PERFORMANCE OF SELECTED DIFFERENT TYPES OF STONE FRUITS IN A SUMMER RAINFALL AREA, SOUTH AFRICA

BY

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DEDICATIONS

I dedicate this work to my:

- ❖ Husband Vhonani Theophilus Makuya, daughter Phophi Princess Makuya and Muhali Thompho Makuya
- ❖ Parents Mr M.F. and Mrs T.S. Ramphinwa
- ❖ Parents in laws Mrs P. Makuya and the late Mr R.F. Makuya

ABSTRACT

Temperate fruit trees cultivated in areas of mild winter conditions result in a number of insufficient chilling symptoms. Such insufficient symptoms are described in general, as the absence of bud break, delayed foliation, reduced fruit set as well as reduced fruit quality. Therefore, after bud break, fruit trees show insufficient symptoms such as paralysis of the shoot growth, development of small leaves, low rate of effective fructification, and reduction of the flowering-maturity circle and development of small flat fruits. Adequate information of chilling requirements, dates of dormancy breaking and appropriate chemical agents, which should be applied to meet chilling requirement is required for successful production of stone fruit. South African (SA) deciduous fruit has been exported successfully (primarily to the UK and Europe) since 1892 and SA is currently a major Southern Hemisphere supplier of fresh fruit between the months of October and August (Huysane, 1996). In order to remain competitive, there is a need to expand the production of stone fruits from traditional Western Cape to a summer rainfall area in Limpopo Province. The broad objectives of the study was to evaluate some quantitative and qualitative performance traits of different types of stone fruits in a summer rainfall area in Limpopo Province.

The project was initiated in 2007 by Agricultural Research Council through the collaboration of Agricultural Research Council (ARC) Infruitec-Nietvoorbij (Stellenbosch) Western Cape and University of Venda in Limpopo Province. This was a continuous assessment about the performance of selected stone fruit cultivars in a summer rainfall area, South Africa. Growth data was sampled on each tree. Circumference measurement of the graft union after the growing season was measured using a soft pliable measuring tape in order to get an indication of the growth rate. This was done annually during winter period.

The experimental design was a completely randomized design (CRD) with six trees (experimental units) randomly selected for each of the four species (‘Charisma’, ‘Summersun’, ‘Pioneer ‘and ‘Mayglo’). Analysis of variance was performed on all variables accessed using GLM (General Linear Models) Procedure of SAS statistical software version 9.2 (SAS Institute

Inc., Cary, NC, USA, 2003). Shapiro-Wilk test was performed to test for normality (Shapiro, 1965).

There was significant different on diameter of stems, scion height and production of secondary branches of trees on the four different stone fruit trees studied. 'Mayglo' and 'Summersun' trees had high buds production, blooming, and fruit-set than 'Charisma' and 'Pioneer' trees in year 2009. All trees had a very good bud production and blooming, but only 'Mayglo' and 'Summersun' had a good fruit set compared 'Charisma' and 'Pioneer' in year 2010.

Key words: Bud break, chilling units, flowering, fruiting and stone fruits

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Last, but not least, thanks be to God for my life through all tests in the past five years. You have made my life more beautiful. May Your name be exalted, honored, and glorified.

DECLARATION

I, Ramphinwa Maanea Lonia hereby declare that the dissertation for Masters in Agric (MSc in Agric) degree at the University of Venda hereby submitted by me has not previously been submitted for a degree at this or any other university, and that is my own work in design and in execution and that all reference material contained therein has been duly acknowledged.

Signature................................

Date.........27/06/12.............

CERTIFICATION PAGE

I certify that Ms Ramphinwa Maanea Lonia carried out this work in the Department of Horticultural Sciences University of Venda.

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SYMBOL AND ABBREVIATION

ANOVA - Analysis of variance

ARC - Agricultural Research Council

NDA - National Department of Agriculture

PIO – 'Pioneer'

SUM –' Summersun'

CHAR – 'Charisma'

MAY – **'**Mayglo'

MASL - Meters Above Sea Level

MOU- Memorandum of understanding

N - Nitrogen

MTB - Mean Time of Bud Break

CU - Chilling Units

GML - General Linear Model

LSD - Least Significance Difference

P - Phosphorus

SAS - Statistical Analysis Software

SA- South Africa

SSC- Soluble solids concentration

R&D - Rural and Development

AFSFGA - Australian Fresh Stone Fruits Growers Association

LAN - Lime Ammonium Nitrate

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CHAPTER 1

1. INTRODUCTION

1.1 Background information

Stone fruits belong to the Rosaceae family containing a single hard seed. The most popular stone fruits in South Africa include apricots, nectarines, peaches and plums. Apart for local consumption and processing, fresh fruit can be exported from South Africa, as the deciduous fruit industries have been doing over many years (South Africa, Republic of Fresh Deciduous Fruit Special Stone Fruit Report, 1999). The process of transporting fresh fruit from the producers to the end user require companies and systems which are reliable in every way, especially when the users are on the other side of the world (OABS, 2007).

The main areas in which deciduous fruits are produced in South Africa are the Western and Eastern Cape Provinces. This is primarily due to the fact that these areas enjoy warm, dry summers and also cold winters. It is estimated by the Department of Agriculture, Forestry and Fisheries that there are about 2,254 producers of fruit for consumption (1,174 producers of stone fruit, 954 producers of dry and table grapes and 700 producers of pome fruit) (NDA, 2010).

Deciduous fruit contributes greatly to exports for South Africa. During the 2008/09 season, about 47.7% of deciduous fruit produced was exported and approximately 83.1% of the gross value from deciduous fruit came from foreign exchange export earnings. Total exports amounted to 797,259 tons. This represented 2.4% increase on the previous season. Over the past five seasons, a majority of the deciduous fruit has been processed to juice, with the exception of apricots and peaches, which were mainly canned (Euromonitor International for PMA, 2010).

Periodic, rather than continuous growth is almost universal among trees. In tropical, as in temperate trees, periods of shoot growth (flushing) alternate with periods of bud rest or dormancy. Various types of dormancy have been identified in woody plants adapted to temperate climates with a relatively short growing season and large annual variations in temperature and photoperiod which strongly synchronize vegetative and reproductive tree development (Crabbé, 1994; Crabbé and Barnola, 1996). In the tropics monthly mean temperatures often vary by < 1–

2°C and annual variation in photoperiod is 1 h or less. Climatic seasonality is therefore mainly determined by duration and severity of the dry season (Crabbé, 1994).

In contrast with winter cold, severe seasonal drought does not synchronize periodic development of tropical trees, and bud break in vegetative or flower buds during the dry season is common. Periodic tree development is even less synchronized in tropical forests with a short dry season (Borchert, 1998). The periodic arrest of shoot growth in such forests should be caused mainly by developmental constraints inherent in trees as large, complex, long-lived plants, not by environmental cues (Borchert, 1991, 1992; Crabbé and Barnola, 1996). These endogenous constraints are the consequence of size- and time-dependent changes in the functional interactions among a tree's organs and will be referred to as correlative control. With increasing climatic seasonality, the role of environmental changes causing the temporary arrest of bud growth become more important (e.g. control of bud dormancy of cold-temperate trees by annual variation in temperature and photoperiod).

Due to the sessile nature, plants have been forced to adapt to the dynamic environmental conditions that surround them. Temperature creates a selective pressure on plants growing in temperate climates and has affected their geographical distribution based upon a capacity to survive seasonal thermal fluctuations (Smithberg and Weiser, 1968). In woody plants, two distinct and fundamentally different strategies for the seasonal survival of subzero temperatures have evolved: freeze tolerance (nonsupercooling) and freeze avoidance (supercooling) (Burke, Gusta, Quamme, and Li, 1976). Freezing behavior strategies employed by a woody plant vary from tissue to tissue and are species specific. For example, cortical tissues are strictly nonsupercooling; however, buds and xylem ray parenchyma may exhibit either strategy. In nonsupercooling tissues, ice formation is initiated within extracellular spaces and generates a dehydrative vapor pressure gradient between extracellular ice and intracellular water. Nonsupercooling cells readily desiccate in response to extracellular ice formation (George, Becwar, Burke, 1982; Fujikawa, Kuroda, and Ohtani, 1997) and are capable of surviving low temperature extremes (Guy, Niemi , Fennell, and Carter, 1986) due to an inherent capacity to tolerate desiccation (Ashworth, 1993). In supercooling tissues, ice may also initiate in extracellular spaces; however, cells are thought to resist intracellular desiccation (Burke *et al*., 1976) and maintain intracellular water in a non-equilibrium condition. The supercooling of intracellular water is limited to the approximate point of homogeneous ice nucleation −40°C (Rasmussen and MacKenzie, 1972). When the capacity for supercooling is exceeded, spontaneous and lethal intracellular ice formation may occur (Ashworth, 1993).

The broad objectives of the study was:

- To evaluate some quantitative and qualitative performance traits of different types of stone fruits in a summer rainfall area in Limpopo Province.

The specific objectives of the study was to evaluate and compare:

- Four quantitative fruit yield parameters namely graft union circumference, duration to first flowering, fruit diameter and total fruit weight (yield per tree).

CHAPTER 2

2. LITERATURE REVIEW

2.1 Introduction

This chapter provides an overview of studies done in the stone fruit complex, both locally and internationally. Selected studies are reviewed in terms of their methodologies, results and findings. This chapter consists of components focusing on the origin, domestication and distribution, crop description, environmental requirements, production of planting material, care and maintenance of stone fruit, constraints in deciduous fruit production, and environmental control of bud growth in deciduous fruits.

The Western Cape is ideally suited to the growing of quality stone fruit and is the major production area in South Africa (South Africa, Republic of Fresh Deciduous Fruit Special Stone Fruit Report, 1999). This area enjoys a mild Mediterranean-type climate with a diversity of unique micro-climate areas and varying soil conditions, which enables the production of more than 280,000 tons of stone fruit varieties during the harvesting season which commences in October and lasts until April. More than 30,000 tons of stone fruit are exported every year. Good sunny weather in South Africa increases the production of stone fruit (South Africa, Republic of Fresh Deciduous Fruit Special Stone Fruit Report, 1999).

2.2 Origin, domestication and distribution of stone fruits

Deciduous fruits were first introduced into Australia by both European and Chinese settlers at the end of the 1890s (George, Nissen, Lloyd and Richens, 1988). Fruit quality and productivity of temperate fruits grown have been gradually improved through introduction and selection of better quality varieties, mainly from the USA. Over a period of time, the most suitable regions to grow these fruits have been selected. About 90% of Australia's production is consumed domestically (George *et al.,* 1988). Australia was a major exporter of apple to the UK in the 1970s. However, with the UK entering the European community, Australian's exports to this market collapsed. Since then, a major restructuring of most temperate fruit industries has occurred and now Australia has repositioned its exports to Japan and South-east Asia.

It was reported in 1998 by Foreign Agricultural Service/USDA that Italy, Spain, and the United States, are the leading stone fruit exporters in the Northern Hemisphere, however in the Southern Hemisphere, Chile is a major exporter of stone fruit. Of all selected country stone fruit exports in 1998, peach and nectarine shipments comprised more than a 70 percent share, by volume, followed by plums and prunes at 17 percent (Foreign Agricultural Service/USDA, 1998).

South African (SA) deciduous fruit has been exported successfully (primarily to the UK and Europe) since 1892, and SA is currently a major Southern Hemisphere supplier of fresh fruit between the months of October and August (Huysamer, 1996). The exporters are represented in the industry by the Fresh Produce Exporters Forum (FPEF). The current members of the FPEF include 88 of 172 registered exporters, representing more than 80% of exported volumes. During the 2005 season 108 exporters were responsible for exporting more than 50% of the total exported volume (Fresh Produce Exportes' Forum (FPEF), (2009)

2.3 Description of stone fruits

Stone fruit is a drupe, a fruit in which an outer fleshy part (exocarp, or skin; and mesocarp, or flesh) surrounds a shell (the pit or stone) of hardened endocarp with a seed inside. These fruits develop from a single carpel, and mostly from flowers with superior ovaries. The definitive characteristic of a drupe is that the hard, lignified stone (or pit) is derived from the ovary wall of the flower (South Africa, Fresh deciduous fruit special stone fruit report, 1999).

2.4 Environmental requirements of stone fruits

All deciduous fruit plants require chilling during the winter rest period to enable their buds to sprout evenly, and for good flowering and fruit set to occur in spring (Erez, Fishman, Linsley-Noakes, and Allan, 1990). Insufficient winter chilling results in prolonged rest or delayed foliation, and consequently poor production and quality of fruits. While the major deciduous fruit producing areas in South Africa are in the SW and S Cape, colder areas of the Free State and lower Orange River, and there is limited production in subtropical KwaZulu/Natal where problems with lack of winter chilling often occur (Richardson, Seely, and Walker, 1974; Erez , Yablowitz, and Korchinski, 1993; Allan and Burnett, 1995). In the subtropics (mean temperature of coldest month between 13 and 18°C, and occurrence of light frost) the winter day/night temperature variations are much greater than in temperate regions, due to typically cloudless days and nights, and greater radiative heat loss at night. High day temperatures (>16 and especially >19°C) have an adverse effect on chilling accumulation even when night temperatures are sufficiently cold (Erez *et al*., 1993; Allan and Burnett, 1995).

2.5 Production of planting material of stone fruits

Scion cultivars are important, but in order to optimize the performance of the tree, it must be supported by the most suitable rootstock (Reighard and Loreti, 2008). Correct cultivar on the most suitable rootstock, for specific conditions, is therefore a necessary requirement for stone fruit growers. Rootstock provides a tool for stone fruits growers to increase productivity and improve efficiency (Reighard and Loreti, 2008). The producer must make this choice early and order trees in good time from a reputable nursery. The nursery must provide well hardened trees with optimum available reserves and a well developed feeder root system. Trees should be established in the winter while still dormant, to favour early root development before flowering and shoot growth.

Stadler and Lotze (1991) showed that the fruit of kakamas seedlings grown from seeds from virus free source are significantly larger than fruit of kakamas seedling from seeds direct from canning factories. Currently all new plantings are virus-free material. 64 rootstock, from 1971 to 2008 including Marianna hybrids from South African breeding programme, were evaluated for peaches and nectarines (Du Toit, 2005). South Africa is currently conducting its own stone fruit rootstock breeding programme (Du Toit, 2005). Rootstock cultivation and evaluation programmes are long-term and costly, therefore it is important that potential rootstocks are well studied prior to inclusion in intensive long term evaluations.

2.6 Care and maintenance of stone fruits

2.6.1 Tree Training

Currently there are various training systems for stone fruit trees South Africa, but for Vhembe district in SA it is recommended that peach, nectarines, apricot and plums trees be pruned to the four leaders (Scaffolds) vase shape system (Smith, Mentjies and Deklerk, 2007). This does not imply that the other training systems must be excluded in future planning. Vase shape tree consist of relatively short trunk of 50cm with three to four scaffold branches spaced equally around the main trunk with the lowest one at least 30cm from the ground. Side branches developing from the main scaffold branches, should be well spaced to allow optimum light penetration, minimum injury from chafing, control pests and disease and maximum fruit production. Depending on the cultivar planted, the main scaffold branches should be trained as upright as possible to allow enough space for secondary scaffold and side branches. Main scaffold branches must always be more vigorous than the other side branches (Smith *et al*., 2007). It should gradually taper off in vigor towards the tips of the scaffold branches to prevent over shading of side branches to lower parts of the trees. The spreading of side branches on the tree should be controlled to fit in with the particular planting distance and the height should preferably not be more than 80% of the row width with maximum height of 3.2 meters. The higher the trees are, the more expensive it becomes to harvest the fruit in the upper parts of the trees.

2.6.2 Application of Fertilizers

Nitrogen appears to be the key element affecting fruit size of temperate fruits (George and Nissen, 1992). Excessive N application increases vegetative growth and shading, resulting in a reduction in fruit size and quality. However, when paclobutrazol and N are applied together, fruit size may be increased by as much as 39% (George *et al*., 1992). The improvement in fruit size may be attributed to three factors; increased photosynthetic capacity of leaves higher in nitrogen, delayed leaf abscission, and control of excessive vegetative growth (George *et al*., 1992). Potassium is the other major element affecting fruit quality. Potash may increase fruit size by as much as 8% (George *et al*, 1988). In high rainfall regions, deficiencies of minor nutrients like B, Cu and Zn are common. These can be corrected through either foliar applications during the flowering and early fruit set period or through soil application (George *et al*., 1992). Late summer applications of minor elements may also be important to ensure availability within the tree for the next season's flowering and early fruit development. The most commonly used fertilizers are straight inorganic. Very few organic fertilizers are used except for young trees at planting. Fertilizer rates are normally based on crop removal rates and an allowance is made for leaching and fixation losses (George *et al.,* 1988).

2.6.3 Thinning

Fruitlets thinning will increase fruit size while also reducing total yield, and thus a balance between yield and fruit size must be achieved (Day, Johnson, DeJong, and Crisosto, 1992). Generally, maximum profit does not occur at maximum marketable yield since larger fruit bring a higher market price. Leaving too many fruit on a tree not only reduces fruit size, but also decreases their (soluble solids concentration) SSC. Thus fruit quality can be sacrificed in several ways by incorrect thinning. Grower experience is the best determinant of the optimum thinning level for each orchard and cultivar (Day *et al*., 1992).

2.6.4 Weeding

Newly planted trees find it difficult to compete with weeds for water and nutrients. Therefore, weed control in the immediate vicinity of the young trees is vital. This is achieved by mulching and spot spraying under and around the trees. Where weeds grow through the mulch they are either hand-weeded or spot-sprayed with herbicides. With young trees, the most commonly used herbicide is paraquat. With older trees glyphosate is commonly used during the summer months in combination with paraquat (George *et al*., 1992).

2.6.5 Mulching

The most commonly used mulches are black plastic, coarse hay or straw, such as sorghum stubble. The grassed inter-row area is also a valuable source of on-site mulch. Mulches are normally applied in spring. The mulched/sprayed area extends to just beyond the drip line of the trees, making it roughly two metres wide. Besides reducing weeds, mulching increases soil organic matter, improves soil structure and reduces root temperature fluctuations. It also increases water retention and may reduce irrigation requirements (George *et al*., 1988).

2.6.6 Irrigation

Trees supplied with optimum amounts of water (100% evapotranspiration, E.T.) during the season will produce maximum fruit size (Crisosto, Johnson, Luza and Cisosto, 1994). However, higher soil soluble concentration (SSC) levels can be obtained by imposing moderate water stress during fruit growth prior to harvest. This might also reduce fruit size, but in some cases only slightly. Moderate water stress can also reduce vegetative growth, thus maintaining lower fruiting wood, especially in high density plantings.

Over-irrigation (150% E.T. in the month prior to harvest) can be detrimental to long term productivity. Although fruit size may increase in the short term, the resulting excess vegetative growth can lead to shading out of lower fruiting wood and loss of yield. A micro jet or drip irrigation system is normally sufficient in wetting the root zone of the trees and flood irrigation can also be used to certain extend. Control and application of the soil moisture content within the root zone should always be kept more or less at field water capacity for successful fruit production (Smith *et al,* 2007).

2.6.7 Pruning

The greater the light interception by an individual fruit and its surrounding leaves the better its quality (including fruit color, size, SSC, and flavor). Fruit in the top of the tree, for example, always have better quality than fruit in the lower, shaded part of the canopy (Day *et al*., 1992). The differences can sometimes be substantial, even though the lower fruit remain on the tree for a longer period to reach maturity.

Prudent summer pruning practices which increase light penetration into the canopy will generally improve fruit quality. For example, the removal of interior water shoots can significantly increase light penetration and improve fruit size, color and SSC of lower position fruit. However extensive summer pruning which removes many leaves surrounding the fruit can have the opposite effect, since these leaves supply carbohydrates to the fruit. In the same way, the practice of removing ("pulling") leaves around fruit to increase fruit color may decrease fruit size and SSC (Day *et al*., 1992).

2.6.8 Control of Pests and Diseases

The most serious pests for the major temperate fruit species are: Queensland and Mediterranean fruit fly, fruit spotting bug, white peach scale, and oriental fruit moth, for stone fruits; codling moth, light brown apple moth, San Jose scale, two spotted mite, mealy bug, and Monolepta and dried (Borchert, 1994). Stone fruit varieties planted in South Africa are subjected to fungal and bacterial diseases if the right conditions for these diseases would occur in a specific region. In areas with prevailing dryer conditions during the summer months, most of stone fruits varieties would show a higher tolerance to bacterial and fungal diseases compared to wet areas like Vhembe district (Smith, *et al.*, 2007). Very comprehensive pest and disease control programs for stone fruits are available from agricultural chemical companies in South Africa, for example, UAP (www.uap.co.za)

2.6.9 Harvesting of fruits and yields

The maturity of stone fruits at harvest will determine their ability to achieve high eating quality, their susceptibility to mechanical injuries, their postharvest performance and their potential postharvest life. Any maturity index should clearly separate fruit based on physiolnogical maturity, and any legal standard should be independent of growing conditions or location (Crisosto, 1992; Mitchell and Kader, 1989).

Fruit harvested at too high a maturity will be incapable of withstanding the rigors of postharvest handling and distribution, and may have increased susceptibility to invasion by fruit rotting organisms (Mitchell, Mayer, Saenz, Slaughter, Johnson, Bias and Delwiche, 1991). These fruit will have a short postharvest life, and may develop undesirable off flavours and mealy texture. Fruit harvested at too low a maturity will be incapable of ripening to their potential flavour and texture qualities. They will also lose water more readily, and may be at increased risk of physiological deterioration, especially if susceptible to internal breakdown. With the increasing volume of fresh stone fruits entering long distance marketing, there has been a tendency to harvest the fruit at lower maturity; the idea being that they would be better able to carry to distant markets. The result has often been negative, however, because such fruit are more subject to shrivel and to the development of internal breakdown symptoms (Mitchell *et al.,* 1991).

Plums are the biggest fruit type within the stone fruit industry and estimates indicate that volumes could increase by 7 % in the 2010/2011 season. The peach crop is expected to grow by 6 % and nectarines by 8 % as compared to the previous season. In contrast to other fruit types, apricot volumes are expected to be slightly lower than last season, i.e.1 % decline as compared to previous season. (South African fruit trade flow November, 2010).

2.6.10 Processing

Approximately 70-80% of the plum crop is exported and the remainder of produce used for the local fresh market. The processing component is insignificant. For peaches on the other hand, between 70% and 80% of the total crop is being processed (canned) followed by the local market and dried market segments (OABS, 2007). Only a small percentage (3-5%) is being exported as fresh fruit. The distribution of apricots is similar to peaches with between 70 and 80% being processed, followed by dried apricots. However, since 1996/97 export volumes of apricots overtook the local market fresh volumes (OABS, 2007). The scope to expand apricot exports with the right cultivars and an increase in market access to markets that are not currently part of the marketing portfolio.

2.7 Constraints in deciduous fruit production in South Africa

2.7.1 Regulatory issues

Labour regulations are often cited as a hindrance to growth, but it should be noted that similar regulatory factors exist in competitor countries, such as Chile and New Zealand. Furthermore, one of the hallmarks of a competitive industry is its capacity to pay reasonable wages and social investment, which provides for human resource growth and development. Current labour legislation in South Africa allows for employers to apply for exemptions regarding work hours during critical farm activities (FAO, 2005). In a number of cases, these exemptions have proven valuable during periods of peak workloads.

2.7.2 Labour markets

A major constrain in terms of labour in South Africa is the lack of skilled labour. At the same time, farm wage levels do not attract skilled or qualified people to undertake menial and hard work. Smaller producers, who pay comparatively lower wages, are more exposed than the larger producers to the threat of labour shortages. Squatter communities have developed within the urban sprawl of the main fruit industry towns, such as De Doorns and Grabouw, and have given rise to widespread local social and economic problems that have further eroded the quality of the available labour. The incidence of HIV/Aids is undoubtedly the most serious of these problems. The industry has launched an awareness programme (Deciduous Fruit Producers' Trust(DFPT), 2005), "Let's talk status at farm level".

2.7.3 Infrastructure

In the development of the fruit plan in 2007, participants at the various workshops identified similar constraints in all different provinces in South Africa. During 2003/2004 and 2004/2005, a number of other serious problems have been raised, which not only have an impact on costs (direct and indirect), but also on the competitiveness of the industry (OABS, 2005). Solutions to these problems need a focused and purposeful approach and cooperation among all relevant role players. These problems are summerised as imbalance of packed fruit deliveries to cold storage and ports, lack of cold storage capacity at certain times of the year, hygiene and micro-bacterial quality of water available for use in packhorses and domestic purpose on farms, electricity outgage during the fruit season as well as transport from pack house to the market, logistic systems which are not applied at full efficiency and poor communication between agricultural sector and service providers in terms of planning and future expansion on issues such as energy and transport (FAO, 2005).

2.7.4 Other

Competition for scare natural resources (i.e. water and land) is putting continued pressure on good farmland that can be used for agricultural purposes. Furthermore, the opening up of Elgin/Grabouw as a niche wine growing area has resulted in grubbing of orchards in favour of vineyards and also an opportunity for exit from deciduous fruit forming. Fruit production in South Africa is under threat from the impact of climate change (Fruit SA, 2006). Lack of winter chilling gives rise to delayed foliation and the problem of small fruit of poor quality. Increased average maximum temperatures in January and February may result in poor colour development in "bicolour" fruit. Government financial support for land reform initiatives as well as public sector housing support in a number of key fruit areas is not keeping pace, with the rate at which growers are geared to implement change (Calvert, 2006).

2.8 Environmental control of bud growth in deciduous fruits

2.8.1 Vegetative buds of deciduous species

Stone fruit trees develop their vegetative and fruiting buds in the summer and, as winter approaches, the already developed buds go dormant in response to both shorter day lengths and cooler temperatures (Byrne, and Bacon, 1992). This dormancy or sleeping stage protects these buds from oncoming cold weather. Once buds have entered dormancy, they will be tolerant to temperatures much below freezing and will not grow in response to mid-winter warm spells. These buds remain dormant until they have accumulated sufficient chilling units (CU) of cold weather. When enough chilling accumulates, the buds are ready to grow in response to mid-winter warm spells (Byrne, *et al*. 1992). As long as there have been enough CUs the flower and leaf buds develop normally. If the buds do not receive sufficient chilling temperatures during winter to completely release dormancy, trees will develop one or more of physiological symptoms associated with insufficient chilling such as the absence of bud break, delayed foliation, reduced fruit set and buttoning as well as reduced fruit quality (Byrne, *et al*. 1992).

2.8.2 Determination of the degree of dormancy

The degree of dormancy was determined by the one-node cutting test (Rageau, 1978). The time to bud break at 25 °C, which was calculated as the mean time to bud break, was directly related to the depth of dormancy. For cv. 'Redhaven,' end dormancy is considered to be released when MTB is less than 12 days (Bonhomme, Rageau and Gendraud, 2000). The end of dormancy is also characterized based on the Utah model (Richardson, Seeley and Walker, 1974) and local temperatures. For cv. 'Redhaven' peach trees, dormancy is considered to be over when 900 chilling units (CU) have been accumulated (Richardson *et al*., 1974).

2.8.3 Analysis of Bud Growth Patterns

Control mechanisms involved in bud break or growth arrest were inferred from temporal correlations between changes in environmental conditions, tree development and tree water status. Synchronous bud break of many trees in a landscape indicates an inductive environmental change such as rainfall or change in photoperiod. Correlative control was indicated by a synchronous bud break among conspecific trees in the absence of notable environmental change (Borchert, 1994).

Changes in tree water status and soil water availability correlated with the initiation or arrest of bud growth, and were measured with a pressure chamber. Predawn stem water potential measured in defoliated twigs indicated water status of tree branches at equilibrium with available soil water. The difference between Predawn stem water potential and midday leaf water potential reflects the balance between transpiration and water uptake and is an indirect measure of stomatal control (Borchert, 1994).

2.8.4 Correlative Control of Bud Growth

Correlative control of bud growth reflects functional interactions among the organs of a tree. Continuous shoot growth requires the provision of water, nutrients and growth regulators by other organs at rates exceeding consumption by growing shoots. As the tree increases in size and hence in the number of growing shoots and transpiring leaves, maintaining this functional equilibrium becomes progressively more difficult (Borchert,1991).

In large, cold-temperate trees shoot growth therefore ceases well before the end of the growing season under climatic conditions permitting the continuing growth of tree saplings and herbs. Shoot growth may be arrested in the absence of adverse environmental conditions by a shortage in any one of the substances provided by other organs, i.e. by loss of the functional equilibrium among the tree's organs (Borchert, 1991; Crabbé and Barnola, 1996). Correlative control of tree growth periodicity should be carefully distinguished from spatial controls such as apical dominance, which determine tree architecture. As the physiological mechanisms of correlative and spatial control differ substantially, applying the same term, paradormancy, to both mechanisms appears questionable (Lang, Early, Martin, and Darnell 1987; Crabbé, 1994).

Defoliation soon after the end of seasonal shoot growth induces bud break and flushing in temperate trees (Borchert, 1991; Crabbé and Barnola, 1996). That indicated that trees have a limited carrying capacity for leaves and attain an optimum leaf area during each growing season.

Leaves are involved in the correlative feedback inhibition arresting shoot growth once this optimum has been attained. Changes in tree water balance play a central role in the correlative control of bud rest and bud break of tropical trees during the dry season, when water was the principal factor limiting tree growth (Borchert, 1991, 1992, 1998).

Therefore stone fruits for local consumption are sourced mainly from our South African suppliers. The most popular stone fruit include apricots, nectarines, peaches and plums and are adapted to temperate areas. Tropical and sub-tropical areas in the Southern hemisphere have a challenge of accumulating insufficient chilling units during the winter period (May to July) which cannot sustain production of stone fruits (Linsley-Noakes, Louw and Allan, 1995). Deciduous fruit varieties with low chilling characteristics normally require approximately 200 chilling units for sustainable commercial fruit production (Linsley-Noakes *et al*., 1995). Stone fruit production is a new initiative for improving incomes at household level among communities in Limpopo Province. Being temperate crops, this region which is sub-tropical offers a promising climate for the cultivation of low chilling varieties. However, delayed foliation has been established as a problem for some cultivars grown commercially in other parts of South Africa. Therefore this study is designed to assess the performance of low chilling types of stone fruits in a summer rainfall area.

CHAPTER 3

3. MATERIALS AND METHODS

3.1 Site description

The experimental site for this study is in Thohoyandou, Vhembe district. The site is situated at longitude and latitude of 2258.081`S and $30^0$26.411`E respectively. The elevation of the site is 595 meters above sea level. The site is characterized by deep, well-drained clay soil and is classified as Hutton form soil type (Soil Classification Workgroup 1991). The annual rainfall is about 500 mm that falls predominantly in the summer, and the average maximum and minimum temperatures are 31^0C and 18^0C, respectively (Tadross, 2006). During warm winters, cold units range between 200 and 300 infruitec units (Liensley-Noakes, 1995).

3.2 Different trees of stone fruits

Four different types of stone fruit trees grafted on the Kakamas rootstock were used in the study. Each stone fruit species was represented by a commercial trees (i.e. 'Charisama' (Apricot), 'Pioneer' (Plums), 'Summersun' (Nectarines) and 'Mayglo' (Peaches). Trees were developed at Stemmet nursery in Monpague area in Western Cape Province. These trees had already accumulated chilling units which were between 500 to 600 Infruitec-Units before introduced to the experimental farm at University of Venda. In Limpopo and Mpumalanga Provinces early dessert peaches and nectarines are cultivated under very low cold units, between 200 and 300 Infruitec-Units (Linsley-Noakes, 1995). During warm winter the cold units will be even less than 200. The commercial yield of a fruit tree is influenced by genetic or environment inter-action on a particular cultivar. Therefore climate, disease susceptibility and time of blossoming were the factors to be considered in influencing the cultivar choice.

Kakamas rootstock are very sensitive to free lime, which is manifested by iron, zinc and manganese deficiencies on leaves, as a result of the insoluble carbonate forms of the cations (Du Preez, 1980). It is also sensitive to high pH, root knot nematodes and wet conditions. All these aspects reflect in lower fruit mass. It performs well in medium to high potential soils without limitations.

3.3 Sampling of fruit trees for measurement

Each type of stone fruits consisted of tree population not exceeding sixteen trees planted in a field plot measuring 15m X 35m in order to provide optimum density. Each plot had two rows of fruit trees spaced 5m between the rows. In each row, trees were spaced 2m apart in order to allow adequate branching. The density of these trees was consistent with those used in similar studies by Crocker and Williams, (2000). In order to standardize the experimental conditions for all treatments, it was assumed that this optimum density is the same for all trees of each of the four different types stone fruits. The measurements for each selected trait were conducted on six randomly selected experimental units (i.e. six trees) of each type of stone fruit population.

3.4 Experimental design and statistical analysis

A field experiment was conducted during winter in 2009 and 2010. The experimental design was a completely randomized design with six trees (experimental units) randomly selected for each of the four different types of stone fruit trees ('Charisma', 'Summersun', 'Pioneer' and 'Mayglo'). The stone fruit trees were obtained from Agricultural Research Council (ARC), Infruitec-Nietvoorbij (Stellenbosch), South Africa. Analysis of Variance was performed on all variables measured using GLM (General Linear Models) Procedure of SAS statistical software version 9.2 (SAS Institute Inc., Cary, NC, USA). Shapiro-Wilk Test was performed to test for normality (Shapiro, 1965).

3.5 Cultural practices

3.5.1 Soil analysis and fertilizer application

Soil samples were collected at various depths i.e. 30cm and 60cm, and submitted for soil analyses to BemLab in the Western Cape. Phosphate (Super phosphate 10.5)) was applied at rate of 245 kg per hectare as a top dressing (50%) as well as in the planting holes (50%) with the trees. The land was prepared and irrigated a week before planting. At six weeks after planting, LAN (28%) at a rate of 30 gram per tree per month was applied. Land was irrigated after application of fertilizers.

3.5.2 Weather data and fertilization programme

Weather data (daily minimum and maximum temperature, and humidity) was obtained from an automatic weather station that was approximately 100 metres from the experimental site. Fruit trees were fertilized with lime ammonium nitrate (LAN) during the first year after they leaved out in the spring and summer by placing the fertilizer at and slightly beyond the canopy edge of the tree but never against the trunk. This procedure was repeated in each and every year.

3.5.3 Irrigation programme

Tensiometers were installed next to tree at 30 and 60 cm depth and irrigation was done according to the readings shown on the tensiometers. Normal irrigation commenced when tensiometers readings were below 30kPa and the amount of rain received was taken into consideration before irrigating. Weeding was done as required during the seasons using a hand hoe in order to avoid competition of nutrients with the plants.

3.5.4. Pruning

The first pruning process took place during winter following planting of the young trees. All shoots developing below the graft union originating from the rootstock were removed as the shoots were going to hamper the growth development of the tree. Shoots in the 35cm zone of the trunk of the tree above ground level were removed, thus encouraging shoots higher up to develop fully in the next growing season. During the second winter pruning, new side branches were selected very carefully and were spaced about 25cm apart alternately on opposite sides of the scaffold branches, in order not to develop opposite to each other, but diagonally to the side of the tree. Summer pruning was used as a handy tool to overcome shading problem. In late summer, before leaf fall starts, leaders of scaffolds and side branches were cleared of all competitive shoots from the first 30 to 50cm. Shoots on the scaffold and side branches were selected and spaced about 20cm apart on a herringbone system.

3.5.5 Pest and disease spray programme

COPROX Extra® @ 3.5g/liter of water (Copperoxychloride) was sprayed during winter in order to control leaf drop as well as controlling fungal diseases. At bud break of trees; THIRAM® @1,5g/liter of water was applied to control curly leaves on peaches and nectarines. Thiram® was sprayed at 2 x 5 days interval during the blooming time on all the trees for the control of blossom blight.

3.5.6 Tree growth measurements

Growth data was sampled on each experimental unit. Circumference measurement of the graft union (2 cm above the graft union) after the growing season was taken using a soft pliable measuring tape in order to get an indication of the growth rate. Numbers of primary and secondary branches were counted before and after pruning in 2009 and 2010 season respectively. Height of the leading branch or scion was measured using a measuring tape. This was done annually during winter period for two years. Regular visits (2-3 days per week) to the orchard were conducted in order to evaluate the trees. Dormancy breaking agents (Dormex) was sprayed before flowering for uniformity. First bud break, flowering and track record of flowers was measured (rate of opening) when 50% of all processes respectively occured, on which branch formed first and where. The number of fruits per type was recorded three times a week.

3.5.7 Thinning

Thinning was done as early as possible not later than 50 days after full bloom depending on the cultivars planted. Fruitlets were thinned during early fruit formation, before hardening of the stone (pit) in the fruit sets, fruits were thinned by leaving approximately one fruit every 15cm along the shoots for fruit varieties maturing earlier than December.

3.5.8 Fruit yield

Fruit yield was not measured, as no fruit was harvested in year 2010 and 2009 as the area was not protected against vermins. Therefore a large number of cultivars of each species need to be further investigated to on to determine those that will produce high yield and offer better opportunity market opportunities.

CHAPTER 4

4. RESULTS AND DISCUSSON

4.1 Tree growth data for year 2009 and 2010 seasons

The results of tree growth of 'Summersun' were bigger than the tree growth of 'Pioneer', 'Charisma' and 'Mayglo' (Fig4.1.1). Therefore, 'Summersun' had significantly higher with error bars and number of branches as compared to 'Pioneer', 'Charisma' and 'Mayglo' (Appendix 1, Figure 4.1.1).

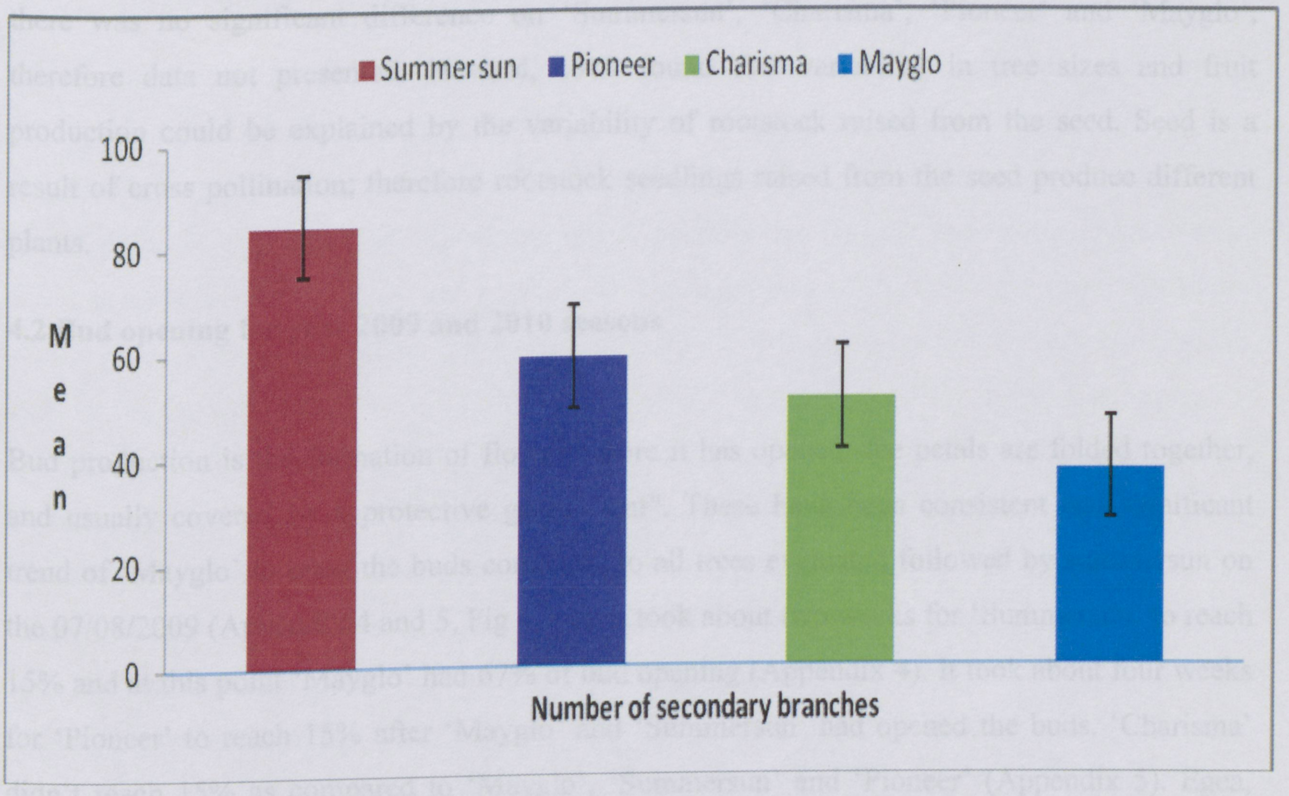

Figure 4.1.1 Means of trees growth measurements

It was found that there was no significant effect of scion height on 'Summersun', 'Pioneer', 'Charisma', and 'Mayglo' since the scion height of all trees was the same. Therefore, the mean of scion height of all trees was statistically non-significant at P<0.001 (Appendix 2).

4.1.1 Number of secondary branches

Numbers of secondary branches showed that 'Summersun' had more secondary branches when compared to 'Pioneer', 'Charisma' and 'Mayglo' (Appendix 3, Fig. 4.1.1). Therefore, the number of secondary branches for 'Mayglo' were significantly lower at P<0.001 when compared with 'Pioneer', 'Charisma' and 'Summersun'. The number of primary branches was counted, and there was no significant difference on 'Summersun', 'Charisma', 'Pioneer' and 'Mayglo', therefore data not presented. Howard, 1989 found that variability in tree sizes and fruit production could be explained by the variability of rootstock raised from the seed. Seed is a result of cross pollination; therefore rootstock seedlings raised from the seed produce different plants.

4.2 Bud opening for year 2009 and 2010 seasons

Bud production is the formation of flower before it has opened; the petals are folded together, and usually covered by a protective green "leaf". These have been consistent and significant trend of 'Mayglo' to open the buds compared to all trees evaluated followed by summersun on the 07/08/2009 (Appendix 4 and 5, Fig 4.5.1). It took about two weeks for 'Summersun' to reach 15% and at this point 'Mayglo' had 67% of bud opening (Appendix 4). It took about four weeks for 'Pioneer' to reach 15% after 'Mayglo' and 'Summersun' had opened the buds. 'Charisma' didn't reach 15% as compared to 'Mayglo', 'Summersun' and 'Pioneer' (Appendix 5). Egea, Ruiz and Martinez Gomez, (2004), studying the apricot cultivar 'Orange Red', found a significant flower bud drop when the chilling requirements were not adequately satisfied. Competition between vegetative and floral buds, appear to be of great importance in relation to flower bud drop. Bartolini, Viti and Zanol (2004) found that overcoming of flower bud dormancy is affected by several endogenous and environmental factors that may interact differently on a particular genotype. In figure 4.5.1, results showed that there was significant difference at P<0.001 in the opening of buds between the four different types of stone fruits. (i.e. 'Mayglo' was significantly different from 'Summersun', 'Charisma' and 'Pioneer').

'Mayglo' was the promising trees to open buds by 5.7% on the 09/07/2010, followed by 'Summersun' at 4.5% on the 11/08/10 (Appendix 8). It took about four weeks for 'Summersun' to reach 4.5% and at this point 'Mayglo' had 76.0% (Appendix 9, Figure 4.6.1) and 'Charisma' took 5 weeks ' to reach 4.2% (Appendix 10). There was a significant difference at P<0.001 for bud break during 2010 in all trees. Alburquerque, Burgos and Egea, (2004) also found significant differences between cultivars in relation to flower bud production.

4.3 Flower opening for 2009 and 2010 seasons

Flower production is when the bud has opened and started to spreads its petals. Trees within 'Mayglo' were the earliest to start flowering by 9.5% on the 11/08/09 as compared to all trees evaluated (Appendix 6, figure 4.5.1). 'It took about 2 weeks for 'Summersun' to reach 7.3% and at this point 'Mayglo' had 63% flowering rate (Appendix 6). 'Pioneer' took three weeks to reach 9.3% as compared to 'Mayglo' and at this point 'Mayglo' had a 95% flowering rate. 'Charisma' didn't produce flowers at all in 2009 (appendix 6 and 7) because its flower buds had aborted. Similar results were found by Viti (2006) where 'SEO' and 'Orange Red' cultivars in apricot did not bloom, their flower buds dropped and therefore fruit set became 0.0%. The high chilling requirements of trees within 'Charisma' probably are the cause of these flowering problems (Guerriero, Viti, Monteleone and Gentili, 2002). Early frosts can reduce the number of buds which become flowers (Rodrigo, Hormaza and Herere, 2000).Warm pre-blossom temperatures also have been described as the cause of the underdevelopment of pistil at the time of flower opening in apricot (Rodrigo and Herrero, 2002).

'Mayglo' trees were the earliest to start flowering by 5.0% on the 12/07/10 followed by 'Summersun' (Appendix 11, 12 and 13 Figure 4.6.1), 'Pioneer' and 'Charisma'respectively. It took about 5 weeks for 'Pioneer' to reach 3.7% and at this point 'Mayglo' had already reached full bloom (Appendix 12). It took about 7 weeks for 'Charisma' to reach 4.2% as compared to 'Mayglo', 'Summersun' and 'Pioneer'. It was found that flower production was significantly different at P<0.001 for all four different types of stone fruits in 2010 (Appendix 11, 12 and 13). The two potential flowering seasons (2009 and 2010) observed for 'Mayglo' and 'Summersun' may not result into the same yield every year. (Bal, 1997) found that it is possible that one season will be heavier and another season may crop poorly. Flowering time for all trees was earlier in 2010 compared to 2009. Flowering time is a good indicator of the chilling requirements of apricot cultivars (Ruiz, Campoy and Egea, 2007).

Figure 4.3.3: Flower production for 'Mayglo' in 2009 (Photo by T.T. [illegible], University of Venda, 2009)

Figure 4.3.3: Flower production for 'Mayglo' in 2009 (Picture by M.L. Ramphinwa, University of Venda, 2009)

4.4. Fruit production for year 2009 and 2010 seasons

'Mayglo' trees were the earliest to start fruiting by 7% on the 23/08/10 followed by 'Summersun' by 4.5% on the 06/09/10 and at this point 'Mayglo' had 42.5% (Appendix 14, Figure 4.4.1). 'Pioneer' and 'Charisma' did not set fruit in year 2010. Similar results were obtained by Guerriero, Viti, Monteleone and Gentili (2002) where 'Currot' and 'San' cultivars in apricot had higher fruit set compared to those with higher chilling requirements ('SEO', Orange Red', and "Gold rich'). In 2009 (third year after planting), they were no fruit set for all trees since it was warm year season. Deciduous fruit trees suffer from physiological disorders called delayed foliation as a result of inadequate low temperatures in tropical regions (Rice, Rice and Tindale, 1987). In Appendix 14 and 15, significant difference were observed at P<0.001 for fruiting in 2010 in all four different types of stone fruit trees.

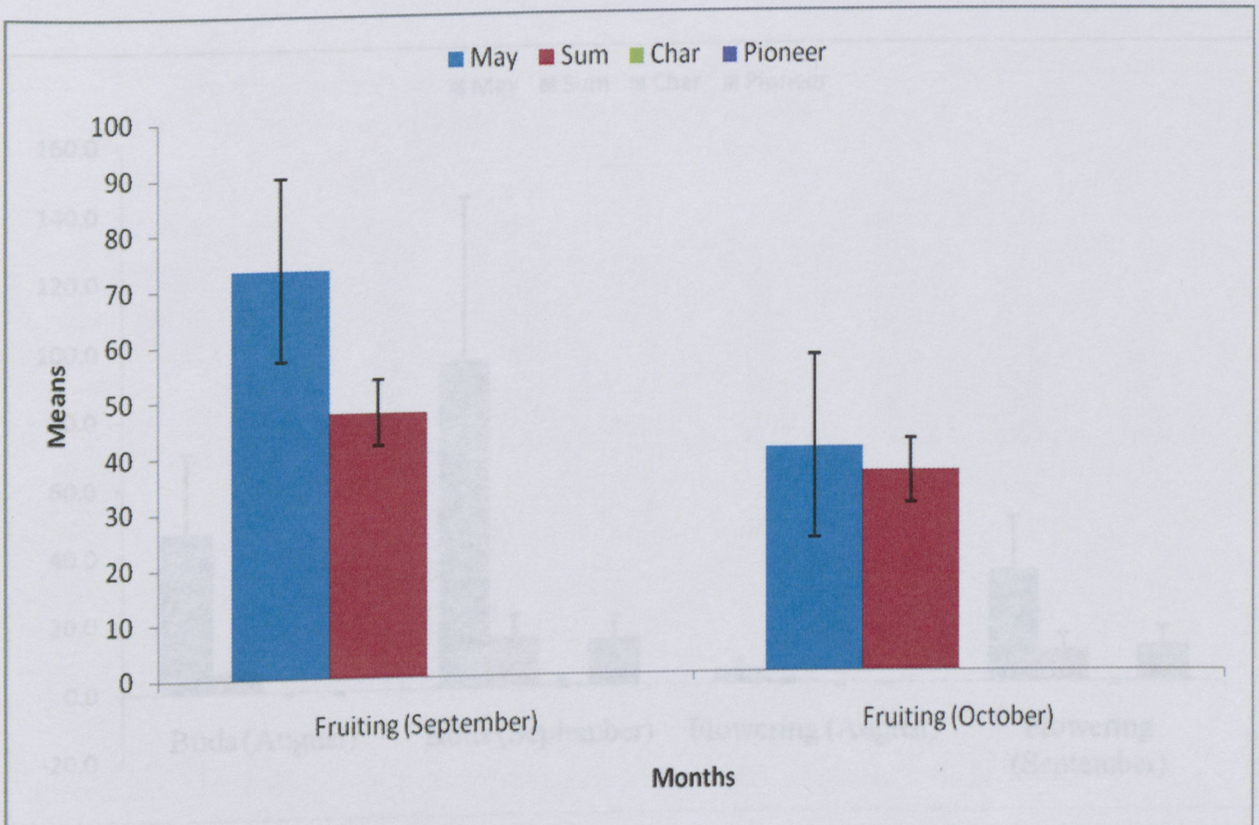

Figure 4.4.1: Mean fruit set for 'Mayglo', 'Summersun' 'Charisma' and 'Pioneer' trees in 2010.

4.5 Comparison for bud break, flowering and fruit set for 'Mayglo', 'Summersun' 'Charisma' and 'Pioneer' trees in 2009.

Figure 4.5.1 indicates mean bud break, flowering and fruit set for 2009 in Limpopo Province in August and September. It represent that 'Mayglo' trees were the earliest to respond to bud break, flowering and set fruit in 2009 followed by 'Summersun'trees. Mayglo reached 100% of bud break while 'Summersun' was still at 0%. All trees didn't set fruit in 2009. 'Mayglo' and 'Summersun' trees showed positive respond compared to 'Charisma' and 'Pioneer' trees in a summer rainfall area. All flowers on 'Mayglo', 'Summersun' and 'Pioneer' trees dropped in 2009 before they could fruit set. Adequate knowledge to control flower abortion, birds and wild animals damages is needed. Griesbach (1992) found that lack of insufficient cold temperatures to break dormancy is one of the limiting factors in the production of deciduous fruit.

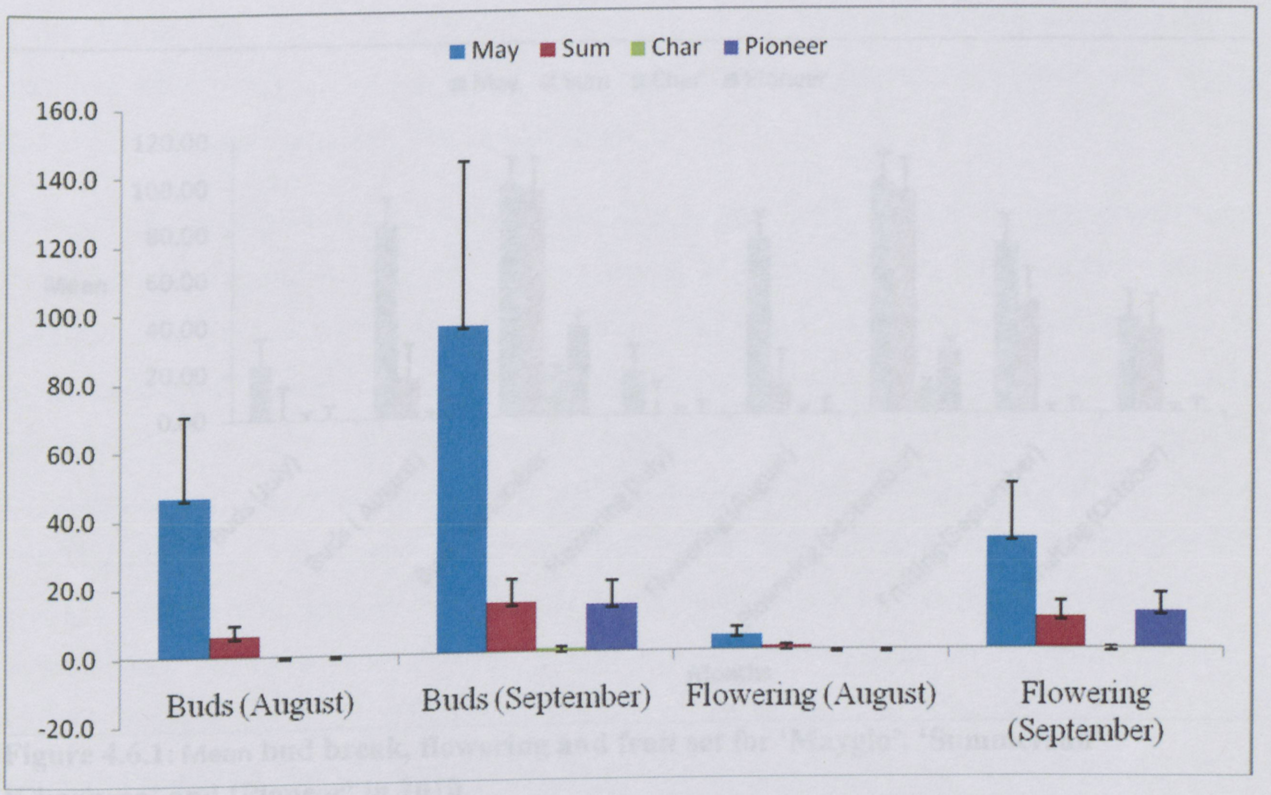

Figure 4.5.1: Mean bud break, flowering and fruit set for 'Mayglo', 'Summersun' 'Charisma' and 'Pioneer' in 2009.

4.6. Comparison for bud break, flowering and fruit set for 'Mayglo', 'Summersun' 'Charisma' and 'Pioneer' cultivars in 2010.

Figure 4.6.1 indicates mean bud break, flowering and fruit set for 2010 in Limpopo Province from July, August and September. It showed that 'Mayglo trees were the first to produce buds, flowers and fruit set when compared to 'Summersun', 'Charisma 'and 'Pioneer'. Flowering period for 'Mayglo' was earlier by almost a month as compared to 'Summersun' which was the second type of stone fruit to produce flowers and fruiting respectively. Mayglo reached full bloom while 'Summersun was 95%. These results confirm that 'Mayglo' and 'Summersun' are promising stone fruit trees which require low chilling units in order to produce quality fruits. 'Charisma' and 'Pioneer' appeared to be stone fruit trees which require high chilling units in order to sustain its production.

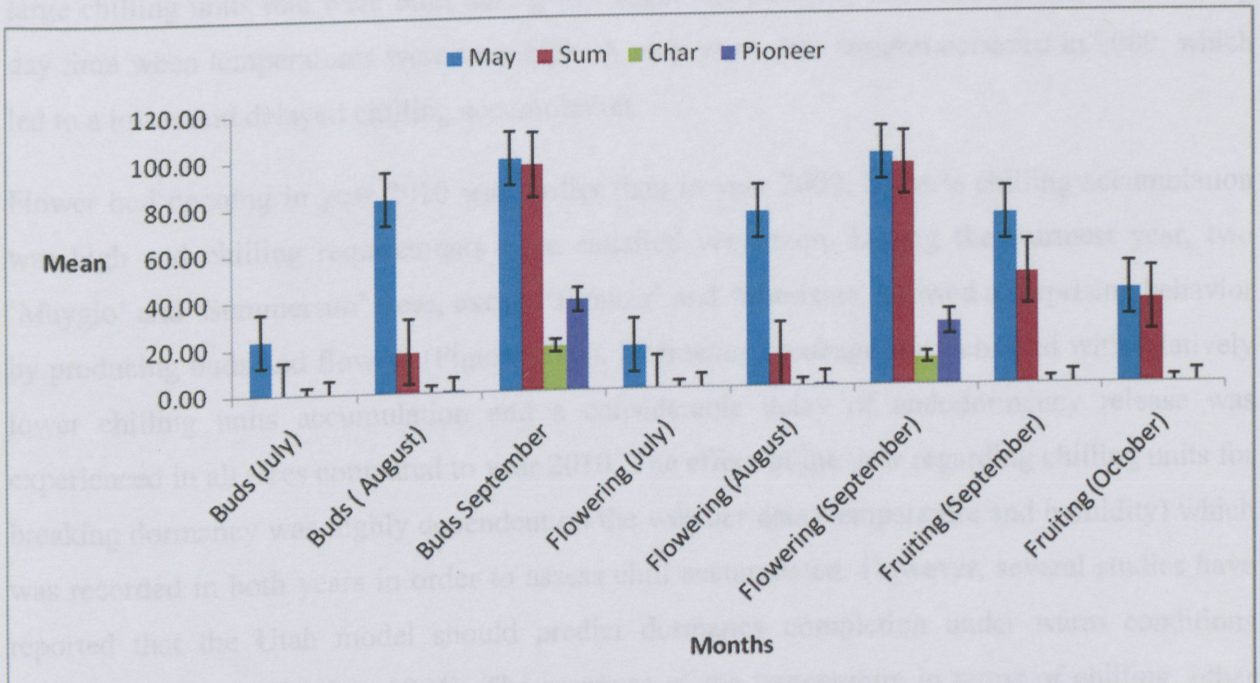

Figure 4.6.1: Mean bud break, flowering and fruit set for 'Mayglo', 'Summersun' 'Charisma' and 'Pioneer' in 2010.

4.7 Effect of climatic conditions on yield parameters 2009 and 2010

In temperate climatic zones, deciduous fruit trees rest (start dormancy) in autumn, lose their leaves during the chilling winter time (natural defoliation) and start growing in spring (flowering and producing leaves) while in the tropics, large chilling units that are built during the low night temperatures are usually cancelled during day time when temperatures are very high (Rice *et.al.,* 1987). In general, the number of hours below 7° C required to terminate the rest period has been used as index for the classification of various temperature fruit tree species. Griesbach, (2007) found that even temperature at or just below 13° C are sufficient to break bud rest in peaches. There were considerable variation in winter climatic conditions in 2009 and 2010. The year 2009 was characterized by relatively high average daily temperature and low humidity in late autumn (August) and in the early winter while the year 2010 was characterized by low daily temperature and high humidity in early winter (July). Similar results were confirmed by Rice, (1987) where large chilling units that were built during low night temperatures were usually cancelled during day time when temperatures were very high. A very warm late autumn occurred in 2009, which led to a lower and delayed chilling accumulation.

Flower bud opening in year 2010 was earlier than in year 2009, because chilling accumulation was high and chilling requirements were satisfied very soon. During the warmest year, two 'Mayglo' and 'Summersun' trees, except 'Pioneer' and 'Charisma' showed a surprising behavior by producing buds and flowers (Figure 4.7.1). Dormancy breakage was achieved with relatively lower chilling units accumulation and a considerable delay of endodormancy release was experienced in all trees compared to year 2010. The effect of the year regarding chilling units for breaking dormancy was highly dependent on the weather data (temperature and humidity) which was recorded in both years in order to assess chill accumulated. However, several studies have reported that the Utah model should predict dormancy completion under warm conditions (Linsley Noakes and Allan, 1994). The response of the temperature in terms of chilling, other climatic parameters, such as temperature flunctuations between day and night and the time of chilling fulfillment (late autumn , early winter or mid winter), could result into an important role in regulating the breaking of dormancy (Ruiz *et.al.,* 2007).

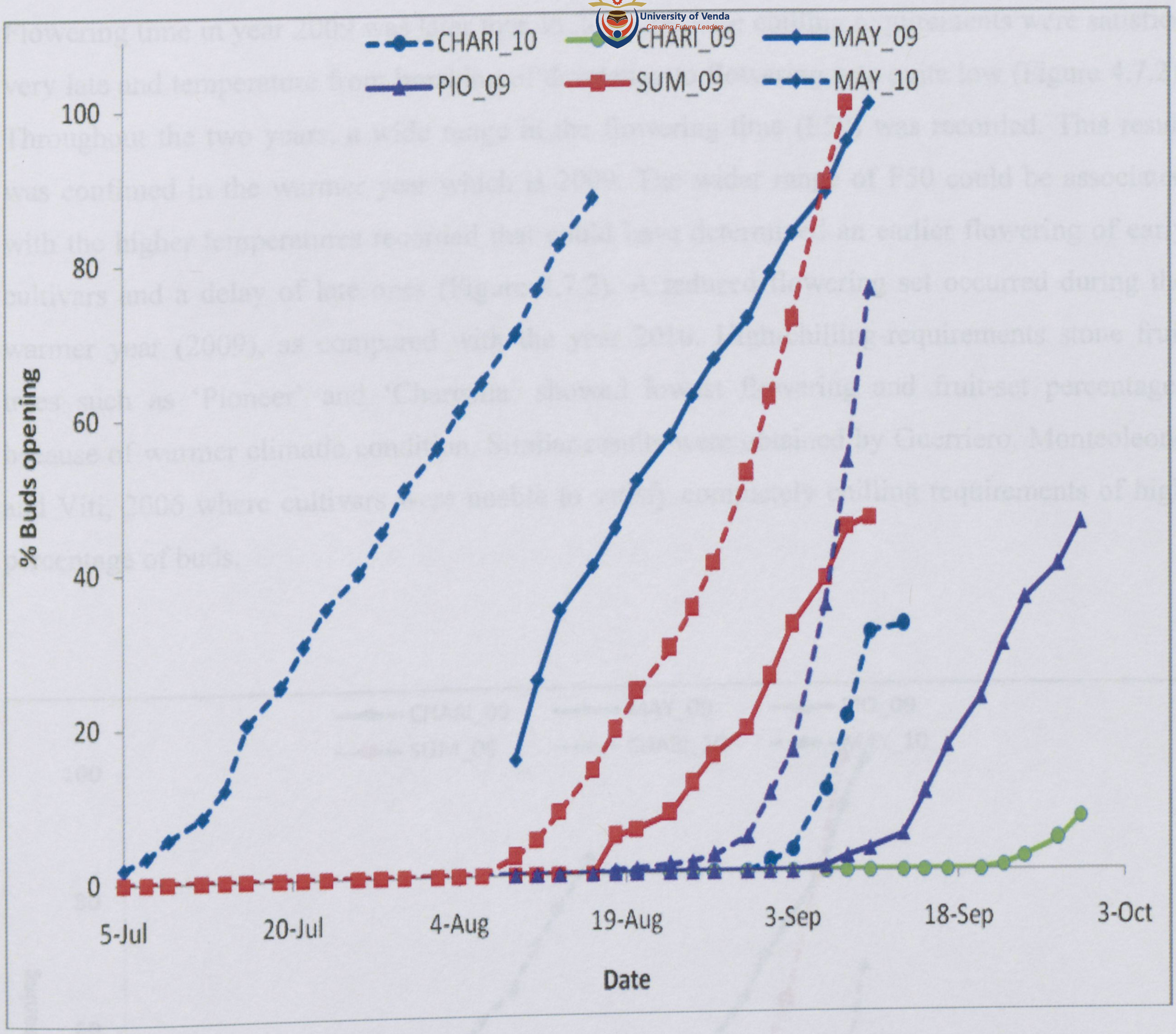

Figure 4.7.1: Buds opening in 2009 and 2010

Flowering time in year 2009 was later than in 2010, because chilling requirements were satisfied very late and temperature from breaking of dormancy to flowering was quite low (Figure 4.7.2). Throughout the two years, a wide range in the flowering time (F50) was recorded. This result was confimed in the warmer year which is 2009. The wider range of F50 could be associated with the higher temperatures recorded that could have determined an earlier flowering of early cultivars and a delay of late ones (Figure 4.7.2). A reduced flowering set occurred during the warmer year (2009), as compared with the year 2010. High-chilling-requirements stone fruit trees such as 'Pioneer' and 'Charisma' showed lowest flowering and fruit-set percentages because of warmer climatic condition. Similar results were obtained by Guerriero, Monteoleone and Viti, 2006 where cultivars were unable to satisfy completely chilling requirements of high percentage of buds.

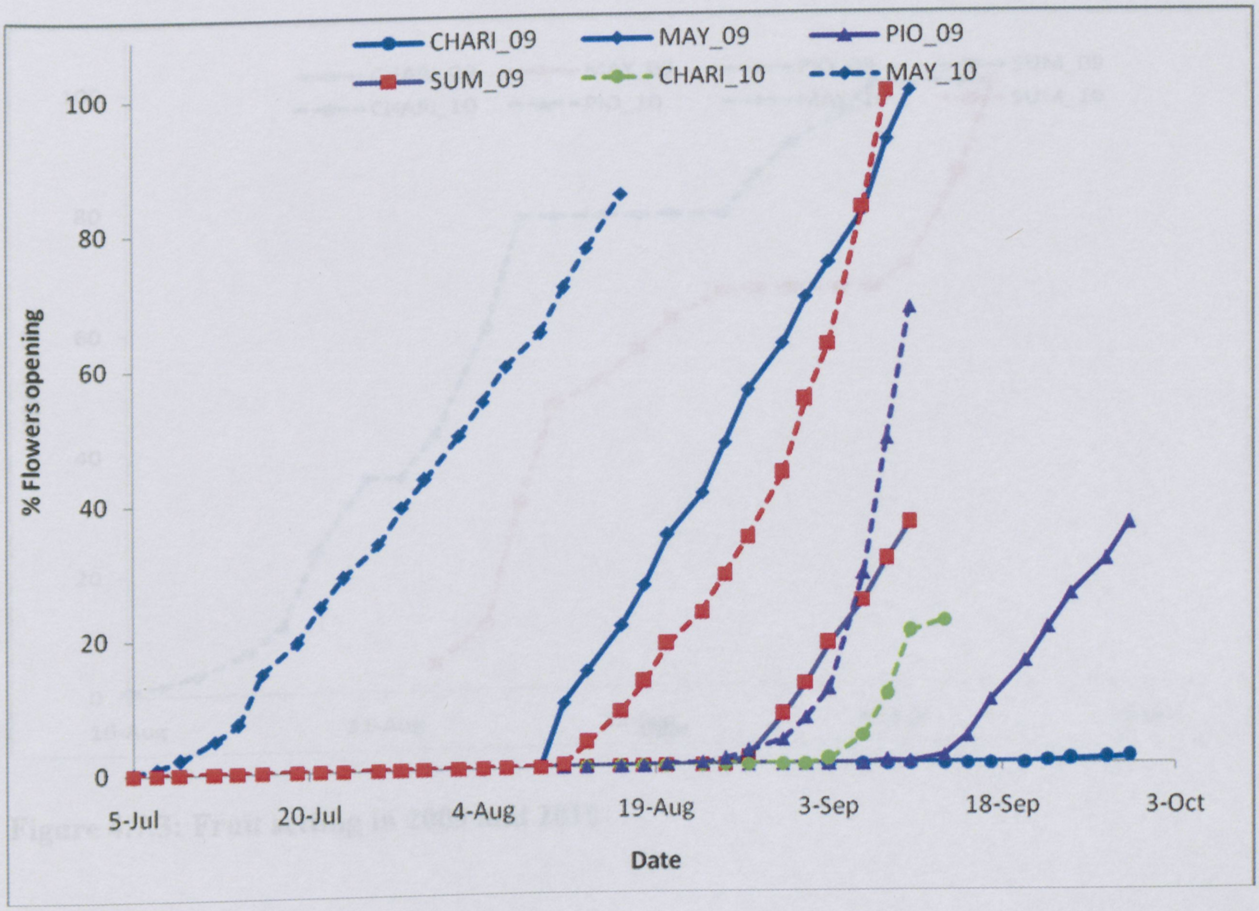

Figure 4.7.2: Flower opening in 2009 and 2010

Fruit set in year 2009 became 0.0%, because chilling requirements were not fully satisfied for obtaining best fruit-bearing capacity. Similar results were found by Samish and Lavee, (1982), where the chilling requirements of established area were not satisfied adequately, and vegetative and productive behavior was affected negatively. Fruit production in year 2010 was 100% in Mayglo and Summersun trees, because chilling requirements were quickly satisfied (Figure 4.7.3). Similar results to this study were found by Ruiz *et al.,* (2007), where bud break, flower and fruit production in 2002 was earlier than in 2004. Chilling requirements were also reported by Samish and Lavee, (1982). The poor fruit set in 'Pioneer and 'Charisma' could be a result of an altered flower bud development, determined by a lack of synchronization of dormancy cycle, xylem differentiation and microsporogenesis processes (Bartolini and Viti 2006), as well as inadequate mobilization of store metabolites (Rodrigo *et.al.*, 2000).

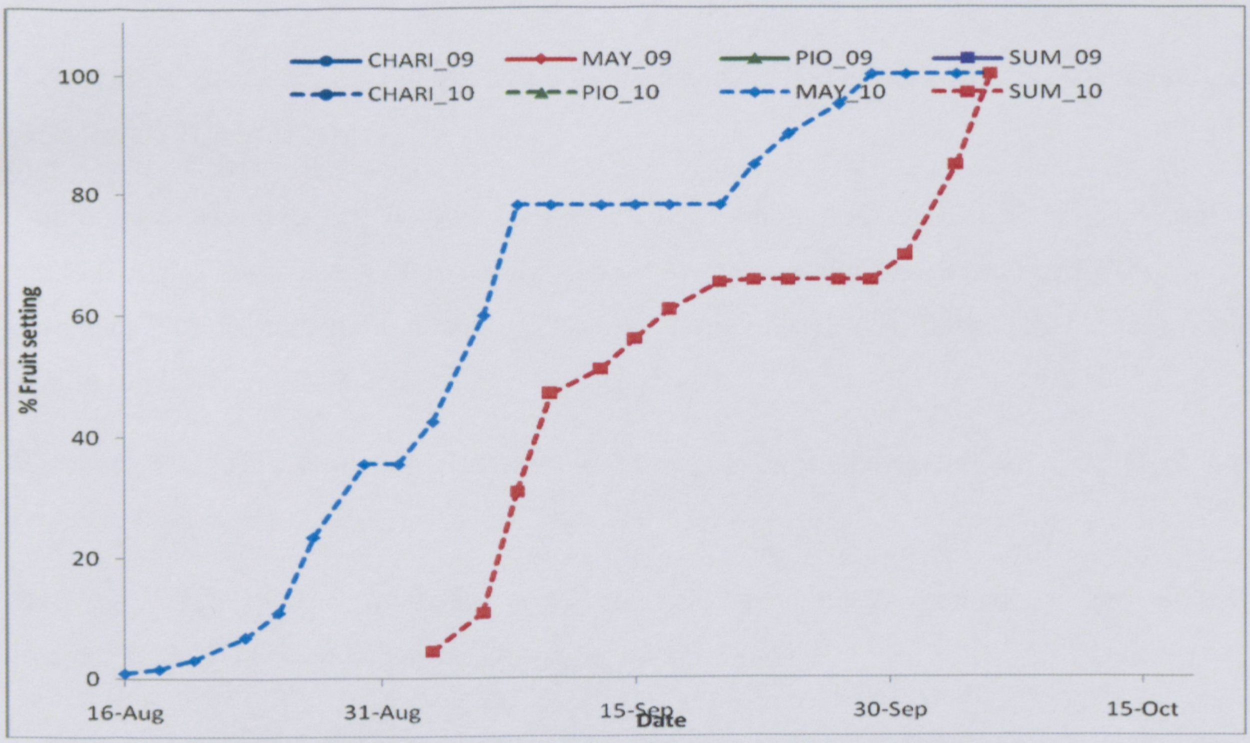

Figure 4.7.3: Fruit setting in 2009 and 2010

In 2010 (colder year), all trees satisfied the chilling requirement, even though there were some differences as compared to the findings obtained by Guirriero *et al*,. 2006. The results of flowering in charisma and fruit setting in all trees in 2009 show the lack of adaptation of these cultivars to warm climatic conditions. A large number of stone fruit tress of each species need to be further investigated to find which ones will be able to give positive results in the tropical regions.

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APPENDICES

Appendix 1. Mean of diameter of stem of 'Mayglo', 'Summersun' 'Charisma' and 'Pioneer' cultivars in year 2009 and 2010.

Mean of diameter of stem after transplant in 2009 and 2010				
Cultivar	No of trees	Mean of diameter before pruning in 2009	Mean of diameter after pruning in 2010	Average mean difference of diameter in 2009 and 2010
May	6	12.8	25.2	12.3
Sum	6	17.4	29.6	12.3
Char	6	20.9	23.5	2.6
Pioneer	6	19.4	31.5	12.2

Appendix 2. Mean of scion height before and after pruning of 'Mayglo', 'Summersun' 'Charisma' and 'Pioneer' cultivars in year 2009 and 2010.

Mean of scion height in 2009 and 2010				
Cultivar	No of trees	Mean of Scion height before pruning in 2009	Mean of Scion height after pruning in 2009	Mean differences between scion height in 2009 and 2010
May	6	2.9	4.3	1.4
Sum	6	2.5	3.5	1.1
Char	6	2.7	4.2	1.5
Pioneer	6	2.8	4.2	1.4

Appendix 3. Mean of the number of secondary branches before and after pruning of Mayglo', 'Summersun' 'Charisma' and 'Pioneer' cultivars in year 2009 and 2010.

Mean of the number of secondary branches before and after pruning in 2009 and 2010				
Cultivar	No of trees	Mean of the number of secondary branches before pruning in 2009	Mean of the number of secondary branches after pruning in 2010	Mean differences of the number of secondary branches before and after pruning in 2009 and 2010
May	6	12.3	63.5	51.2
Sum	6	101.1	138.5	37.7
Char	6	17.7	76.7	59.0
Pioneer	6	75.7	60.2	84.5

Appendix 4. Buds opening percentages and dates of May, Sum, Char and Pio on August 2009.

Buds dates (August 2009)										
Cultivar	07/8/09	11/8/09	14/8/09	17/8/09	19/8/09	21/8/09	24/8/09	26/8/09	28/8/09	31/8/09
May	15.0^{a}	25.3^{a}	34.2^{a}	40.0^{a}	44.8^{a}	51.0^{a}	56.7^{a}	61.8^{a}	66.7^{a}	71.8^{a}
Sum	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	4.8^{b}	5.0^{b}	7.67^{b}	11.5^{b}	15.1^{b}	18.7^{b}
Char	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}
Pioneer	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}
P-Value	0.0001	0.0001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
LSD	3.2982	4.37	4.8236	3.7315	4.3893	4.9753	5.8424	5.6893	5.4672	5.7264

Means in the column followed by the same letter are not significantly different at 1% probability

Appendix 5. Buds opening percentages and dates of May, Sum, Char and Pio on September 2009.

P-Buds P-value September 2009

Cultivar	02/9/09	05/9/09	07/9/09	09/9/09	11/9/09	14/9/09	16/9/09	18/9/09	21/9/09	23/9/09	25/9/09	28/9/09	30/9/09
May	77.8^{a}	83.0^{a}	88.3^{a}	95.0^{a}	100.00^{a}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{c}	0.0^{c}
Sum	25.2^{b}	31.8^{b}	38^{b}	44.7^{b}	45.8^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{c}	0.0^{c}
Char	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{b}	0.0^{b}	0.0^{b}	$0^{b}.0^{b}$	0.500^{b}	1.7^{b}	3.8^{b}	6.8^{b}
Pioneer	0.0^{c}	0.0^{c}	0.5^{c}	1.8^{c}	2.8^{c}	4.7^{b}	10.2^{b}	16.2^{b}	22.3^{b}	29.3^{b}	35.3^{b}	39.7^{a}	45.2^{a}
P-Value	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
LSD	6.4837	6.3888	4.6083	4.3603	12.03	1.5074	1.6344	1.4953	1.8527	2.1004	2.1988	2.4998	2.5787

Means in the column followed by the same letter are not significantly different at 1% probability

Appendix 6. Flowering percentages and dates of May, Sum, Char and Pio on September2009.

Flowering (August 2009)										
Cultivar	07/8/09	11/8/09	14/8/09	17/8/09	19/8/09	21/8/09	24/8/09	26/8/09	28/8/09	31/8/09
May	0^{a}	9.5^{a}	14.3^{a}	21.0^{a}	26.8^{a}	34.2^{a}	40.3^{a}	47.8^{a}	55.5^{a}	62.5^{a}
Sum	0^{a}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	1.2^{b}	7.3^{b}
Char	0^{a}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{c}
Pioneer	0^{a}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	$0.^{b}0$	0.0^{c}
P-Value	0	0.006	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
LSD	0	5.9459	6.2772	5.1237	4.2137	3.8729	3.5249	4.3492	5.07	5.3781

Means in the column followed by the same letter are not significantly different at 1% probability

Appendix 7. **Flowering percentages and dates of May, Sum, Char and Pio on September 2009.**

Flowering P-value September 2009													
Cultivar	02/9/09	05/9/09	07/9/09	09/9/09	11/9/09	14/9/09	16/9/09	18/9/09	21/9/09	23/9/09	25/9/09	28/9/09	30/9/09
May	69.3 a	74.5 a	82.2 a	92.7 a	100.0 a	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b
Sum	12.0 b	17.8 b	24.2 b	30.2 b	35.5 b	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b
Char	0.0 c	0.0 c	0.0 c	0.0 c	0.0 c	0.0 b	0.0 b	0.0 b	0.0 b	0.3 b	0.5 b	0.7 b	0.8 b
Pioneer	0.0 c	0.0 c	0.0 c	0.0 c	0.3 c	1.2 a	4.0 a	9.3 a	15.0 a	20.0 a	25.0 a	30 a	35.3 a
P-Value	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
LSD	6.2424	5.9266	6.7144	5.6978	3.0830	1.2043	1.7313	1.1204	2.1204	1.9667	2.042	2.0032	1.9074

Means in the column followed by the same letter are not significantly different at 1% probability

Appendix 8. Buds opening percentages and dates of May, Sum, Char and Pio on July 2010.

Bud (%) July 2010												
Cultivar	05/7/10	07/7/10	09/7/10	12/7/10	14/7/10	16/7/10	19/7/10	21/7/10	23/7/10	26/7/10	28/7/10	30/7/10
May	1.8 [a]	3.3 [a]	5.7 [a]	8.3 [a]	12.0 [a]	20.0 [a]	25.0 [a]	30.2 [a]	35.0 [a]	39.5 [a]	44.7 [a]	50.2 [a]
Sum	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]
Char	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]
Pioneer	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]
P-Value	0.0072	0.0003	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
LSD	1.1687	1.5548	2.0032	2.2745	2.4386	3.0862	3.2982	3.4152	3.2982	3.7653	3.6661	3.7006

Means in the column followed by the same letter are not significantly different at 1% probability

Appendix 9. Buds opening percentages and dates of May, Sum, Char and Pio on August 2010.

P-Buds P-value August 2010													
Cultivar	02/8/10	05/8/10	06/8/10	09/8/10	11/8/10	13/8/10	16/8/10	18/8/10	20/8/10	23/8/10	25/8/10	27/8/10	30/8/10
May	55.5[a]	60.3 [a]	64.0 [a]	70.2 [a]	76.0 [a]	81.8 [a]	87.0 [a]						
Sum	0.0[b]	0.0[b]	0.0 [b]	2.3 [b]	4.5 [b]	8.2 [b]	13.5 [b]	18.5 [a]	23.5 [a]	29.0 [a]	34.2 [a]	40.2 [a]	51.7 [a]
Char	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0[c]	0.0 [c]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]
Pioneer	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [c]	0.0 [c]	0.3 [b]	0.5 [b]	1.0 [b]	1.3 [b]	2.2 [b]	4.5 [b]
P-Value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
LSD	4.0618	4.1136	3.4064	4.5075	4.9911	5.0644	5.6123	2.2204	2.4816	2.77	3.4831	4.3989	5.0921

Means in the column followed by the same letter are not significantly different at 1% probability

Appendix 10. Buds opening percentages and dates of May, Sum, Char and Pio on September 2010.

P-value Opening of buds 2010											
Cultivar	03/8/10	06/8/10	08/8/10	10/8/10	13/8/10	15/8/10	17/8/10	20/8/10	22/8/10	24/8/10	27/8/10	29/8/10
May												
Sum	71.6[a]	89.7[a]	100.0[a]									
Char	2.8[c]	10.7[c]	20.2[c]	31.0[b]	31.8[b]	30.7[b]	27.0[a]	24.0[a]	14.3[a]	9.3[a]	4.2[a]	0[a]
Pioneer	15.7[b]	34.7[b]	53.3[b]	75.7[a]	61.7[a]	50.0[a]	41.2[a]	29.3[a]	15.7[a]	6.2[a]	0[a]	0[a]
P-Value	0.001	0.001	0.001	0.001	0.001	0.0039	0.0995	0.6760	0.8935	0.633	0.1556	
LSD	6.4923	6.3706	4.2885	11.239	9.2063	11.544	17.385	27.607	21.607	14.337	6.0452	0

Means in the column followed by the same letter are not significantly different at 1% probability

Appendix 11: Flowering percentages and dates of May, Sum, Char and Pio on July 2010.

Flowering (%) P-value July 2010												
Cultivar	05/07/10	07/07/10	09/07/10	12/07/10	14/07/10	16/07/10	19/07/10	21/07/10	23/07/10	26/07/10	28/07/10	30/07/10
May	0.17^{a}	1.0^{a}	2.2^{a}	5.0^{a}	7.3^{a}	14.8^{a}	19.3^{a}	24.5^{a}	28.8^{a}	33.7^{a}	39.0^{a}	43.2^{a}
Sum	0.0^{a}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}
Char	0.0^{a}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}
Pioneer	0.0^{a}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}
P-Value	0.4133	0.0275	0.0078	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
LSD	0.2458	0.7617	1.395	1.9789	2.3061	3.3073	3.4417	3.5878	3.5198	3.8963	4.0350	4.1268

Means in the column followed by the same letter are not significantly different at 1% probability

Appendix 12. Flowering percentages and dates of May, Sum, Char and Pio on August 2010.

Flowering P-value August 2010														
Cultivar	02/8/10	04/8/10	06/8/10	09/8/10	11/8/10	13/8/10	16/8/10	18/8/10	20/8/10	23/8/10	25/8/10	27/8/10	30/8/10
May	49.5 [a]	54.5 [a]	59.7 [a]	64.5 [a]	71.2 [a]	77.0 [a]	85.0 [a]						
Sum	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.3 [b]	3.5 [b]	8.2 [b]	12.5 [a]	18.0 [a]	22.7 [a]	28.2 [a]	33.7 [a]	43.2 [a]
Char	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [c]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]
Pioneer	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [b]	0.0 [c]	0.0 [b]	0.2 [b]	0.33 [b]	0.8 [b]	2.0 [b]	3.7 [b]
P-Value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
LSD	4.61	4.61	4.51	4.79	4.43	5.05	6.0	1.54	1.38	1.51	2.24	4.26	4.13

Means in the column followed by the same letter are not significantly different at 1% probability

Appendix 13. Flowering percentages and dates of May, Sum, Char and Pio on September 2010.

Flowering P-value September 2010												
Cultivar	03/9/10	06/9/10	08/9/10	10/9/10	13/9/10	15/9/10	17/9/10	20/9/10	22/9/10	24/9/10	27/9/10	29/9/10
May												
Sum	62.3^{a}	82.7^{a}	100^{a}									
Char	0.7^{c}	4.2^{c}	10.2^{c}	19.5^{b}	21.2^{b}	20.5^{b}	18.7^{b}	18.2^{a}	12.2^{a}	7.0^{a}	2.7^{a}	0
Pioneer	0.0^{b}	11.2^{b}	28.2^{b}	48.2^{a}	67.7^{a}	55.0^{a}	45.0^{a}	31.7^{a}	20.3^{a}	10.0^{a}	1.8^{a}	0
P-Value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0005	0.0001	0.8416	0.7960	0.2803	0.1491	0
LSD	5.9571	6.4415	3.5047	9.2661	9.2839	10.942	14.774	23.532	18.178	10.087	3.8016	0

Means in the column followed by the same letter are not significantly different at 1% probability

Appendix 14. Fruit percentages and dates of May, Sum, Char and Pio on September 2010.

P-Fruit September 2010											
Cultivar	06/9/10	08/9/10	10/9/10	13/910	15/9/10	17/9/10	20/9/10	22/9/10	24/9/10	27/9/10	29/9/10
May	42.500^{a}	60.000^{a}	78.333^{a}	78.333^{a}	78.333^{a}	78.333^{a}	78.333^{a}	78.333^{a}	78.333^{a}	78.333^{a}	78.333^{a}
Sum	4.500^{b}	10.833^{b}	30.833^{b}	47.000^{b}	51.167^{b}	56.167^{b}	65.500^{a}	65.833^{a}	65.833^{a}	65.833^{a}	65.833^{a}
Char											
Pioneer											
P-Value	0.0006	0.0001	0.0001	0.0024	0.0070	0.0186	0.1380	0.1429	0.1429	0.1429	0.1429
LSD	17.052	16.061	17.038	17.371	17.918	17.592	17.736	17.517	17.517	17.157	17.157

Means in the column followed by the same letter are not significantly different at 1% probability

Appendix 15. Fruit percentages and dates of May, Sum, Char and Pio on September 2010.

P-Fruits October 2010								
Cultivar	01/10/10	04/10/10	06/10/10	08/10/10	11/10/10	13/10/10	15/10/10	18/10/10
May	73.667 [a]	70.833 [a]	66.000 [a]	63.167 [a]	27.500 [a]	15.833 [a]	6.500 [a]	0.0000
Sum	60.500 [a]	56.667 [a]	53.167 [b]	50.333 [b]	23.167 [a]	17.000 [a]	10.167 [a]	16.000 [a]
Char								
Pioneer								
P-Value	0.0853	0.0564	0.0449	0.0198	0.1473	0.5465	0.0631	0.0070
LSD	15.366	14.634	12.478	10.325	6.147	4.1652	3.909	1.0412

Means in the column followed by the same letter are not significantly different at 1% probability