can easily break under crop load or excessive icing during the winter. Make sure that when choosing the bottom limbs of the tree, they are at the desired height from the ground. Limbs that are too low may make the tree difficult to mow around and limbs which are too high may result in fruits that cannot easily be reached from the ground. Most commercial apple growers will prune and train their trees in the shape of a Christmas tree. This means that their longest limbs are going to be the bottom branches and the limbs will get

progressively shorter as you go up the tree. This type of training improves sunlight penetration into the tree, which helps with disease control and better fruit quality (Heinicke, 1964).

Unlike most shade trees, apple trees require annual training and pruning from the time of planting to produce an attractive and productive tree (Edwin, 2014). Proper training and pruning are also a valuable part of an effective pest management program. Pruning to open up the canopy improves air flow, reducing some disease problems. An open canopy also allows better access for managing insect pests (Edwin, 2014). Training and pruning cannot compensate entirely for poor horticultural factors such as poorly matched scions (the above-ground portion of the tree) and rootstocks. For example, if a strong spur-type scion, which produces little vegetative growth, is grafted to a dwarfing rootstock, the resulting tree will "run out." That is, it will produce little new growth and small fruit, regardless of how it is pruned. On the other hand, a vigorous scion on a standard or semi-dwarf rootstock planted in a fertile soil will become large, unmanageable tree that can-not be pruned into submission.

2.6.3. Fruit thinning

In favourable conditions fruit trees set more fruits than is ideal. Fruit thinning involves removing excess fruits from a cluster to improve fruit size and quality (Dennis, 1999). It is carried out on apples, pears, plums, peaches and nectarines. Many healthy fruit trees drop fruits naturally in early summer in what is known as the 'June drop'. Where a heavy crop has set, too many fruit lets may remain on the branches, resulting in a final crop of disappointingly small fruits. Deliberate thinning of the fruitlets produces better-sized, ripe and healthy fruits, albeit in smaller numbers.

The main purpose of thinning is to improve fruit size and quality. When a tree is carrying a very heavy crop, the fruits are often small and of poor quality, thinning allows sunlight and air to penetrate the branches, so improving evenness of ripening, there is a risk of branches breaking if trees over crop, thinning lessens the demand on the tree's resources so it is able to make good growth and develop fruit buds for the following year so avoiding the risk of biennial bearing, young trees allowed to crop too heavily will be set back, fruit thinning may reduce the spread of pests and diseases, such as brown rot. Fruit thinning has been practiced for thousands of years, and serves a number of purposes. Too many fruits per tree can result in small fruit size and poor quality, breakage of limbs, exhaustion of tree reserves, and reduced cold hardiness (Dennis, 1999). In some species/cultivars, heavy fruiting can also partially or completely inhibit flower bud initiation.

Thinning is done for two reasons. First, a certain portion of the fruits is removed so that the remainder will develop adequate size and quality. Second, the thinning process serves to increase the plant's ability to form flower buds for the next year—provided the thinning is done early enough (Basak, 1996). Thinning also reduces the total load on the branches and reduces breakage. Hand thinning is the easiest and safest way to remove excess fruits. Hand thin fruit when the fruits are the size of the end of your little finger—about 1/2 inch in diameter (Jones *et al.*, 1988). Simply start at one end of a branch and systematically remove fruits, leaving one fruit at every 6 to 10 inches. It is best to cut the fruit off rather than pulling the fruit. Cutting the fruit will lessen the chance of damaging the spur. Be sure to leave only one fruit at a given site. Where doubles or triples are left, insects and disease will be difficult to control. Keep in mind that only 7 or 8 percent of the tree's flowers are needed to set a full crop of fruit. An alternative to

hand thinning is foliar application of the insecticide Sevin (carbaryl). This method might be necessary on large trees that are difficult to reach. Disadvantages of chemical thinning include the inability to selectively position fruits; there is danger of removing too many or too few fruits, and the potential to increase mite populations. Sevin as a 50WP should be mixed at a rate of 2 to 4 tablespoons per gallon of water and applied in a foliar spray to thoroughly wet the leaves. Apply 10 to 14 days after bloom. Wait for 7 days, and then assess the number of remaining fruits. If too many fruits remain, they can be hand thinned easily, or a second application of Sevin can be applied at the same rate.

Fruit thinning is the most important technique in apple growing for improving fruit quality (Basak, 1996). Since thinning can be performed mechanically or chemically, thinning intensity may vary not only on the method used but also on the physiological condition of the trees and cultural practices employed. For the fresh market, fruit size, appearance, flavour, firmness and storability are of main interest. The grower therefore, will have to focus his orchard practices to satisfy these market demands in order to produce high quality fruit consistently at maximum yields.

It is impossible to maximize all quality factors simultaneously, because there are positive and negative interrelations among them. Therefore, a reasonably balanced compromise between quality and quantity must be achieved. The grower must find the correct point of this compromise, based on his management skills, cultivars grown, cultural practices employed and marketing goals. There is little chance to provide a recipe to fit all situations

Apple orchards at Kalengyere and Bugongi research sub stations in Kabale district are managed in accordance to recommended agronomic and silvicultural practices and offer demonstration visits to farmers. In addition to the management practices that farmers are familiar with, apple farmers also have to learn numerous specific fruit tree management practices such as tree training, bending and staking of branches, defoliation, fruit thinning and pruning for worthwhile investment in apple growing. A survey of farmers' management practices by ICRAF showed that of the farmers given seedlings in 2000-2001, only 38% were practising the recommended practices (ICRAF 2004). On many farmers' orchards recommended management practices are not widely practised because farmers are given seedlings without sufficient sensitization in apple growing. Farmers still view apple trees as any other tree, which can be left to grow and produce without much management. The problems of tree management are indicative of the limitations in the provision of advisory services in apple production. The limited capacity of scientists and organizations promoting apple production technologies in Kigezi is unlikely to be able to cope with the potential management problems that may emerge as more and more farmers engage in apple production. This is worsened by the fact that the first dissemination of the apples was not confined to specific zones but spread over large areas within the zone and beyond, thus complicating the provision of services to farmers.

2.6.4. Synchronization of flowering and fruiting

The synchronization of flowering and fruiting so as to obtain more than one crop per year has been identified by Kachwekano ZARDI as a major challenge and one likely to remain so in the near future (Field report 2014, Unpublished). The main problem seems to be the uniformity of bud burst after breaking dormancy. Flower buds on the same trees do not open at the same time, causing a prolonged tree flowering/fruiting period. This can have a negative effect on fruit

quality as development of the late flower buds may not fall within favourable weather for fruit set.

Fruit set is likely to experience problems when flowering coincides with the wet season (Notodimedjo *et al.*, 2005) as well as when temperatures are high (Edwards, 2005). Other problems that apple farmers face are related to flower abortion and premature fruit falling. Evaluation of both farmers' orchards and on-station orchards revealed that fruits on the same tree were at different stages of growth, some trees were defoliated, while some were flowering and others were fruiting. These flowering and fruiting problems are likely to become a major impediment to apple production. The ability to have two fruiting seasons per year namely March to June and September to December may also present opportunities for marketing. For example, farmers in a sub-county may synchronize flowering to harvest around June while other groups may synchronize the flowering to exploit the market in December period. Alternatively, individual farmers could manage sections of their orchards to produce fruits alternately in the two seasons. In the future, opportunities in the use of chemicals to defoliate and break rest (where defoliation is not sufficient) should be explored (Edwards, 2005). Ways of dealing with these problems need to be studied especially with respect to synchronization with the season. For example, are the apples fruiting at the best possible time in the season? Research is needed to develop standard agronomic and silvicultural practices suitable for on-station and on-farm apple growing.

2.5 Management of apple diseases

Apple scab is the major disease that constrains apple production in the tropics, affecting both the fruit quality. The management of apple scab is vital for the overall orchard health and maintenance of fruit yields (Agaba 2008). The reduction or prevention of primary infections of

apple scab during the rainy seasons is the main goal of disease management by orchard owners. Extensive primary infections result in poor fruit set and make apple scab control during the season more difficult. If primary infections are successfully controlled, secondary infections will not be serious. The key to success in apple scab control is choice of materials, exact timing and full coverage during spraying (Gubler, 2006). Apple scab prediction systems have been developed and successfully used in practice to assist in timing fungicide applications (MacHardy, 1989; Xu *et al.*, 1995; MacHardy 1996; Berrie, 1997). Use of forecasting systems led to a reduction in fungicide inputs while maintaining satisfactory control of apple scab in England (Berrie, 1994; Berrie, 1997). These apple scab forecasting systems are based on relationships between apple scab incidence or severity, resulting from infection by conidia and ascospores, with temperature, amount and duration of rainfall, and duration of leaf wetness (Schwaba, 1980; MacHardy, 1989; Xu *et al.*, 1995; MacHardy, 1996). Wet periods, temperature, and relative humidity are important factors (Rossi *et al.*, 2003).

Good sanitation practices are necessary to control apple scab problems, cutting all dead or diseased wood, removal of weak branched and clearing leaves and fallen debris away from trees minimizes disease spread (Parker, 1997). The leaf litter removal reduces fruit scab incidence and severity by over 54.6% and 67.7% respectively, because leaf litter management by leaf removal allows a reduction in apple scab inoculum thus the benefit of a complete removal of the leaf litter (Gubler, 2006). Pruning and training branches horizontally to induce lateral bud growth and reduce re-growth of the terminal buds, hand defoliation to induce bud burst and flower emergence (Chemining'wa *et al.*, 2005).

In bid to control apple scab, an alternative to spraying is the cultivation of resistant cultivars, which can be grown with no fungicide application (Tiirmaa *et al.*, 2006; Crosby *et al.*, 1992;

Janick, 2002). The most environmentally friendly and consumer-safety oriented method for the control of apple Scab is the use of scab-resistant cultivars (Koch *et al.*, 2000). Molecular markers linked to apple scab resistance would accelerate breeding by making it possible to select resistant individuals, regardless of the growth stage, interaction between resistance genes, and source of inoculum or environmental conditions (MacHardy 1996; Cheng *et al.*, 1998). For apple growers, it is very important to know the apple scab resistance of the cultivars in the orchard, so that the most susceptible ones can be avoided (Sandskar and Gustafsson, 2004).

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Description of Study Area

The study was conducted in Kigezi highlands because the area has the largest number of apple orchards in Uganda dating back over 10 years. Kigezi is located in South Western Uganda between approximately latitudes $1^{\circ}32'S$ and longitudes $29^{\circ}53'20'E$ (Grisley and Mwesigwa, 1995). It is composed of districts of Kabale, Kisoro, Kanungu and Rukungiri. To the West, Kigezi is bordered by Democratic Republic of Congo, Kasese, Mitooma and Ntungamo in the North, Republic of Rwanda to the South (See *the map of the study area below*)



Kigezi highlands are characterized by rugged and broken hills, dead arched river valleys, scattered rift valley lakes, and gentle to steep convex slopes of 5-10 to 10-350 adjacent to reclaimed papyrus swamps (Aniku, 2001). The middle slopes are covered by upland bracket vegetation (ferns) creepers while the upper slopes are covered by grasses such as *Digitaria scalarum* and *Pennisentum perpereum* (Aluma, 2001). *Eucalyptus* species dominate in the area as people planted them extensively on bare hill slopes, small house hold woodlots and in valleys to meet energy demands of the surrounding communities and to control soil erosion especially due to their fast growth characteristic (FAO, 1985).

Kigezi highlands share the Ankole-Karagwe system whose rocks rest on the Buganda-Toro system with meta-calcareous rocks at the base. Most of the surface rocks are detrital sedimentary rocks, common shells, silt stones, phyllites, and mudstones. On the gentle slopes adjacent to the valleys, arenaceous rocks mainly arkoses and grey wackes are common. Over 70% of the area is covered with ferralitic sandy clay loams (Harrop, 1962 and Hadoto, 2001). The clay loams, clay and peat clay alluvium occurring in valleys (Hadoto, 2001). The soils in Kigezi are volcanic and humic, dystic and entric, nitosols and ferralsols which are usually fertile. These soils are arranged on the Kigezi catena though on principle ridges and more particularly in saddles of the steep topography, the transition sometimes is quite sharp, to dark horizons of the Mafuga unit and there is much local variation often, attributed to changes in parent rock material in form of outcropping bands of quartzite (Harrop, 1962).

Kigezi highlands experience a bimodal pattern of rainfall with two marked dry and wet seasons (Aniku, 2001). The first rains are from March to June and second rains from September to December. The driest period is from June to September. The average annual rain fall is about 1000mm and varies from 720-1500mm. Most of the rainfall is relief because of the hilly nature of the area. The humidity of the area has been declining as evidenced by low morning mist and at times absence of the morning fog as it used to be a decade ago, fog hours have reduced from up to 11 o'clock to about 9 o'clock or even completely absence of it (Kabale meteorological station, 2005). Kigezi is generally cold with daily temperatures modified by altitude, ranging from 14⁰c to 18⁰c indicating a diurnal range of 4⁰c and an average temperature of about 16⁰c. Arise in temperature to a maximum of 30⁰c has been recorded during the day in the dry season which is attributed to massive deforestation and swamp reclamation for agriculture. Nights are cold while mornings in most valleys and higher grounds are foggy; also mornings in Kigezi are very chilly due to the mist that stays up to around 10 O'clock (Kabale meteorological station, 2000).

3.2 Research design

This study involved use of both quantitative and qualitative approaches. Quantitative approaches were utilised in capturing variables like fruit yield, fruit sizes, stem diameter, age of the tree and tree growth characteristics among others. Qualitative approaches were employed in capturing data on site location, management practices, and challenges facing farmers in apple production.

3.2.1 Selection of study area

The population of the study comprised of farmers who had been growing apples for at least five years. The study was carried out on 54 apple farming households that were spread in the districts of Kanungu, Kabale, Kisoro and Rukungiri that form Kigezi region. The study used

multi-stage sampling technique. The first stage was purposive selection of four (4) districts and at least three (3) sub-counties in each district on the basis of concentration of apple production. The second stage involved purposive selection of two parishes from each of the apple producing sub-counties. The third and final stage involved random selection of at least 50 percent of apple producers from each parish, making a total of 54 on-farm orchards for the study (Table 3.1). Due to the fact that ICRAF was based in Kabale district, three (3) on –station research orchards were purposely selected in Kabale district. A random sample of twenty (20) apple trees from each on – farm orchard and on- station orchards were studied. Twenty (20) trees per orchard were selected because these would represent the released apple cultivars as there were no farmers who had planted more than five cultivars. A total of 1140 trees (1080 trees from on-farm orchards and 60 trees from on-station orchards) were monitored for this present study.

Table 3. 1 Number of apple farmers selected from each parish

Districts	Sub counties	Parishes	Apple farmers	Sampled Apple farmers
Kisoro	Nyakabande	Gisoroza	04	02
		Gisiza	05	03
	Mulora	Kibumba	04	01
		Chahafi	02	01
	Chai	Muganza	02	01
		Nyaruhinda	02	01
Kabale	Kyanamira	Katokye	08	04
		Muyumbu	05	02
	Kitumba	Bukoora	08	03
		Mwendo	09	07
	Kabale Municipality	Rushoroza	04	02
		Bugongi	02	01
	Maziba	Kanjobe	05	02
		Nyanja	06	02
	Kamuganguzi	Buranga	07	04
		Mukarangye	06	03
Rukungiri	Nyarushanje	Ruyonza	02	01
		Rucence	02	01
	Buyanja	Rwakirungwa	04	02
		Muramba	02	01
	Nyakagyeme	Kaheoko	03	02
		Rushasha	02	01
Kanungu	Rutenga	Mafuga	05	02
		Katojo	04	02
	Rugyeyo	Nyarurambi	05	02
		Katungu	02	01
Total			110	54

Source: Field Data, 2016

3.3 Data collection

Data were collected using a check list and data sheets administered through direct interviews and direct observation respectively (Appendix 1). The study used both quantitative and qualitative data, quantitative data on fruit yield and tree growth characteristics were collected using data

sheets. Qualitative data on site location, management practices, and challenges facing farmers in apple production were collected using open ended questions and observational guides.

3.3.1 Assessment of yield in relation to orchard location

Using a GPS orchard location was mapped and gradient determined. Any orchard that was located in the gradient less than 15% was considered valley bottom orchard. Any orchard that was located between 15% and 60% slope was considered hillside orchard. Any orchard that was located in an area with flat surface or gradient less than 15% was considered hilltop orchard. In each orchard both slope and altitude was measured. This meant that valley orchards had less meters above sea level than hillside and hill top in each sub-county. Altitude per sub-county was considered because there were cases where a valley had a high altitude than hilltop depending on the sub-county. Data were collected from 20 sampled trees from each on-farm and on-station orchards. The following data were collected:

- (i) Number of cultivars per orchard
- (ii) Number of fruits per kilogram per cultivar
- (iii) Age of the tree
- (iv) Stem diameter was measured using a vainer calliper at collar height
- (v) Branch length was measured using a measuring tape
- (vi) Branch size was measured using a measuring tape.
- (vii) Number of fruits per tree per cultivar per season was recorded as fruit yield
- (Viii) Fruit weight were measured using a weighing scale
- (Ix) Fruit sizes were measured using a tape measure

3.3.2 Comparing cultivar yield with tree management

Apple farmers manage their orchards differently and this has an influence on fruit yield. Data were collected in different cultivars under different management regimes and recorded basing on the following parameters:

Initial spacing: This varied among farms. Some farmers used a spacing of 3mx3m; others 4mx4m while others 5mx5m. Data were recorded relating initial spacing with fruit yield by size and quantity.

Pruning intensity: Some farmers prune their trees and others do not prune at all. Data were collected by comparing yield per cultivar as follows; no pruning, 10% pruning, 20% pruning, 30% pruning and 40% pruning of tree branches. No farmer pruned beyond 40% of the tree branches.

Fruit thinning: Fruit sizes were recorded by size depending on thinning intensities to assess effect of thinning on yield.

Bending and staking/tree training: Yield data were also collected basing on the age of bending and staking. In this approach, information was collected on fruit number and size in relation to age of bending.

Growth facilitation: Data were collected by relating yield with application of manure, inorganic fertilizers and no facilitation at all.

Timing of defoliation: Number of fruits and size per tree per cultivar were recorded in relation to the days of defoliation between the on-set of rain. Data were recorded as no defoliation, 30 days before rain, 20 days, 15 days and 10 days before rain.

3.3.3 Assessment of farmers' challenges.

Assessment of any challenges facing apple production was done. This was mainly done using interview guides (open-ended questions) and observation of current standings in the region.

3.4 Data analysis and interpretation

Descriptive statistics that included frequencies, percentages and means were generated using Stata statistical Package (Stata v13) to achieve objective one and two. To find out a difference between on -station and on- farm orchards, an independent t-test was used. Differences between fruit sizes were assessed using a Chi-square test. An ANOVA was performed to establish the effect of management practises on apple yield and tree characteristics (Objective 2).

To find out the effect of farm characteristics, orchard management practises on apple yield as in objective; multiple regression analysis was performed to estimate the parameters basing on ordinary least square (OLS) method. A normality test was first carried out and it was found that the data were not normally distributed which necessitated log transformation of the dependent variable (Appendix 2). Further, multicollinearity test was carried out to ensure that the regression model does not violate assumptions of the OLS estimator. The test was carried out using the variance inflation factor (VIF) method (Appendix 3). By the rule of thumb, variance inflation factor (VIF) less than 10 in the output generated by Stata package is considered to be a tolerable correlation, implying low levels of multicollinearity (Dawit, 2010) (Appendix 3). To examine the challenges facing apple farming households in the region (objective four).Data collected using interview and observation guide was ordered and analysed using Stata statistical package (stata V13).

CHAPTER FOUR: RESULTS

4.1 Description of farmer and farm characteristics

4.1.1 Distribution of apple cultivars by orchard and site location

A total of 54 farmers' orchards and 3 station orchards were investigated (Figure 1). Out of six (6) cultivars, cultivars Anna (81.8%) and Golden Dorset (14.9%) were the most cultivated cultivars of apples on farmers' fields (Figure 1). On-station orchards, cultivars Anna (55%) and Golden Dorset (45%) dominated the number of apple cultivars cultivated. Others were Winter Banana (2.5%), Red Jonathan (0.5%), Rome Beauty (0.2%) and Shilomit (0.1%) (Figure 1). According to this study, other apple varieties were identified in farmers' orchards. The performance of these varieties is still being assessed by NARO under farmers' conditions and that is why they are very few (Figure 1).

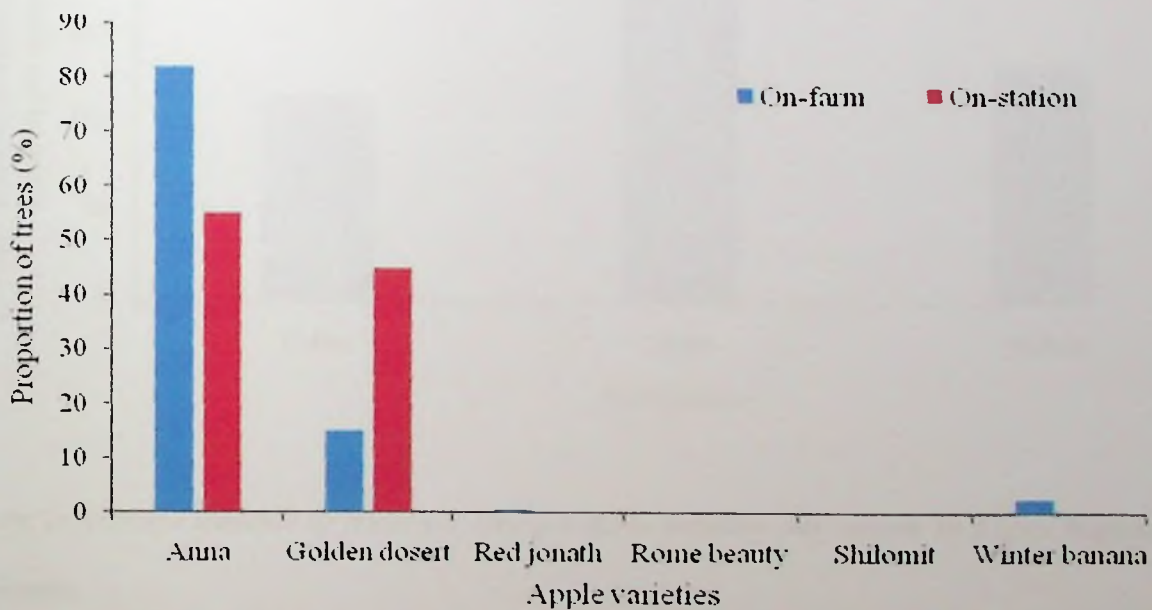


Figure 1: Distribution of the number of trees per apple cultivar on farmers' fields and on-station orchards in Kigezi highlands of Uganda.

4.1.2 Average quantity of fruits and tree characteristics per orchard location/ gradient in Kigezi highlands of Uganda

Based on results in Figure 2, it can be seen that there was a variation in the number of fruits produced per season per cultivar across site location. Specifically, apples planted on the slopes had the highest (192) number of fruits per tree per season while those planted in the valleys had the lowest number of fruits per tree per season (Figure 2). Similarly, there were variations in the average size of fruits per kg across the sites (Figure 3). The study findings showed that trees cultivated in the valleys and hilltops require more fruits (8.59) and (8.15) respectively to make a kilogram while those on the slopes require less (7.91) (Figure 3).

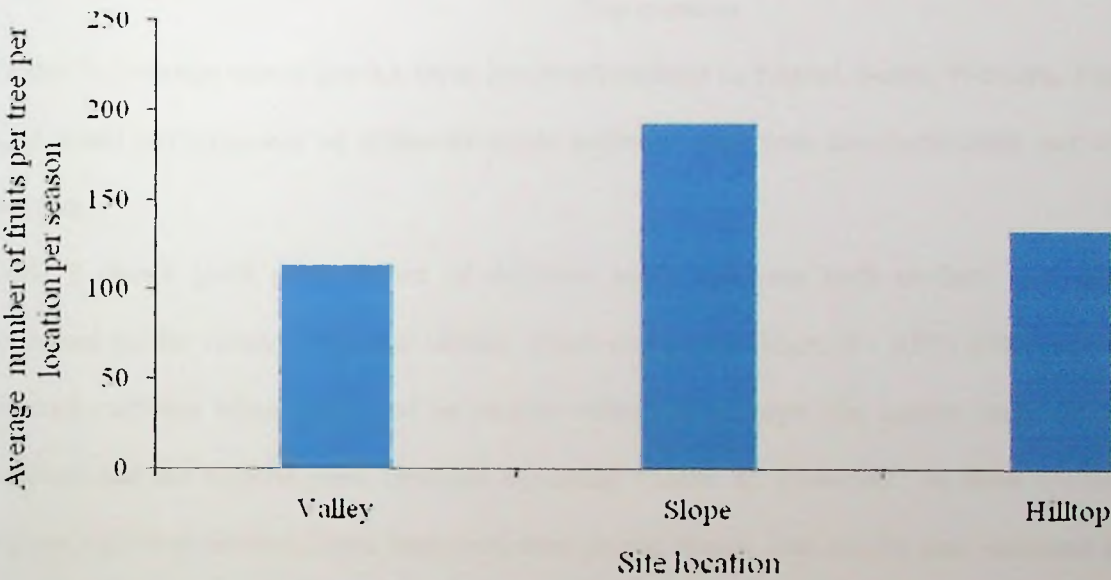


Figure 2: Average number of fruits per tree per farm location per season in Kigezi highlands of Uganda.

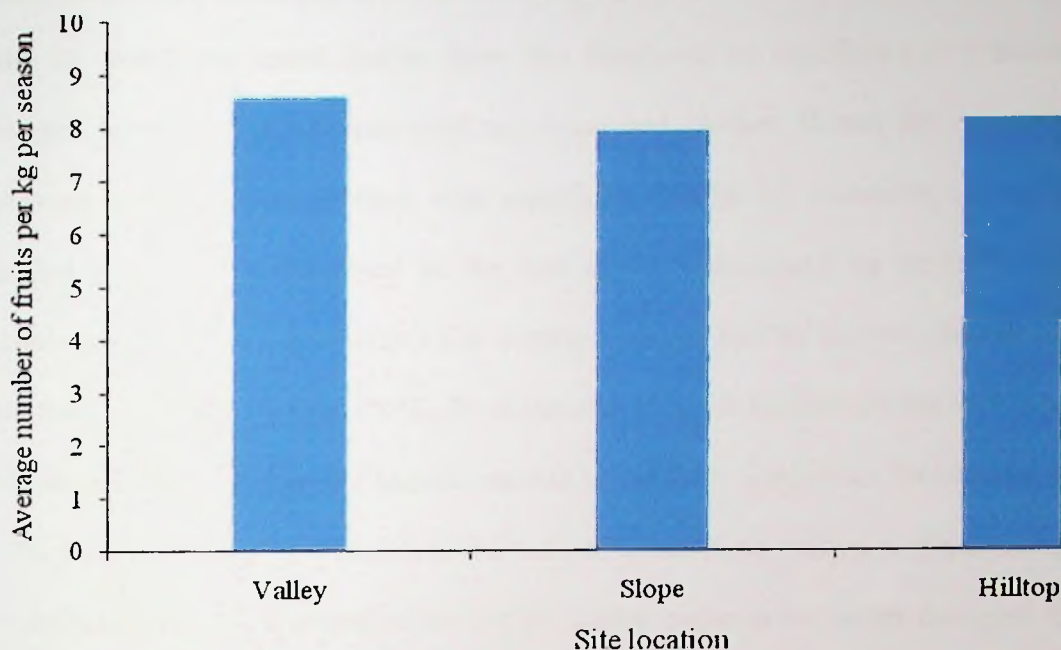


Figure 3: Average size of per kg farm location/gradient in Kigezi, South Western, Uganda.

4.1.3 Yield performance of different apple cultivars and tree characteristics per orchard location

Table 2 shows yield performance of different apple cultivars both on-farm and on-station cultivated on the valley, slope and hilltop. There was a significant ($P < 0.05$) difference in yield for both cultivars when cultivated on slopes, valleys or hilltops. On station orchards for both cultivars had the highest yield obtained on hilltop (Table 2). However on farm orchards, the highest yield was obtained from trees cultivated on the slopes. The results also indicated that less yield for both cultivars was obtained from trees cultivated in the valleys for both on station and on farm orchards (Table 2).

Overall there was a significant difference in the number fruits produced per tree for on-station and on-farm orchards at 1 percent level ($P < 0.01$). Specifically, on-station orchards produced the

highest number of fruits per tree per season for each cultivar compared to on-farm orchards (Table 2). Results indicated further show that there was no significant at 5 percent ($P>0.05$) difference in fruit sizes between cultivars Anna and Golden Dorset for on station orchards though on on-farm orchards they were significant (Table 3). However, study findings also indicated a significant difference in the size of fruits produced by on-farm and on-station orchards at 1 percent level ($P<0.01$). On -station orchards had the highest number of large sized apple fruits for either cultivar (70%) for Anna and 48% for Golden Dorset with no small fruits while on-farm orchards had the highest number of medium sized fruits for either cultivar (Table 3). The study also found out that more fruits are obtained in on-station orchards compared to on-farm orchards. This is attributed to the fact on-station orchards are better managed than on-farm orchards (Table 2)

Table 1: Yield variation of different apple cultivars and orchard location in Kigezi region South Western Uganda

Location	Cultivar	Average number of fruits per tree per site location				
		Valley	Slope	Hilltop	F-value	P-value
On station	Anna	645.36±30.40	867.70±39.59	870.67±32.60	14.53	0.000
	Golden Dorset	765.67±15.66	803.60±39.05	896.75±37.69	3.91	0.034
On farm	Anna	55.73 ± 3.50	171.77 ± 8.58	62.73 ± 3.85	57.25	0.000
	Golden Dorset	43.10 ± 7.12	158.48±10.74	74.74 ± 9.48	30.27	0.000

Generally there was a significant ($P < 0.01$) difference in tree characteristics of apple trees cultivated on- station and on-farm orchards (Table 4). Trees cultivated on-station had the highest stem diameter at 60cm, branch size, branch length and crown diameter for both cultivars Anna and Golden Dorset compared to the on-farm orchards (Table 4).

Table 2: Size of apples fruits cultivated on-farm and on-station orchards in Kigezi region, south western Uganda

Location	Cultivar	Average fruit size per tree per site location (%)				
		Small	Medium	Large	Chi-square-valve	P-valve
On station	Anna	0.0	30.30	69.70	2.87	0.090
	Golden Dorset	0.0	51.85	48.15		
On farm	Anna	17.80	60.10	22.10	12.21	0.016
	Golden Dorset	21.05	55.92	23.03		

Note: small (less than 50 trees in an orchard), medium (between 50 and 250 trees) and large (greater than 250 trees).

Table 3: Tree characteristics of apples cultivated on-farm and on-station orchards in Kigezi region, south western Uganda

Location	Cultivar	Mean tree characteristics			
		Branch length	Crown width	Stem diameter at DBH	Branch size from stem
On station	Anna	325.39± 5.79	358.91± 3.42	51.91± 0.82	27.07± 0.82
	Golden Dorset	334.41± 6.01	365.93± 4.78	52.44± 0.84	28.24± 0.91
	F-value	1.15	1.49	0.20	0.91
	P-value	0.29	0.23	0.65	0.34
On farm	Anna	153.71± 3.09	171.45± 2.46	22.55± 0.40	11.58± 0.33
	Golden Dorset	153.42± 4.84	183.45± 6.56	22.11± 0.90	11.90± 0.88
	F-value	0.31	1.72	1.08	0.58
	P-value	0.74	0.18	0.34	0.56

4.1.4 Fruit yield variation and tree characteristics of apple cultivars per orchard location

Table 5 shows the effect of site location on the most cultivated cultivars of apples in Kigezi region. There was a significant ($P<0.001$) difference in the number of fruits produced by Anna across the 3 sites, however there was no significant ($P>0.005$) difference when cultivar Golden Dorset was cultivated across the sites. All the two cultivars produced a high number of fruits when cultivated on the slopes and least when in the valley (Table 5). The number of fruits making up a kilogram per cultivar were also significant ($P<0.001$) across the three sites for

cultivar Anna and ($P < 0.001$) for Golden Dorset. A high number of fruits is needed to make a kilogram for both cultivars when they were planted in the valleys than when planted on the slopes (Table 5). Notably, both cultivars produced larger fruits (62.50%) for Anna and 45.38% for Golden Dorset when cultivated on slopes while a high number of small fruits were got when both cultivars were cultivated in the valleys (Table 5).

Tree characteristics were significantly different for cultivar Anna across the three sites for example stem diameter at $P < 0.001$, branch size at $P < 0.001$, branch length at $P < 0.001$ and crown diameter at $P < 0.001$ (Table 6). For cultivar Anna, fruit trees cultivated on the slopes had the largest stem diameter at 60cm (25.79cm), branch size (13.17 cm), branch length (161.69cm) and largest crown diameter (200.35cm) (Table 5). However there was no significant ($P < 0.005$) difference in tree quality characteristics for cultivar Golden Dorset across the three sites except for stem diameter and crown width which were both significant at $P < 0.001$ (Table 5). Similarly like for cultivar Anna, branch size, stem diameter and crown width were largest when Golden Dorset was cultivated on the slopes.

Cultivar	ANNA		GOLDEN DORSET					
	Valley		Gentle slope		Hill top		Slope	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Fruits per tree per season	92.58	151.55	185.6	213.0	113.4	204.5	230.9	227.2
			5	6	9	9	7	0
							9	2
Number of fruits per kg	8.61	1.02	7.91	0.81	8.17	1.03	7.90	0.75
							8.08	1.11
								0.0034
Stem diameter at 60cm (cm)	22.29	14.03	25.79	11.69	19.34	13.13	29.95	11.86
							24.66	15.75
								0.0101
Branch size (1 st layer)	11.28	6.95	13.17	9.63	10.34	12.62	15.41	7.20
							14.23	17.69
								0.3537
Branch length (cm)	167.86	74.96	161.6	55.69	144.4	72.63	188.0	64.17
			9		1		0	
								85.28
								0.2634
Crown width (cm)	148.45	75.39	200.3	73.54	149.4	74.39	233.9	86.70
			5		6		1	
							3	102.7
							3	0.0050
Fruit size								
								0.005

Small (%)	30.87	42.95	26.17		37.50	34.38	28.13		
Medium (%)	23.00	60.23	16.76		22.22	56.57	21.21		
Large (%)	5.77	62.50	31.73		10.42	45.83	43.75		

Table 4: Effect of site location on the yield of different apple cultivars in Kigezi region, Uganda

SD represents Standard deviation

4.2 Orchard Management Practices, tree quality characteristics and yield performance of apples.

4.2.1 Effect of spacing on apple yield performance in Kigezi highlands

Results in Figure 6 indicated that spacing affected yield and tree quality characteristics of apples. From Figure 10, spacing had no significant ($F_{2, 986} = 0.38$, $P=0.68$) effect on the number of fruits produced per tree per season. However, there was a significant ($F_{2, 986} = 31.37$, $P<0.001$) difference in the number of fruits per kilogram across the 3 spacing types (Figure 6). Apple trees spaced at 3m x 3m produced the highest number of fruits per tree per season while 4m x 4m produced the least number (Figure 6). Notably, using 5m x 5m, less number of fruits was needed to make a kilogram compared to 4m x 4m and 3m x 3m (Figure 7).

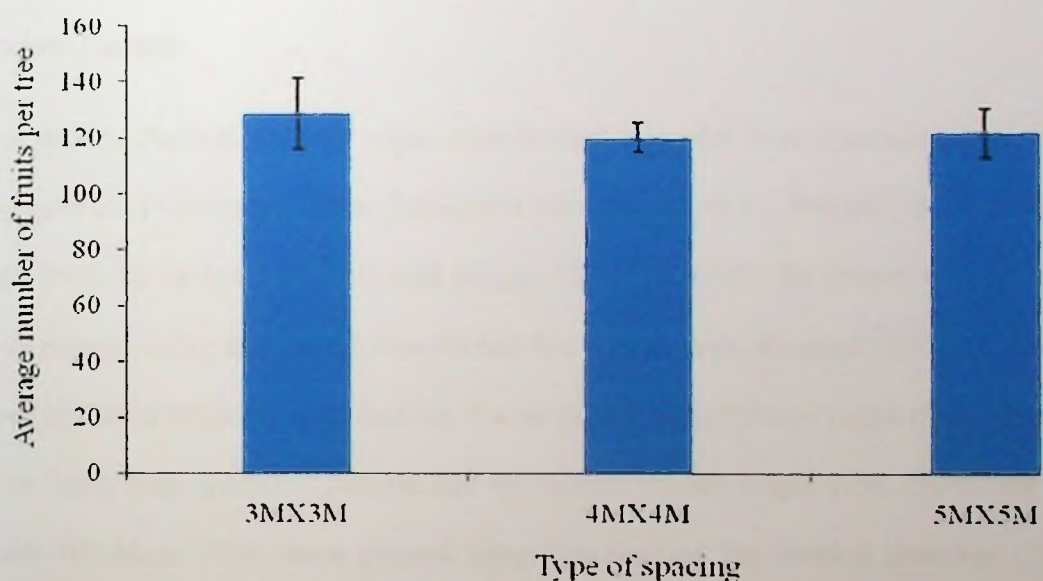


Figure 4: Effect of spacing on number of apple fruits per tree in Kigezi region, south western Uganda

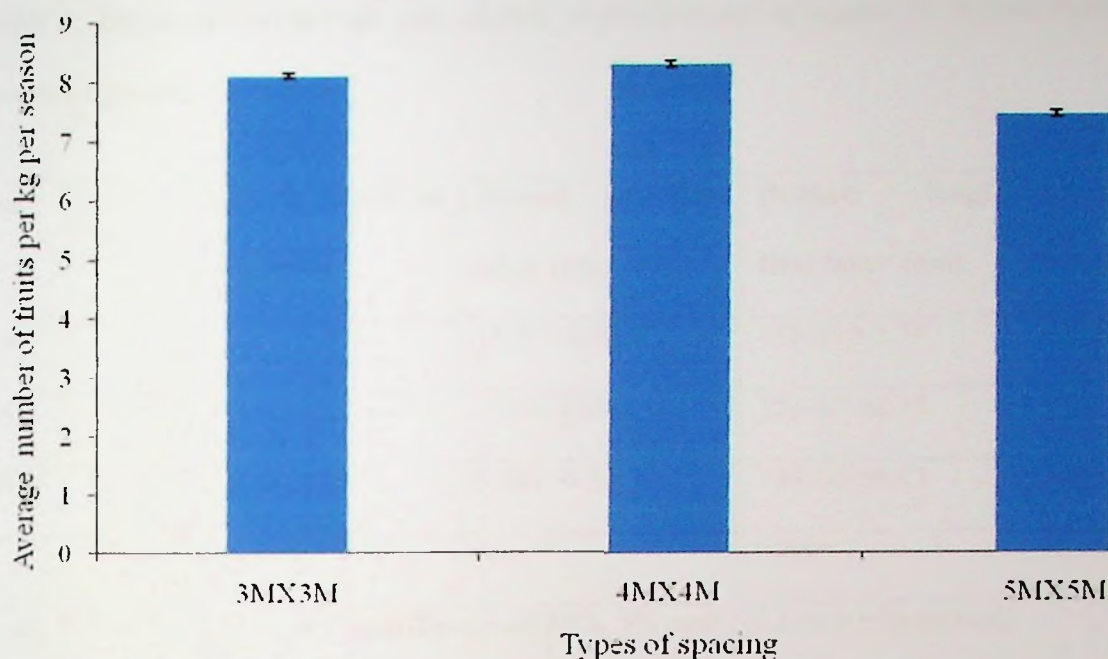


Figure 5: Effect of spacing on number of fruits per kg per season (size) in Kigezi region, south western Uganda

Tree quality characteristics of apple trees planted using the three spacings varied significantly at ($F_{2, 986}=6.67$, $P<0.001$) for stem diameter at 60cm, ($F_{2, 986}=4.91$, $P<0.005$) for branch size, ($F_{2, 986}=3.65$, $P<0.10$) for branch length and ($F_{2, 986}=12.46$, $P<0.001$) for crown width (Table 6). Apple trees planted using spacing of 4mx4m had the largest stem diameter (23.70cm), longest branch size (12.36cm) while 5mx5m had the lowest (20.09 cm), 8.96cm respectively (Table 6). On the other hand, trees spaced at 3mx3m had the longest branch length (158.59cm) and largest crown width 187.68cm while those planted using 5mx5m had the shortest branches (139.06cm) and those planted using a spacing of 4mx4m had the smallest crown width (Table 6).

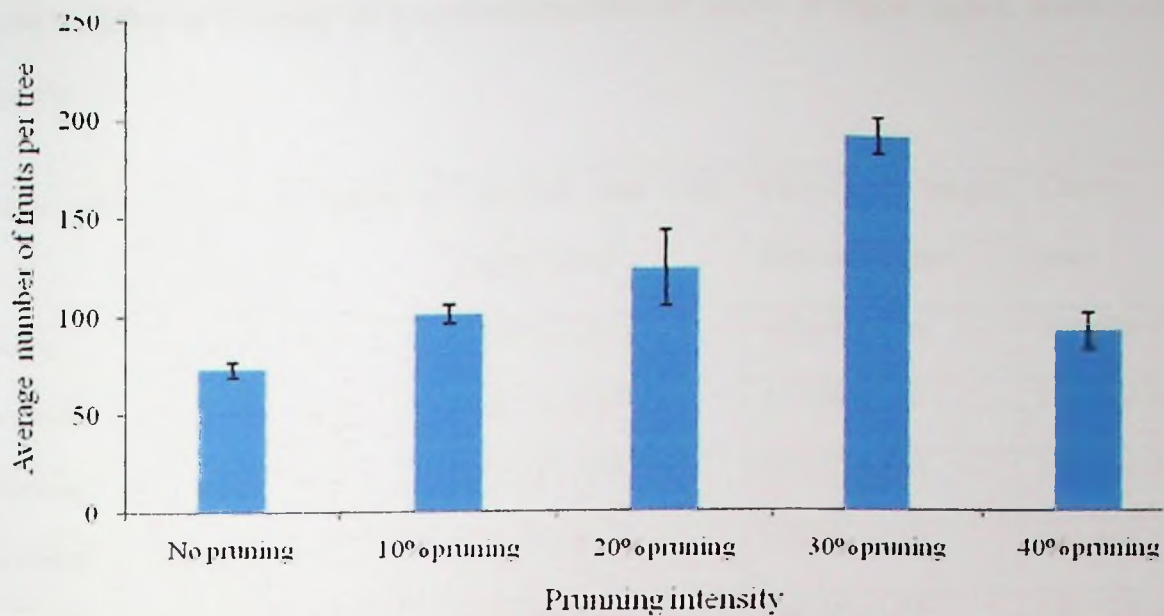


Figure 6: Effect of Pruning on number of apple fruits per tree in Kigezi region, south western Uganda

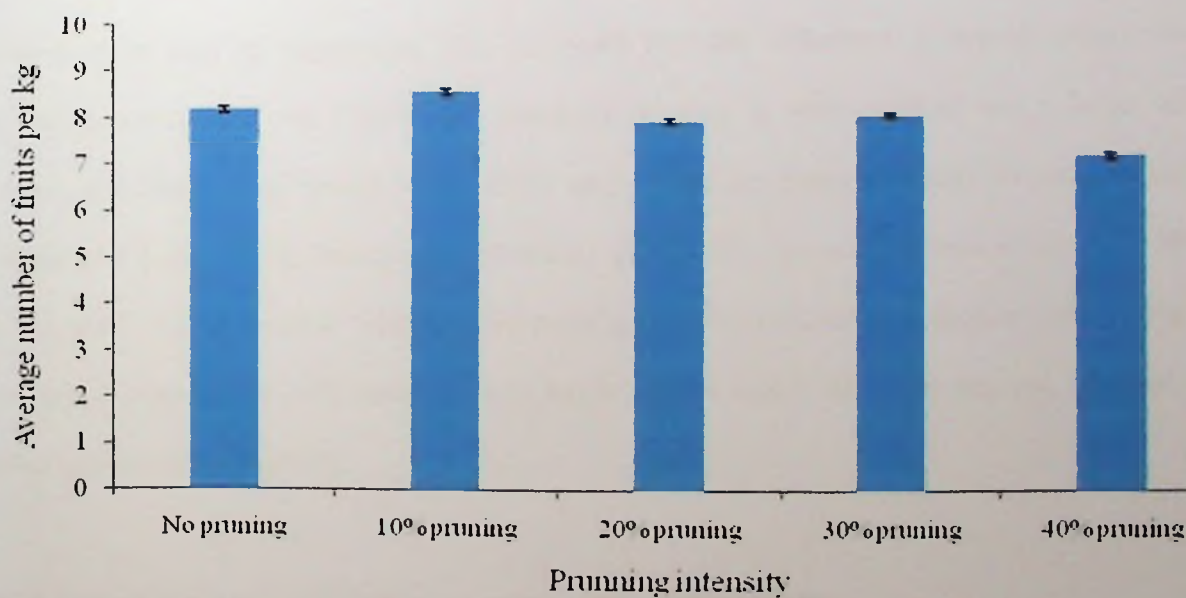


Figure 7: Effect of Pruning on number of fruits per kg of apples in Kigezi region, south western Uganda

Table 6: Effect of Pruning on tree characteristics of apples in Kigezi region, south western Uganda

Pruning intensity	Stem diameter at 60cm (cm)	Branch size first layer (cm)	Branch length first layer (cm)	Crown width (cm)
No pruning	18.98 ± 0.85	9.44 ± 0.33	158.81 ± 4.74	144.60 ± 4.39
10% pruning	22.13 ± 0.69	11.87 ± 0.67	152.08 ± 3.85	156.35 ± 4.39
20% pruning	21.25 ± 0.99	11.24 ± 0.83	153.78 ± 4.96	185.97 ± 5.77
30% pruning	26.07 ± 0.62	12.97 ± 0.34	156.57 ± 3.12	201.48 ± 4.48
40% pruning	28.35 ± 1.78	16.72 ± 3.99	140.18 ± 5.05	191.82 ± 6.81
F-test	14.74***	6.06**	0.85ns	26.92***

, *Represents significance at 5% and 1% levels respectively and ns not significant

However there was no significant ($F_{4, 984} = 0.85$ $P=0.49$) difference in branch length with increased pruning intensity (Table 7). Intensive pruning at 40% resulted into a large stem diameter (28.35cm) and branch size (16.72 cm) while no pruning results in smaller stem diameter (18.98 cm) and branch size (9.44cm) (Table 8). No pruning and pruning at 30% resulted into a longer branch length while pruning at 40% resulted in a shorter branch length (140.18cm). Pruning at 30% resulted into larger crown width while no pruning resulted in smaller crown width (Table 7).

4.2.2 Effect of timing of defoliation on apple yield performance

Time of defoliation had a significant ($F_{3, 985}=17.40$, $P< 0.01$) impact on the number of fruits per tree and ($F_{3, 985}=11.07$, $P< 0.01$) for number of fruits per kilogram (Figure 10, 11).

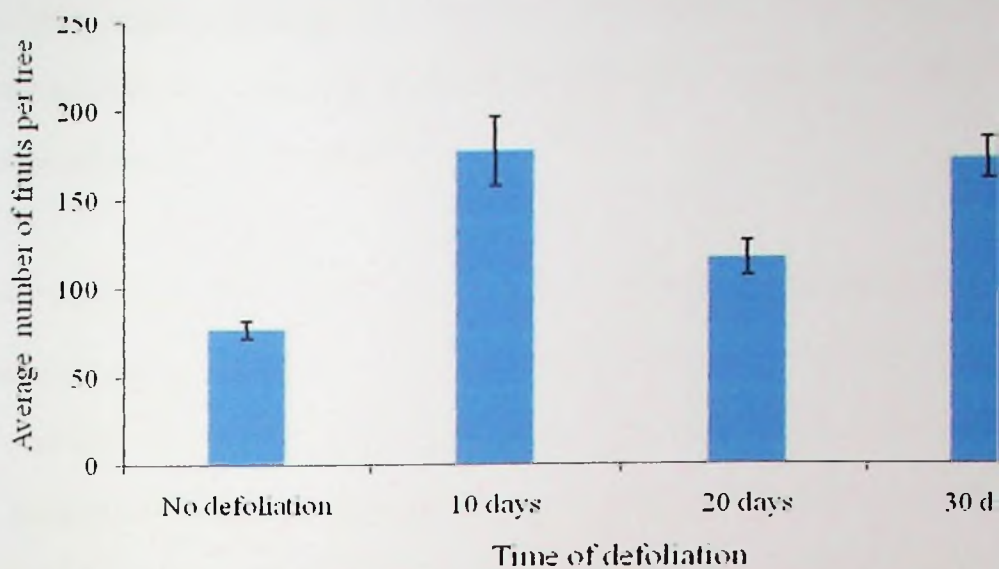


Figure 8: Effect of defoliation on number of apple fruits per tree in Kigoma western Uganda

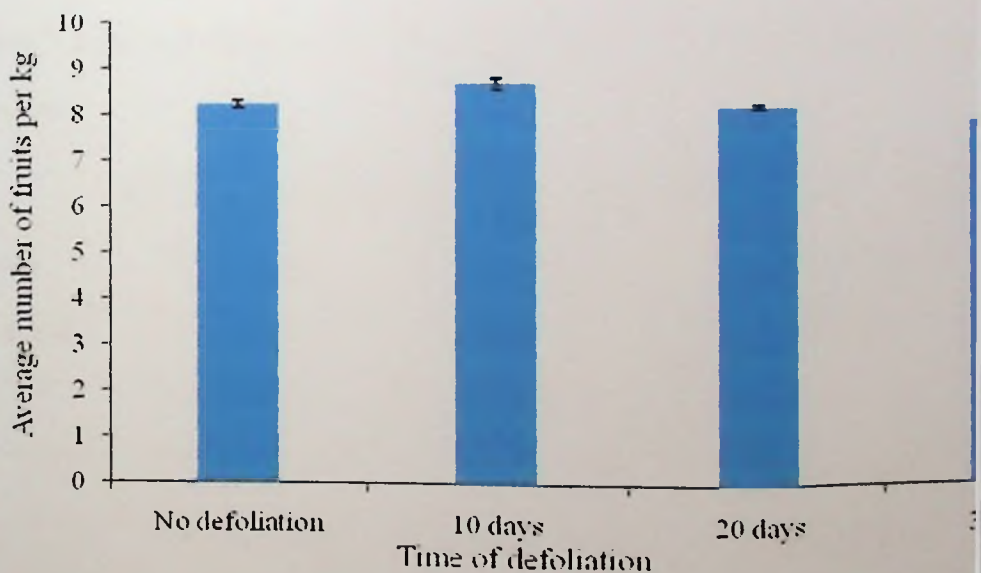


Figure 9: Effect of defoliation on number of apple fruits per kg in Kigoma western Uganda

Defoliation at 10 and 30 days resulted into the highest number of fruits per tree while not defoliating resulted into the least number of fruits (Figure 10). However, a lower number of fruits are needed to make a kilogram when defoliation is done at 30 days and more fruits at 10days after defoliation (Figure 11).

From Table 8, time of defoliation had a significant effect on tree quality characteristics of apple trees at ($F_{3, 985}=29.82, P<0.01$) for stem diameter at 60cm, ($F_{3, 985}=12.83, P<0.01$) for branch size, ($F_{3, 985}=2.61, P<0.05$) at branch length and ($F_{3, 985}=14.76, P<0.01$) for crown width. Defoliation at 30 days had the largest stem diameter (27.49cm), branch size (14.86 cm) and crown width (186.63cm) while no defoliation resulted into the smallest stem diameter (17.47 cm), branch size (9.32 cm) and crown width (145.06cm) (Figure 18). Branch length was longer when defoliation was done at 20 days while it was shortest when it was done at 10 days (Table 8)

Table 7: Effect of defoliation on tree characteristics of apples in Kigezi region, south western Uganda

Time of defoliation	Stem diameter at 60cm (cm)	Branch size first layer (cm)	Branch length first layer (cm)	Crown width (cm)
No defoliation	17.47 ± 0.60	9.32 ± 0.91	148.39 ± 4.83	145.06 ± 4.92
10 days	20.24 ± 1.34	9.82 ± 0.66	144.11 ± 8.21	183.41 ± 9.08
20 days	22.62 ± 0.61	11.38 ± 0.30	159.72 ± 3.05	178.30 ± 3.77
30 days	27.49 ± 0.78	14.86 ± 0.93	152.28 ± 3.13	186.63 ± 4.49
F-test	29.82***	12.83***	0.61**	14.76***

, * Represents significance at 5%, 1% levels respectively

4.2.3 Effect of fruit thinning on apple yield performance

Fruit thinning had a significant effect on the number of fruits per tree at ($F_{1, 987}=13.58$, $P<0.05$) while the number of fruits were significant at 5 percent level ($F_{1, 987}=28.69$, $P<0.01$) (Table 9). Fruit thinning resulted in a high number of fruits per tree (155.36) and larger fruits since few fruits were needed to make a kilogram (7.86) compared to when thinning was not done (Table 9).

Table 8: Effect of fruit thinning on yield of apples in Kigezi region, south western Uganda

Fruit thinning	Number of fruits per kg per season		Number of fruits per kg	
	Mean	Standard Deviation	Mean	Standard Deviation
No	113.78	141.42	8.24	0.98
Yes	155.36	175.82	7.86	0.80
P-value	0.0002		0.0000	
F-test	13.58**		28.69***	

*Note: *** significance at 1%, ** significance at 5%*

4.2.4 Effect of age of tree training on apple yield performance

Number of fruits per tree and number of fruits per kilogram varied significantly at 1 percent ($F_{3, 985}=22.25$, $P<0.01$) for fruits per tree and ($F_{3, 985}=27.21$, $P<0.01$) for fruits per kg with the age of bending and staking (Figure 12, 13).

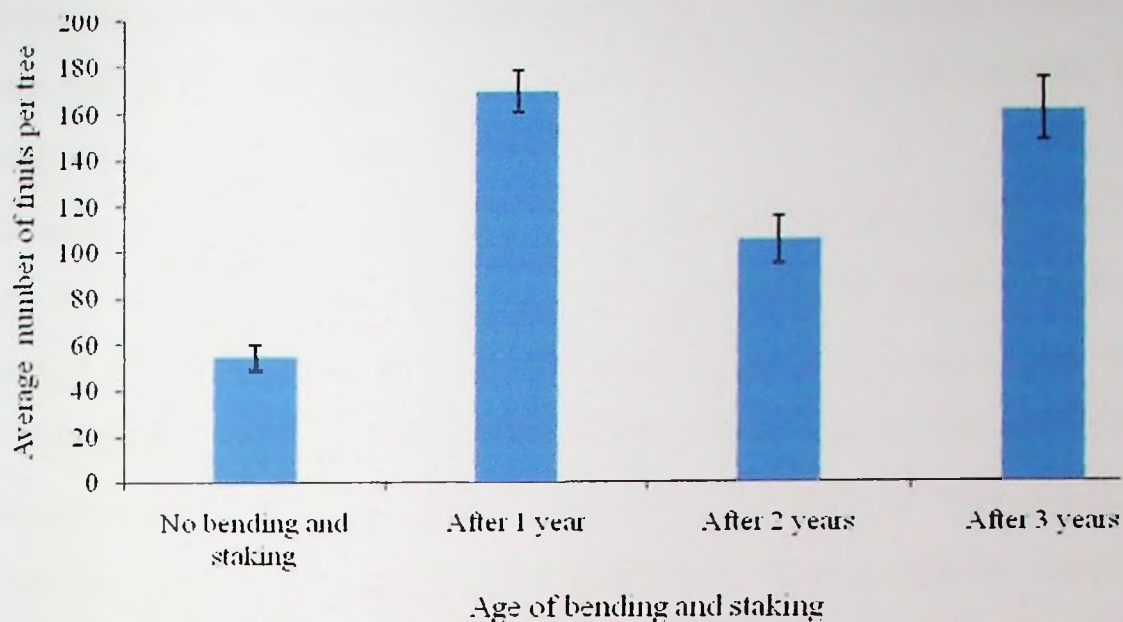


Figure 10: Effect of tree training on number of apple fruits per tree in Kigezi region, south western Uganda

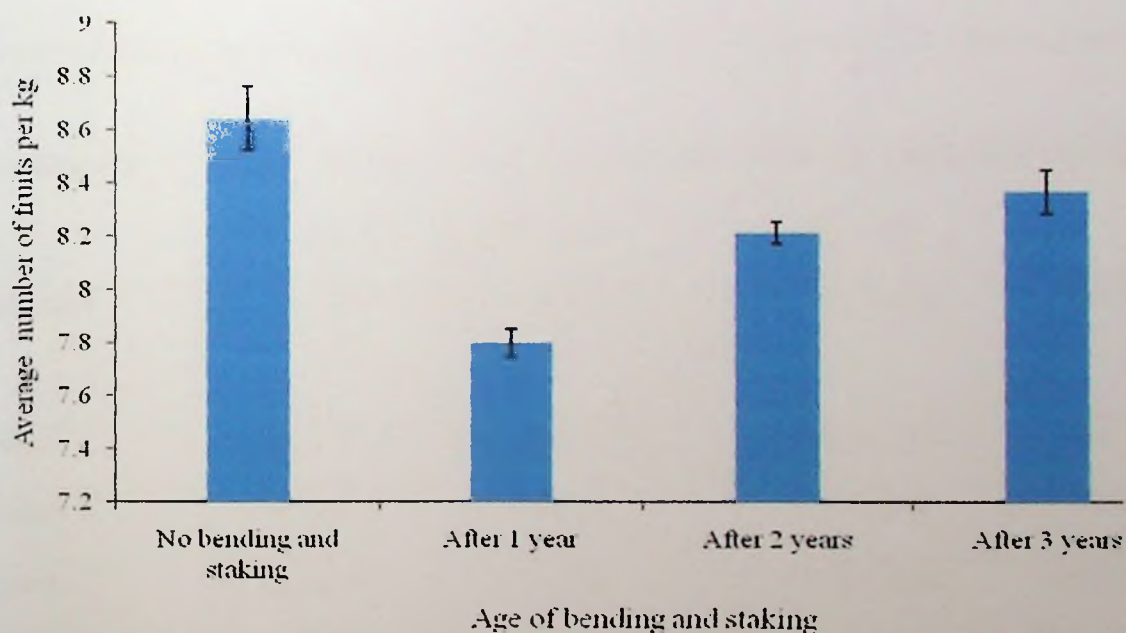


Figure 11: Effect of tree training on number of apples fruits per kg in Kigezi region, south western Uganda

Bending and staking of branches after one year resulted in a high number of fruits per tree per season (168.95) and lower number of fruits per kilogram (7.80) compared to when bending and staking was not done (Figure 12,13).

Tree quality characteristics of apple trees varied significantly with age of bending and staking ($F_{3, 985}=29.77$, $P<0.01$) for stem diameter at 60cm, ($F_{3, 985}=10.94$, $P<0.01$) for branch size and ($F_{3, 985}=29.77$, $P<0.01$) for crown width (Table 10). However, there was no significant ($F_{3, 985}=1.80$, $P=0.15$) difference in branch length when bending and staking was done. Practicing bending and staking after 2 years resulted into a larger stem diameter (25.04 cm) and branch size (12.85cm) (Table 10). On the other hand, bending and staking after 3 years resulted in a longer branch length (168.82cm) and larger crown width (193.17 cm) compared to when bending and staking was not done (Table 10).

Table 9: Effect of tree training on tree characteristics in Kigezi region, south western Uganda

Effect of bending and staking	Stem diameter at 60cm (cm)	Branch size first layer (cm)	Branch length first layer (cm)	Crown width (cm)
Control	14.25 $\pm$ 0.58	7.01 $\pm$ 0.28	151.51 $\pm$ 6.72	116.73 $\pm$ 4.80
After 1 year	21.39 $\pm$ 0.69	11.32 $\pm$ 0.48	153.26 $\pm$ 3.55	182.12 $\pm$ 4.14
After 2 years	25.04 $\pm$ 0.59	12.85 $\pm$ 0.52	153.98 $\pm$ 3.02	177.09 $\pm$ 3.84
After 3 years	22.02 $\pm$ 1.04	11.55 $\pm$ 0.53	168.82 $\pm$ 6.26	193.17 $\pm$ 6.70
F-test	29.77***	10.94***	1.80ns	28.41***

*** Represents significance at 1% level and ns not significant

4.2.4 Effect of growth facilitation on apple yield performance

Growth facilitation had a significant effect on the number of fruits per tree at $F_{2, 986}=7.52$, $P<0.001$) and number of fruits per kilogram at ($F_{2, 986}=20.97$, $P<0.001$) (Figure 14, 15).

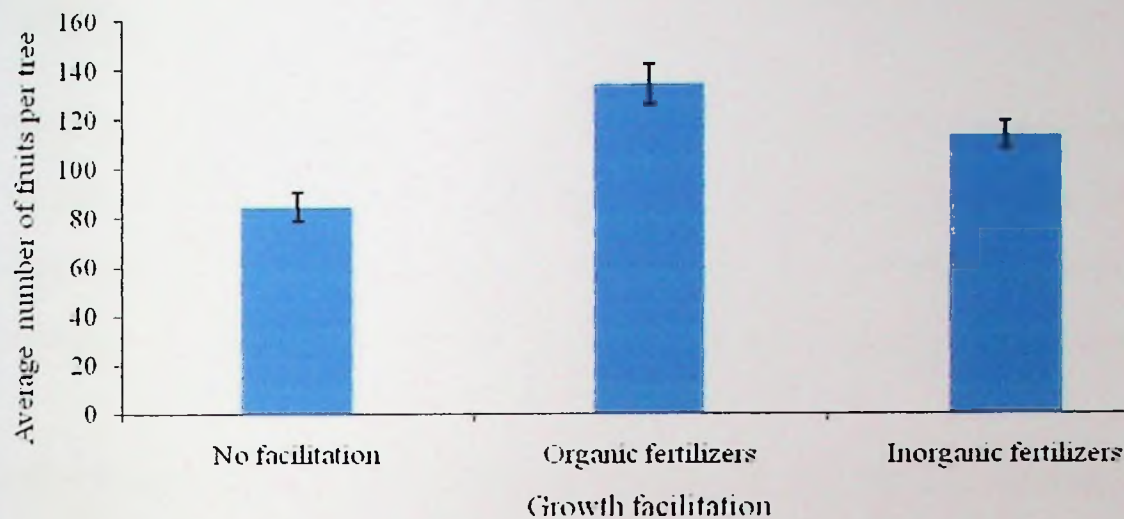


Figure 12: Effect of growth facilitation on number of apple fruits per tree in Kigezi region, south western Uganda

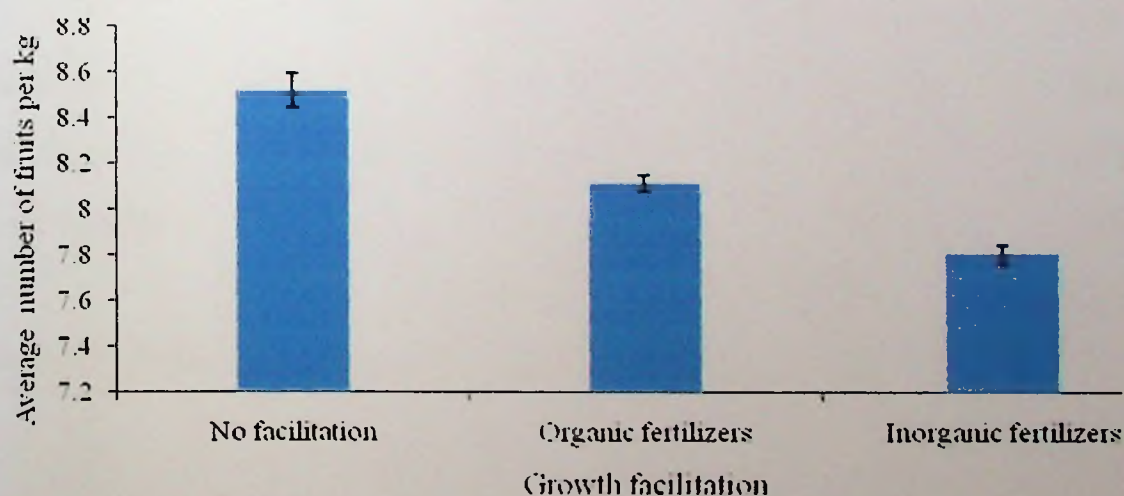


Figure 13: Effect of growth facilitation on yield performance of apples in Kigezi region, south western Uganda

Application of organic fertilizers increased the number of fruits per tree per season (133.81) compared to when growth facilitation was not used (Figure 14). However using inorganic fertilizers resulted in lower number of fruits per kilogram (7.80) compared to when organic fertilizers were used (Figure 15).

Results in Table 11 show that growth facilitation had a significant effect on tree quality characteristics of apple trees at 1 percent level for stem diameter at 60cm and for crown width while branch size had significant effect at 5 percent (Table 11). However there was no significant difference in branch length at 5 percent with or without growth facilitation (Table 11).

Table 10: Effect of growth facilitation on tree characteristics of apples in Kigezi region, south western Uganda

Growth facilitation	Stem diameter at 60cm (cm)	Branch size first layer (cm)	Branch length first layer (cm)	Crown width (cm)
No facilitation	20.35± 0.81	10.04 ±0.37	164.54 ±5.38	148.25 ±5.84
Organic fertilizers	23.23± 0.49	11.80 ±0.36	152.67 ±2.43	181.02 ± 3.04
Inorganic fertilizers	20.58 ±1.04	13.03± 1.63	154.36 ±6.36	159.57± 5.08
F-test	5.72**	3.26**	2.62ns	16.24***

*Note: **, *** Represents significance at 5%, 1% levels respectively*

Using organic fertilizers resulted into a larger stem diameter (23.23 cm) and larger crown width (181.02cm) compared to no growth facilitation used (Table 11). Notably, using inorganic fertilizers resulted in a larger branch size (13.03cm) while not using growth facilitation resulted in a longer branch (164.54 cm) (Table 11).

4.3 Effect of farm characteristics, orchard management practices on apple yield performance

In order to determine the influence of different farm characteristics and orchard management practices on the yield of apples, a regression analysis was performed (Table 12). The dependent variable was log number of fruits per tree per season. The F-value of the model was significant at 1 percent implying that data fits the model. The R-square of 0.548 implies that 54.8% of the variation in yield of apples is explained by independent variables in the model while 45.2% is due to other factors

Regression model results indicated that age of the orchard had a positive and significant influence on the number of fruits per tree per season ($P < 0.01$) implying that for any unit increase in the age of the orchard, there was a 0.9 percent increase in number of fruits per tree per season holding other factors constant (Table 12).

With regard to site location, using valley bottom as a reference, farmers cultivating on the gentle slopes and the hill top get 1.4 and 0.4 more fruits respectively than those who cultivate in the valley bottom (Table 12). These results indicate that cultivating on the gentle slopes provides more apple yield than cultivating in the valley or hilltop. Spacing of trees 5mx5m had a positive significant ($P < 0.01$) effect on the number of fruits per tree per season. Spacing of the apple trees by 5mx5m yielded more fruits compared to 4mx4m and when you use 3mx3m and this was

significant at 5 percent (Table 12). However in terms of number of fruits per kilogram, you need more fruits at a spacing of 3m x3m than 4mx4m or 5mx5m (Figure 7).

Pruning intensity had a significant effect on the yield of apples especially when 30% pruning was performed (Table 12). Pruning of apple trees by 30% resulted in 23% more fruits than when pruning was not done. These results indicate that 30% pruning is the most effective pruning for high yields in apples.

With respect to use of growth facilitation, use of organic fertilizers results in 31% more fruits than when a farmer does not use any facilitation. Using inorganic fertilizers results in 71% more fruits than when no facilitation are applied, therefore use of inorganic fertilizers is more effective in achieving high apple yields.

Table 11: Regression model results of factors influencing number of fruits per tree per season

(yield)

Variable characteristics	Coefficients	Standard error		P-value
Age of the orchard	0.09	0.10		0.000
Site location				
Slope	1.43	0.77		0.000
Hilltop	0.38	0.96		0.000
Cultivar				
Anna	-0.08	0.65		0.216
Spacing of the fruit trees				
4mx4m	--0.74	0.61		0.225
5mx5m	0.58	0.10		0.000
Pruning intensity				
10% pruning	0.12	0.82		0.141
20% pruning	0.08	0.10		0.428
30% pruning	0.23	0.09		0.015
40% pruning	0.15	0.17		0.371
Growth facilitation				
Organic	0.31	0.75		0.000
Inorganic	0.71	0.10		0.000
Age of bending and staking				
After one year	0.63	0.12		0.000
After two years	0.44	0.11		0.000
After three years	0.43	0.15		0.004
Timing of defoliation				
After 10 days	0.37	0.15		0.015
After 20 days	0.11	0.09		0.197
After 30 days	0.44	0.11		0.000
Fruit thinning	-0.19	0.72		0.009
Constant	-2.19	0.15		0.000

Dependent variable was first transformed to logs before analysis. Bending and staking had a significant ($P < 0.01$) effect on the number of fruits per tree per season when it was done across the three treatments (Table 12). Bending and staking of apple trees after 1, 2 and 3 years resulted in 63%, 44% and 43% more fruits than when it was not done. These results indicate that bending and staking should be done after one year for maximum yield in apples in the study area.

Time of defoliation also had a significant ($P < 0.01$) effect on the yield of apples especially when done after 10 days and 30 days. Results showed that when defoliation was done after 10 days and 30 days resulted in 37% and 44% more fruits respectively more than when no defoliation was done. Defoliation after 20 days resulted in 11% more fruits than when it was not done. This is a clear indication that defoliation done after 10 days and 30 days is more effective practice to increase yield in apples.

Lastly, thinning of fruits had a statistically and significant influence on apple yields. Results in Table 12 revealed that thinning of fruits resulted in 19% less fruits than when it was not done. Normally fruit thinning is aimed at increasing the size of the fruits (Denne, 2016). These results suggested that for more marketable fruits, fruit thinning is recommended.

4.4 Challenges facing apple farmers

The most challenges facing apple farmers were thieves (23%), Birds (21%) and labour intensiveness of apple production (Table 13). Among pests, aphids were the dominant pests affecting apple production (63.79%) while with respect to diseases, powdery mildew (67.24%) and apple scab (56.90%) were the most important affecting apple production in the region (Table 13).

Table 12: General challenges facing apple farmers in Kigezi region, south western Uganda

Challenge	Frequency (n=54)	Percentage of farmers
Thieves	23	39.66
Birds	21	36.21
Labour intensive	14	24.41
Poor agronomic practises	13	22.41
Pests and diseases	12	20.69
Expensive chemicals	6	10.34
Limited access to apple seedlings	4	6.90
Pests		
Aphids	37	63.79
Birds	25	43.10
Diseases		
Powdery mildew	39	67.24
Apple scab	33	56.90
Brown spot	3	5.17
Fire blight	3	5.17
Apple canker	1	1.72

The percentages and frequencies presented are multiple responses from individual farmers.

CHAPTER FIVE: DISCUSSION OF RESULTS

5.1 Effect of site location on the performance of different apple cultivars

5.1.1 Cultivar distribution by orchard location

The results from Kigezi highlands indicated that the dominant varieties of apples both on-farm and on-station were Anna and Golden Dorset. These two varieties have been reported to be popular in tropics because of low chilling abilities (Dereje *et al.*, 2010). Chilling temperatures are necessary for the apples to break bud dormancy. However this depends on the varieties with some requiring higher chilling temperatures while others low (Dereje *et al.*, 2010) According to Njuguna & Morelock, (2004) chilling temperatures hinder apple production in the tropics. Therefore use of low chilling varieties like Anna and Golden Dorset is seen as a remedy for this problem (Olsen, 2005; Dereje *et al.*, 2010).

Secondary, cultivars Anna and Golden Dorset were the two apple cultivars that were widely disseminated to the farmers in Kigezi Highlands (Chemining'wa *et al.*, 2005), during the inception of apple production in the region. This could be another reason why these two varieties were the most dominantly cultivated in this region. Furthermore, a study by Chemining'wa *et al.*, (2005) showed that among the four cultivars tested at the stations, cultivars Anna and Golden Dorset performed better than Rome Beauty and Winter Banana. These were high yielding, sweet and early maturing. This would explain why they were extensively cultivated in the region. Other varieties were not very popular probably because of lack of seedling to plant in their fields.

5.1.2 Distribution of apple cultivars by site location

Results from the current study indicated that the most cultivated apple cultivars on farmer's fields are concentrated on the gentle slopes (Table 1). This agrees with findings by (Namubiru and Buyinza, 2007) who also found a high diversity of fruit trees along the slopes in Kabale. This could be due to most households being concentrated on the top of the hills such that land on slopes which cannot be built on can be used for fruit tree production. Therefore the distribution on the apple cultivars along the three sites could be related to the topography of the area as opposed to varietal differences of the cultivars. Results also indicated apple cultivars being cultivated more on the slopes and hilltops as opposed to the valleys. This is because some of these orchards are located on the top of the hills; therefore for better room of expansion and protection against birds and thieves some were located close to the homes. The fact that more trees for Anna and Golden Dorset being located on the slopes is a clear indication of great adaptability of these varieties to the soils and climatic conditions of the region.

5.1.3 Performance of apples under different orchard locations

The findings of the study from Kigezi Highlands indicated that trees cultivated on the slopes produced the highest yield (high number of fruits per tree per season) and larger fruits followed by those on the hilltops and lastly valleys (Figure 2, 3). The wide variation in topography in this region can result in differences in soil fertility, vegetation and temperatures. This topographic difference could be responsible for the differences in yield and tree growth characteristics between the three sites. Namubiru & Buyinza, (2007) pointed out that performance of temperate fruit trees was influenced by local physical conditions and edaphic factors emphasizing the slope length and soil erodibility.

5.1.4 Yield performance of apples and orchard location

The results showed high apple yields obtained from on-station orchards compared to on-farm orchards (Table 2, 3 and Figure 4). This agrees with Ntakyo *et al.*, (2013) who also found high apple yields obtained on-station than on-farm. Similarly, tree quality characteristics were higher when apple trees were cultivated on-station than on-farm (Table 4). This difference in yield and tree quality characteristics between on station and on-farm orchards could be attributed to management practices, age of the orchard and inputs provided to the apple trees. Management of apple trees for maximum yield requires a lot of labour (Ntakyo *et al.*, 2013). This will therefore increase the cost of production among farmers; it is therefore not surprising that on-station orchards with more capital produced higher yields. The age of the orchard has an effect on yield of apples. Well managed apple orchards can remain productive for up to 40 years (Ntakyo *et al.*, 2013). The average age of on-station orchards was 15 years while on-farm orchards was less. Hester & Cacho.(2003) reported optimal yield of apple trees at 15 years, their finding agrees with this study. It appears that as years increase, more fruits are produced per tree up to maximum of 40 years when reduction in fruit number becomes evident

5.1.5 Apple cultivar yield variations and site location

Results in Table 2 and 5 indicated higher apple yields and good tree quality characteristics when apple cultivars were cultivated on the slopes. This implies that cultivating apple trees on the slopes is the best alternatives for higher apple yield in this region. This difference can only suggest effect of environment on performance of these cultivars as opposed to cultivar differences. It appears that good soil characteristics on the slopes are responsible for better performance of these cultivars when planted on the slopes. The presence of fertile volcanic soils on slopes could be responsible for the high yields when cultivars were grown. According to

Harrop, (1962) and Hadoto, (2001), over 70% of the area is covered with ferralitic sandy clay loams. The clay loams developed are predominantly on the slopes (Hadoto, 2001). It appears that soils in the valley encourage water lodging which is a negative implication in apple production. Apples in poorly drained soils especially in low lying areas may result in phythophora root rot (Parker, 1997). The higher yields obtained when apple cultivars were cultivated on the hilltops and slopes could also be related to lower chilling temperatures at these elevations compared to the valley that would consequently result in flower bud break.

5.2 Orchard management practices, yield performance and tree health of apples

5.2.1 Effect of spacing

Results in Figure 6 showed a high yield (number of fruits per tree per season) when close spacing (3mx3m) was used compared to wider spacing (4mx4m and 5mx5m). This could be due to a high number of trees planted per unit area under close spacing. In contrast yield was lowest when trees were widely spaced 4mx4m and 5mx5m probably due to fewer numbers of trees per unit area. According to Hampson *et al.*, (2004) increasing in plant density (close spacing) increases leaf are index and light interception compared to wider spacing. This increase in interception of photosynthetic active radiation is responsible for high yield in closely spaced trees (Hampson *et al.*, 2004). However, increasing the spacing from 4mx4m to 5mx5m resulted in a lower number of fruits per kilogram (Figure 7). This can only suggest that increasing the spacing of apple trees results in larger fruits. This increase in the size of fruits could be attributed to lower competition for nutrients among the fruit trees unlike when a high number of trees is used. Therefore materials can be fully translocated to the developing fruits.

Results showed a reduction in stem diameter, branch length, branch size and crown width when the spacing was increased from 3mx3m to 5mx5m (Table 6). It should also be noted that

maximum stem diameter and branch size were attained when trees were spaced at 4mx4m while maximum branch length and crown width was attained at 3mx3m spacing. The longer branch length attained with 3mx3m could be related to high number of trees. The result is more assimilates partitioned to some branches in an attempt to be exposed in light. This similar reason could explain the larger crown width, because as more branches elongate in search for light, it creates a larger crown width. However when spacing was increased to 4mx4m a larger stem diameter and branch size was attained, this could attributed to more assimilates being partitioned in stem enlargement, the larger stem diameter ultimately results in larger branch size. It appears as fewer trees are planted per hectare, stem diameter, branch size and length reduce.

5.2.2 Effect of pruning

Pruning of apple trees controls size, stimulates flowering and fruit bud formation. Results indicated that 30% pruning had the highest yield, increasing the intensity of pruning to 40% results in a reduction in the number of fruits though the fruits were large (Figure 8, 9). These results are similar to Kaith *et al.*, (2011) who also found out that increasing the intensity of pruning results in lower yield in apples in India. This decrease in yield is as a result of reduced fruit sites as well as leaves that manufacture food for the fruits. The large size of fruits is attributed to less number of fruitlets left which reduces the competition for assimilates as it would have been if no pruning was done. The results suggest that pruning can be appropriate if it is done at 30%, less and more than 30% results in a lower number of fruits per tree.

Stem diameter, branch size and crown diameter of trees increased with increasing pruning from 30% to 40%, though stem length was lower 40% pruning was done (Table 7). This could be as a result of reduced competition for assimilates among the trees and removal of apical dominance of the bud (Kaith *et al.*, 2011). Similarly Sharma *et al.*, (2003) found out an increase in

vegetative growth of the tree with increased pruning and nitrogen levels. This would indicate that most assimilates are fully utilized for vegetative growth of the tree as opposed to yield since the yield lowers with increased pruning e.g. at 40%. The longer branch length in no pruning trees could be an indication of a tree response in search for light. A high number of branches would result in competition for light which would result in branch elongation.

5.2.3 Effect of time of defoliation

Results from the study showed that defoliation after 30 days resulted in a high increase in the number and size of fruits Figure (10, 11). Similarly defoliation after 30 days resulted in better tree growth characteristics (Table 8). It should however be noted that a high number of fruits were got when defoliation was done after 10 days. However because these fruits were small evidenced by high number of fruits needed to make a kilogram than when done at 30 days, defoliation after 30 days would therefore be the best timing for high yields in apples since it also resulted in large fruits. Removal of foliage after harvest prevents buds from entering endodormancy after growth has stopped and instead stimulates them to regrow (Tromp, 2005; Dereje *et al.*, 2010). This bud –break in the tropics due to defoliation results in an increase in concentration of gibberellins at the apex of the closed buds (Edwards, 1984; Dereje *et al.*, 2010). This is accompanied by a decline in abscisic acid concentration in the buds (Edwards, 1984). Timing of defoliation leads to burst of the buds occurring within one to four weeks. Therefore the best timing of defoliation would result in earlier bud burst and consequently earlier blooming, fruit size and larger fruits due to translocation of materials in the developing fruits. This could have been the case when it was done at 30 days since large fruits were realized (Figure 11). A study by Chandler, (1960) demonstrated that apple trees with limited abscission of leaves in autumn due to high autumn temperatures appear to require greater chilling

requirements than those whose leaves break off. This study continues to stress the importance of timing of defoliation in apple production.

Defoliation of apple trees significantly affected tree growth parameters (Table 8). Results indicated that defoliation at 30 days resulted in better tree quality characteristics. Increasing the time of defoliation after harvest from 10 days to 30 days consequently increased the stem diameter, branch size and length of apple trees. Timing of defoliation was seen to modify patterns of vegetative and reproductive growth in deciduous fruits (Couvillon & Lloyd, 1978). The results suggested that at 30 days after harvesting, both photosynthates and leaf photosynthesis was not limiting for the remaining leaves. This applies that materials were translocated in vegetative and the reproductive parts of the tree unlike when it was done after 20 days. It appears that the photosynthetic activity of the remaining leaves were increased (Zhou *et al.*, 2000). Defoliation after 30 days could be the right time when the trees are about to terminate the dormancy and resume active growth. This increase in plant metabolism after dormancy is responsible larger stem diameter, branch size and crown diameter in trees defoliated after 30 days.

5.2.4 Effect of fruit thinning

Removal of excess fruits from apple trees enhance proper shape and size of apple fruits thus increasing the marketability of the fruits remaining on the tree (Janick *et al.*, 1996). Results from the study showed a significant increase in the number of and size of fruits (Table 9). These results are surprising especially for number of fruits being higher when thinning was done. This could be due to abortion of flowers or natural shading of the flowers/fruitlets in unthinned trees reducing the number of fruits per tree. A study by Denne, (2016) also stressed the importance of thinning and its increase in fruit size among apple fruits. He attributed this increase in size to

increase in cell size and number following thinning of the fruits in a tree. According to this study, by harvest the size of the fruits from thinned trees were four times bigger than those from unthinned apple trees, these results agree with this study.

5.2.5 Effect of age of staking and bending

Bending of branches has been used to control shoot extension and promote flowering in apples (Ferree and Schmid, 1994; Tromp, 1967). A study by Ito *et al.* (1999) also demonstrated that bending of shoots accelerated flower bud formation regardless of the position in pears. Similarly, Tromp, (1967) pointed out that horizontally growing apple trees formed more flower buds than vertically growing buds and consequently more fruits per tree. Results showed that bending apple trees after 1 year resulted in a high number of apples as well as lower number of fruits per kg (Figure 12, 13). These results only suggest that bending and staking of apple trees after one year predominantly increases the number of flowers which results in high yields. However this could be the case with cultivars with low abortion rates of flowers. The timing of bending is very important in flower initiation, if it is done at the end of shoot cessation, it is more likely that more assimilates will be channeled to flower-bud formation (Tromp, 1967; Ito *et al.*, 1999). Therefore bending after one year and three years could probably be at dormant stage of the apple trees which could stimulate fruiting.

Bending of apple trees has an effect on the growth characteristics. Results show no significant difference in branch length with age of bending and staking (Table 10). These results are consistent with Ito *et al.* (1999) who also found no significant difference in shoot length between the vertical and bent shoots in pears. These results suggest that regardless of whether you bend or don't bend shoots, the branch length don't significantly increase. This could attributed to

bending when shoot elongation is about to terminate. Other growth characteristics such as stem diameter, branch size and crown diameter recorded maximum values after 2 years and 3 years of bending shoots. This could be related to bending of the shoots when they were still in active growth. This might have increased the elongation and expansion of shoots accompanied by increased branch size and crown width.

5.2.6 Effect of growth facilitation

Results from the study showed that use of organic matter resulted in more number of fruits per tree per season compared to when no facilitation was used (Figure 14). However inorganic fertilizers resulted in less number of fruits per kilogram (Figure 15). This difference in yield between the organic and inorganic facilitations could be related to nutrient compositions in these growth facilitators. Organic amendments improve the physical and chemical properties of the soil. This in turn improves nutrient availability and uptake by the trees. Both inorganic and organic facilitation improved the yield of the trees compared to when no facilitation was done. Increased nutrient supply from inorganic fertilizers increase the photosynthetic sites which ultimately results in production of more assimilates to the developing fruits.

Fruit trees are in good vigor if the leaves are large, dark green and the shoot growth thick and relatively longer for a given age of the tree. This can only be increased by fertilization of the trees with either organic or inorganic fertilizers. The nutrient content of organic fertilizers depends on the type of fertilizer used, either green manure or farm-yard manure. Even with in manures, certain manures such as poultry manure has higher quantities of a particular nutrient. Vegetative growth of a tree majorly depends on the nitrogen levels in the soil though its expression may depend on the availability of another nutrient that is known as a compound effect. The maximum growth requirements attained when inorganic fertilizers are used is a clear

indication of high amounts of nitrogen applied (Table 11). In contrast the nitrogen quantity of organic fertilizers/amendments would be responsible for the lower growth characteristic values recorded. These results stress the importance of growth facilitation in apple production.

5.3 Challenges facing apple farming households in Kigezi highlands

Results from the current study indicated thieves, birds and labour intensiveness as the major challenges facing apple producers in the region (Table 13). Apple growing is labour intensive with respect to the management practices carried out. These might increase the cost of production if yield gains are to be attained. A study by (Ntakyo et al., 2013) also acknowledges apple production as a highly labour intensive activity in southwestern Uganda. Birds and thieves on the other hand are predominantly important in apple production. This probably is due to the sweetness of the fruit, lack of alternative source of food for birds in some seasons and high prices attached to it which elicited more threat in production. This would explain why most farmers grow apples near their homes or about 100 meters from their homes to provide security against birds and man (Namubiru and Buyinza, 2007). The most common diseases according to the results were white powdery mildew and apple scab (Table 13). These diseases constituted the most important diseases affecting apple growers all over the world (MacHardy, 2000). These results suggest that for better production of apples these two diseases should be given more attention in this region. Furthermore, the most important pests according to farmers were aphids and birds (Table 13). These two pests are popular because of the sweetness of the fruit. As in diseases these should be given more attention for better yields in apples.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

This study set as its prime objective to examine the factors influencing performance of the different apple cultivars in order to come up with the best management option for optimum yield. Empirical results generated from a farm level cross sectional data of apple farmers demonstrate that most dominant cultivars of apple grown were Golden Dorset and Anna and Anna was the most grown in Kigezi region. Both apple cultivars had better yields when they were grown on the slopes. Most farm characteristics and orchard management practices that positively influenced apple yields included; age of the orchard, orchard location, increased farmer's adoption of apple spacing of 5mx5m that enhanced fruit size, 30% pruning was found to have the highest yield among the four pruning treatments. Timing of defoliation at 10 days and fruit thinning, bending and staking after one year produced the highest yield and largest fruits compared to other treatments. Additionally, use of growth facilitation increased yield of apples with inorganic fertilization resulting in more than half of the yields generated from organic fertilization. However, use of organic fertilizers resulted in the largest stem diameter and crown width whereas inorganic fertilization resulted in the largest branch size. Most of the dominant challenges affecting apple farmers in the region were thieves, birds, poor management practices, labour intensiveness, pests and diseases that included aphids, birds and powdery mildew and apple scab as the most critical important pests and diseases in the region.

6.2 Recommendations

One of the current issues in apple production in Kigezi Highlands is how to improve productivity through adoption of apple management practices in order to meet the current and future demand for apples in the region and beyond. Based on the findings and discussions, the study recommends the following;

- I. Planting on slopes is the most recommended site for high yields of apples in Kigezi region.
- II. Farmers should visit on-station orchards and be taught better management practices in order to get high yields as those realized on stations.
- III. The most appropriate spacing is 4mx4m for apple production. With this spacing, there is reduced competition for nutrients among the trees and this results into better yields.
- IV. Thirty (30) % pruning of apple branches at early stage of growth produces highest number of fruits per tree and hence timely pruning is critical for better results.
- V. The best time to do defoliation of apple trees would be 10 days after which it rains for higher yields, increasing timing to after 30 days can also be recommended for larger fruits.
- VI. Thinning is very essential for larger sized apple fruits and therefore should be done by apple farmers for better yields.
- VII. Both apple Anna and Golden Dorset are performing well in the study area and these varieties should be recommended for more planting among apple farmers.
- VIII. Bending and staking of apple branches should be done after one year of planting when branches are still young to encourage bud development on branches.
- IX. Use of growth facilitation is essential for higher yields in apples.

Further research

More research is needed to understand the influence of timing of fruit thinning and yield of apples in the Kigezi region.

Synchronizing of flowering of apple trees in different locations should also be studied. This has problems with a tree having mature, medium sized and very young fruits as well as flowers at the same time.

Future research should attempt to identify the socio-economic and environmental factors influencing adoption of apples and the associated management practices in Kigezi highlands.

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APPENDICES

Appendix 1: work plan/time framework showing time lines for research activities

	Months (2015/2016)											
Activity	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March	April-Aug
Proposal preparation and defense												
Reconnaissance and improvement of questions, check lists and data collection sheets												
Data Analysis												
Draft dissertation												
Final copy and Submission												
Defence												

Appendix 2: Interview Guide for focus group discussions

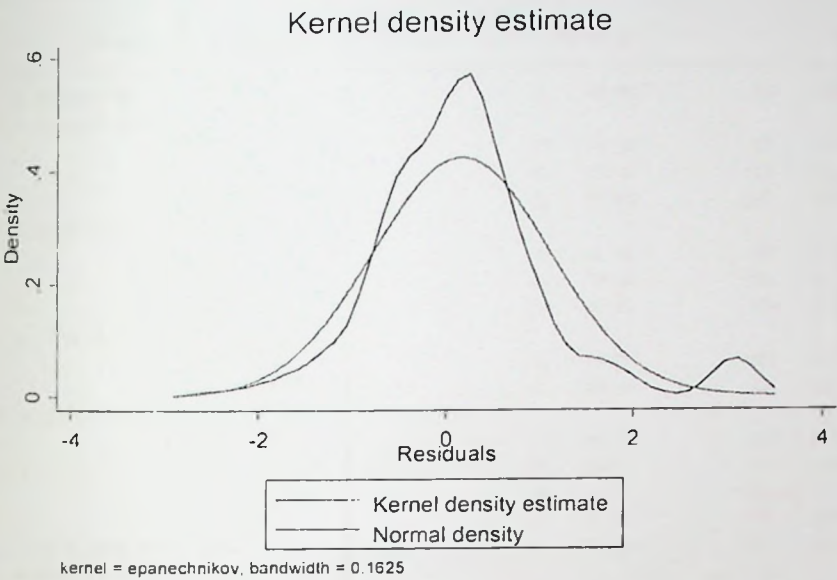
1. Which apple varieties are grown by farmers and research stations in Kigezi region?
2. Are there significant differences in yields of apple fruits between farmers and station orchards
3. What are the common orchard management/ practices carried out by farmers?
4. What are the differences in agronomic and silvicultural practices associated with apple fruit growing in Kigezi region?
5. What are the major challenges face by apple growers in apple orchard management in Kigezi region?
6. What are the farmers' innovations and technologies used to improve tree quality, yields and management of pests and diseases in apple orchards?
7. What is the optimum yield of a mature well managed apple fruit tree per variety/cultivar per season?

Appendix 3: BUDGET

Item	Description	Quantity	Unit cost	Amount
A: Stationary				
Books	A4 Counter Books	6	5,000/=	30,000/=
Pens	Water Proof Pens	6	10,000/=	60,000/=
	Ordinary Pens	2 Packets	5,000/=	10,000/=
	Markers	1 Packet	20,000/=	20,000/=
File Folders	Plastic Files	6	5,000/=	30,000/=
Charts	Flip charts	4	20,000/=	80,000/=
Printing and Photocopying	Assorted			300,000/=
Sub-Total				590,000/=
B: Field Trips				
Transport	Fuel 3 trips per district	510 litres	3,400/=	1,734,000/=
Facilitation	Subsistence 4 trips for data collection in a survey	7 Field Assistants	90,000/=	2,520,000/=
Facilitation	Subsistence allowance for	4 Technicians	200,000 for 6 months	4,800,000/=

	technicians managing experiments — one per district			
<i>Sub-Total</i>				<i>9,054,000/=</i>
data entry	Lump sum			300,000/=
<i>Sub-Total</i>				<i>300,000/=</i>
contingency			5%	<i>497,200/=</i>
<i>Grand Total</i>				<i>10,441,200/=</i>

Appendix 4: Normality test after transformation



Appendix 5: Results from the multicollinearity test

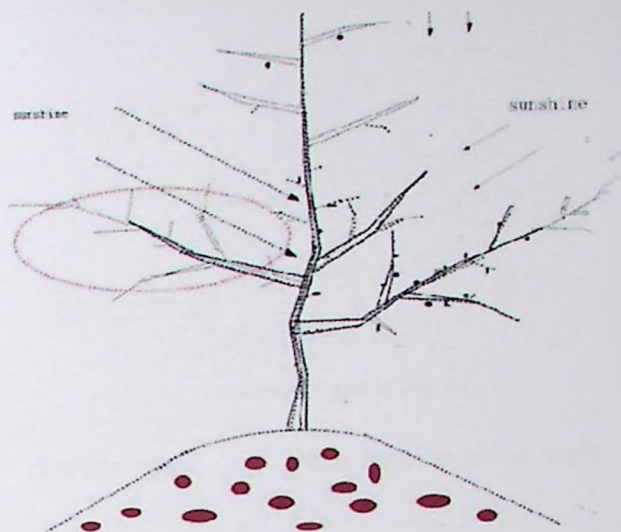
. vif

Variable	VIF	1/VIF
ageoforhard	1.65	0.606414
sitelocation		
2	2.73	0.366967
3	3.06	0.327248
1. Anna	1.05	0.955511
ageofbgand~g		
1	6.14	0.162953
2	5.76	0.173469
3	3.38	0.295434
intialspacg		
2	1.75	0.571750
3	1.54	0.648196
pruningint~y		
1	2.43	0.412195
2	3.32	0.301576
3	3.22	0.310393
4	1.52	0.657186
1. fruitthi~e	1.73	0.578931
timeofdefor~n		
1	2.19	0.457047
2	3.59	0.278317
3	3.79	0.263677
growthfaci~n		
1	2.06	0.485075
2	1.76	0.569112
Mean VIF	2.77	

Appendix 6: Proper management practices of apple crop



Top Left: Bending and staking of apple trees
well-pruned tree



Top right: A cross section of a structure of a



Central left: A well pruned apple tree

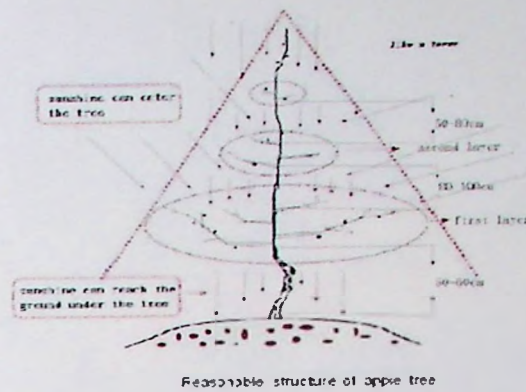


Central right: Defoliating apple tree



Bottom Left: A well shaped apple tree.

structured apple tree



Bottom right : A cross section of a well-

Appendix 7: Poor management practices



Top left: A poorly managed apple tree

Top right: Apples affected by birds



Bottom (Left to right): Apples affected by white Powdery mildew disease

Appendix 8: A check list used in data collection

ANALYSIS OF APPLE CULTIVARS AND THEIR MANAGEMENT OPTIONS FOR
OPTIMUM YIELD IN THE KIGEZI HIGHLANDS

DateName of

Enumerator.....

Name of the

Farmer.....Tel.....

.....

Parish.....Sub county.....

Age of the orchard.....Site location of the

orchard.....

GPS location/Orchard of the

site.....

Name of the Apple Variety/varieties on the farm

.....

1. How many trees of Anna.....
2. How many trees of Golden Dorset.....
3. How many trees of other varieties.....

S.N	Plot ID	Variety	Stem diameter at 60cm	Branch size(1st layer)	Branch length (1st layer)	No_Fruits	Crown width	Age of bending and staking	Initial spacing	Pruning intensity	Fruit size	No_Fruits per tree	Fruit thinning done	Time of defoliation	Growth facilitation
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14															
15															

Codes: Orchard location: V=Valley, S=Slop, H=Hill top: **Variety:** A=Anna, GD=Golden Dorset, 0= others specify; **Age of bending and Staking after planting:** 0= No bending and staking, 1=after one year, 2= after two years, 3=after three years, 4= after 4 years, 5= Bend and stake branches every year; **Initial spacing** 1=3mX3m, 2=4mX4m, 3=5mX5m, **Thinning Intensity;** 0 = no removal of branches, 1=10% removal of branches, 2=20% removal of branches, 4=40% removal of branches, **Fruit size:** S=10cm diameter, M=15cm diameter, L=20cm diameter, **Growth Facilitator:** N= No growth facilitator, O=Organic Manure, I=Inorganic Manure.

Other observations in the method

I. Is there any Farmers innovation?

.....
.....
.....
.....

II. What are the most common pests?

.....
.....
.....

III. What are the pest control methods used?

.....
.....
.....

IV. What are the most common diseases that attack your trees?

.....
.....
.....
.....

V. What are the most effective chemicals in relation to mentioned diseases?

.....
.....
.....

VI. What are the most effective chemicals in relation to pests mentioned ii above?

.....
.....

VII. What are the other apple growing challenges?

.....
.....

Farmers Name	District	Subcounty	Coordinates	Transect	Tree_No	Name pest	No_Pest	Severity score	Apple Variety
			Longitudes	1	1				
					2				
					3				
					4				
					5				
					6				
					7				
					8				
					9				
					10				
					11				
					12				
					13				
					14				
					15				
					16				
					17				
					18				
					19				
					20				
				2	20				
					1				
					2				

