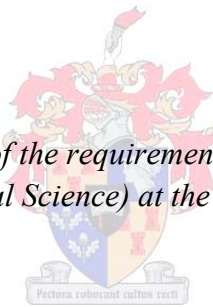


Tree Training and Managing Complexity and Yield in Fig (*Ficus carica* L.)

By

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*Thesis presented in partial fulfilment of the requirements for the degree of Master of Science
in Agriculture (Horticultural Science) at the University of Stellenbosch*



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DECLARATION

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the authorship owner thereof and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Date: 23 February 2010

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SUMMARY

Commercial fig production with popular European cultivars, Bourjasotte Noire, Col de Damme Noire and Noire de Caromb, is new to the Western Cape. Little research on fig production has been conducted in South Africa and producers are struggling to implement effective commercial practices.

In order to establish practices that will maximise yield of quality fruit, the most productive one-year-old shoot lengths were identified in a phenological study. All shoot length categories evaluated in ‘Bourjasotte Noire’ (10 – 15 cm, 25 – 40 cm, 50 – 65 cm, 75+ cm) yielded fruit and will probably yield well the following season. In ‘Col de Damme Noire’, shoots longer than 60 cm seem to be suited to reproduction, yet they might produce a poor yield the following season. Shoots 10 – 20 cm long in ‘Noire de Caromb’ are productive relative to their length, while shoots 30 – 50 cm and 60 – 80 cm long are also fairly productive. Shoots longer than 100 cm produced suitable shoot lengths for yield the following season.

Two experiments were conducted on ‘Bourjasotte Noire’ and ‘Col de Damme Noire’ to establish the type (Experiment 1, different intensity heading cuts) and timing (Experiment 2) of pruning cuts required to stimulate the growth of shoots of the same length as the shoots selected to be optimal for yield in the phenology study, and to reduce the expression of distal branching. In ‘Bourjasotte Noire’, removing one third of the total length of one-year-old shoots on 21 July by heading stimulated the development of more growth and longer current season shoots compared to other treatments, while reducing yield slightly. Heading back to three nodes in ‘Col de Damme Noire’ stimulated the growth of current season shoots of the optimal length established in the phenology study, while heading cuts on 30 June produced the longest average current season shoot length in ‘Col de Damme Noire’.

To further address the effects of distal branching (acrotony), an experiment was conducted to establish whether rest breaking agents (RBA’s) in combination with tip-pruning can increase tree complexity by improving bud break, and whether increased complexity would increase yield in all three cultivars. A second experiment was conducted to evaluate the effects of timing RBA applications on bud break and harvest scheduling. Lift® increased the number of buds breaking in ‘Bourjasotte Noire’, while in ‘Noire de Caromb’ Dormex®

and oil increased bud break. Tip-pruning increased the average shoot length in ‘Bourjasotte Noire’ and ‘Col de Damme Noire’, while causing a reduction in the amount of new growth in ‘Noire de Caromb’. Lift® applied 3 August and Dormex® applied 30 June shortened the number of days to 50% bud break in ‘Bourjasotte Noire’ and ‘Col de Damme Noire’. Both Lift® and Dormex® applied on 30 June decreased the number of days to 50% bud break and 50% harvest of the breba crop in ‘Noire de Caromb’. These treatments increased the number of fruit in both the breba and main crop of ‘Noire de Caromb’, but reduced fruit size.

In conclusion, different approaches with regards to pruning needs to be followed for each cultivar to establish or maintain the optimal shoots for reproduction, while RBA’s can be used to force earlier, increased- bud break and harvest of breba fruit.

OPSOMMING

Boomvorming en die bestuur van kompleksiteit en opbrengs in die vy (*Ficus carica* L.)

Kommersiele verbouing van drie Europese vykultivars, Bourjasotte Noire, Col de Damme Noire en Noire de Caromb is nuut tot die Wes-Kaap. Baie min navorsing oor die verbouing van vye is al in Suid-Afrika gedoen, met die gevolg dat produsente sukkel om effektiewe kommersiële verbouingspraktyke te implementeer.

‘n Fenologiese studie van die drie kultivars is uitgevoer om vas te stel wat die mees produktiewe een-jaar-oue lootlengte is, met die doel om die opbrengs van kwaliteit vrugte te maksimeer. Al vier kategorieë wat ge-evalueer is in ‘Bourjasotte Noire’ (10 – 15 cm, 25 – 40 cm, 50 – 65 cm, 75+ cm) is gevind om geskik te wees vir huidige en volgende seisoen opbrengs. Lote langer as 60 cm is geskik vir opbrengs in ‘Col de Damme Noire’ in die huidige seisoen, maar mag in die volgende seisoen swak presteer a.g.v. die gebrekkige lengte van nuwe lote wat daarop ontwikkel. In ‘Noire de Caromb’ is gevind dat lote 10 – 20 cm lank baie produktief is relatief tot hul lengte en dat lote 20 – 50 cm en 60 – 80 cm lank ook relatief produktief is. Lote langer as 100 cm was minder produktief, maar het nuwe lote gelewer wat geskik is vir opbrengs die volgende seisoen.

Twee snoei eksperimente is uitgevoer op ‘Bourjasotte Noire’ en ‘Col de Damme Noire’ om vas te stel wat die mees geskikte tipe snoeismetode (Eksperiment 1, verskillende dieptes van topsnitte) en tydstip om te snoei (Eksperiment 2) is met die doel om lote te produseer soortgelyk in lengte aan die wat in die fenologie studie uitgewys is as die produktiefste, en om moontlik die voorkoms van “kaalnekke” te verminder. In ‘Bourjasotte Noire’ is gevind dat die wegsnoei van ‘n derde van die loot op 21 Julie aanleiding gee tot meer groei, langer een-jaar-oue lote en ‘n effense afname in opbrengs. Geskikte lote langer as 60 cm kan in ‘Col de Damme Noire’ verkry word deur lote te top sodat net drie nodes oorbly. Die uitvoer van topsnitte op 30 Junie het langer gemiddelde lootlengtes tot gevolg gehad.

Om die probleem van “kaalnekke” (apikale dominansie) verder aan te spreek, is ‘n eksperiment uitgevoer om vas te stel of rusbreekmiddels gekombineerd met tip-snoei gebruik kan word om kompleksiteit te vermeerder deur knopbreek te verhoog, en indien wel, of dit sal aanleiding gee tot verhoogde opbrengs in al drie kultivars. ‘n Tweede eksperiment met

verskillende toedieningstye van rusbreekmiddels is uitgevoer om vas te stel of oeste geskeduleer kan word. Lift® het knopbreek verhoog in 'Bourjasotte Noire', terwyl Dormex® en olie knopbreek verhoog het in 'Noire de Caromb'. Tip-snoei het die gemiddelde lootlengtes verhoog in 'Bourjasotte Noire' en 'Col de Damme Noire', terwyl dit groei verminder het in 'Noire de Caromb'. Lift® toediening op 3 Augustus en Dormex® toediening op 30 Junie het die aanvang van 50% knopbreek vervroeg in 'Boujasotte Noire' en 'Col de Damme Noire'. Beide Lift® en Dormex® toediening op 30 Junie het die bereiking van 50% knopbreek- en 50% oes vervroeg in 'Noire de Caromb'. Hierdie behandeling het ook die aantal vrugte van die breba- en hoofoes vermeerder, maar vruggrootte verminder.

Verskillende snoeibenaderings behoort dus gevolg te word om vir elke kultivar die regte lootlengtes te genereer of te onderhou, terwyl rusbreekmiddels gebruik kan word om knopbreek te vervroeg en verhoog, en om die breba oes te vervroeg.

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GENERAL INTRODUCTION

Figs are cultivated in most warm and temperate (Mediterranean-type) climates (Flaishman et al., 2008); however the Mediterranean basin has been the homeland of the fig for many years (Şahin, 1998). Until recently, there were very few fig cultivars in South Africa with any commercial value. Boujasotte Noire, Col de Damme Noire and Noire de Caromb are European fig cultivars renowned for the superior eating quality of their fruit. These three cultivars were recently introduced to the Western Cape, with its suitable Mediterranean-type climate, with fruit destined for the South African and European fresh market. There is a general lack of reliable information on fig production. It is known that vegetative and reproductive growth in fig is affected by various environmental factors which differ between locations (Şahin, 1998). In order to produce figs profitably in South Africa, production practices need to be established for the local growing conditions. Tree training by use of pruning and rest breaking agents (RBA's) requires an understanding of the phenology of 'Bourjasotte Noire', 'Col de Damme Noire' and 'Noire de Caromb' as expressed under the local growing conditions

Firstly, a literature review was done focusing on background information on fig, and factors related to tree complexity such as dormancy, apical dominance and acrotony in fig, as well as other common fruit crops. Different cultural practices such as tree training systems and pruning were evaluated in terms of their effects on tree complexity. The use of various RBA's to modify bud break was also evaluated in fig as well as other fruit crops.

The first aim of the study was to establish the optimal one-year-old shoot lengths for each cultivar, which would maximise yield of quality fruit. Different shoot lengths were evaluated in terms of vegetative and reproductive growth, and optimal shoot lengths for reproduction determined. Different depths and timings of heading cuts were evaluated in order to establish the pruning practices required to stimulate the growth of optimal shoots identified in the phenological study, and to address the effect of apical dominance expressed in the growth of these cultivars.

In addition to pruning, RBA's were evaluated on 'Bourjasotte Noire', 'Col de Damme Noire' and 'Noire de Caromb', to assess their affect on bud break and vegetative growth. Effects on harvest scheduling were also evaluated by using different application times of the

RBA's. In previous studies on fig, hydrogen cyanimide has been used to schedule bud break and the harvest of breba fruit, while also increasing the yield of breba fruit (Shulman et al., 1986; Yablowitz et al., 1998). TDZ (N-phenyl-N-1,2,3,-thidiazol-5-ylurea), a cytokinin analogue, and mineral oil have been used as an exogenous application especially in apple, to overcome dormancy (Steffens & Stutte, 1989; Wang et al., 1991; Honeyborne, 1996).

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Tree training and managing complexity and yield in fig (*Ficus carica* L.)

1. Introduction

Due to the highly perishable nature of fresh figs, marketing previously was aimed mainly towards local markets. However, with advances in post harvest- and transportation technology, fresh figs are now being exported internationally (Şahin & Balci, 1998). Due to this development, commercial fig production with European cultivars has recently been introduced to the Western Cape Province and the rest of South Africa. Very little research on fig growth, development and production practices have been conducted in South Africa and producers are struggling to implement effective commercial practices to ensure adequate yields of high quality fruit. This dearth of reliable information extends to the international level and has been one of the main limitations to increase fig hectarages (Botti et al., 2003). In addition, the limited information that is available, does not directly address problems related to South African climatic conditions, soils and farming practices.

Three fig cultivars, Bourjasotte Noire, Col de Dame Noire and Noire de Caromb were selected in France and imported to South Africa. The first orchards were established in the Mediterranean-type climate of the Breede River Valley, Western Cape Province. During the third production season, it was noticed that all three cultivars produced large sections of unproductive, bare wood called “blind wood” (Oosthuysen et al., 1992), a condition where proximally situated buds fail to break on one-year-old shoots in spring, leaving them unbranched over a large portion of their length. In apple, “blind wood” is characteristic of one-year-old shoots with an acrotonic (distal branching) growth habit (Oosthuysen et al., 1992; Cook et al., 2001).

It is uncertain whether or not increased complexity (and potential bearing positions) with a subsequent decrease in the amount of “blind wood” will increase yield in fig, although methods to increase complexity are commonly used in apple production (Oosthuysen et al., 1992). The aim of this literature review is to evaluate practices related to the manipulation of complexity and yield in fig. Two such practices employed in the deciduous fruit industry are the use of rest breaking agents (RBA's) (Honeyborne, 1996) and pruning strategies (Puebla et

al., 2003). Apart from the inclusion of the necessary background information on fig, the focus of this literature review is therefore on the use of these two practices with their underlying principles, in fig production, with reference to other fruit crops.

2. Background information

2.1 Name and origin of fig

Being among the oldest fruit types for which written records exist (Ferguson et al., 1990), the English word “fig” is of ancient origin, derived from the Latin “*ficus*” and older Hebrew word “*feg*” (Eisen, 1901). Carica refers to Caria which is an ancient region of Asia Minor noted for figs (Ferguson et al., 1990). The common fig probably originated from southern Arabia (Eisen, 1901 citing Solms-Laubach, 1885), yet many discrepancies regarding the origin of the fig exist in literature (Dickson & Dickson, 1996). The genus *Ficus* is found mainly in the tropics (Flaishman et al., 2008) and the common fig is said to be a subtropical fruit tree (Aksoy, personal communication; Ferguson et al., 1990; Morton, 1987). The cultivated fig industry most likely has its origin in southwest Asia, as do many other subtropical fruits (Eisen, 1901). Figs are currently cultivated in most warm and temperate (Mediterranean-type) climates (Flaishman et al., 2008), nonetheless the Mediterranean basin has been the homeland of the fig for many years (Şahin, 1998).

2.2 Botany

2.2.1 Taxonomy

Ficus carica L., known as the common fig, belongs to the Eusyce subgenus of the Moraceae (mulberry) family which comprises 60 genera (Ferguson et al., 1990) and more than 1400 species (Mars, 2003; Watson & Dallwitz, 2004). *Ficus carica* is a species characterised by only unisexual axillary flowers and by gynodioecism. It is the only member in the genus cultivated for its fruit (Ferguson et al., 1990).

2.2.2 Vegetative morphology

The common fig is a deciduous fruit tree. Its growth habit varies with cultivar, from open and drooping to upright and compact. Fig wood is soft due to thin-walled parenchyma cells and homogenous spongy pith. Figs contain latex cells which grow in the plant tissue in a fashion similar to that of parasitic fungi hyphae. Both fruit- and vegetative buds form in the leaf axils during late summer and fall. Vegetative buds are smaller compared to the plump

fruiting buds. Fig leaves are petiolate, large, rough-pubescent, cordiform, 3-7 lobed to almost entire and sinuate-dentate. The root system is primarily fibrous with considerable lateral and vertical spread (Ferguson et al., 1990).

2.2.3 Fruiting habit

Fig trees can bear two crops (Flaishman et al., 2008). The first crop, called the breba crop, is borne laterally on the growth of the previous season from buds produced in the leaf axils. The buds start developing with the onset of the following spring, and fruit usually start maturing within the first month of summer. The second crop, known as the main crop, also arises from buds in the axils of leaves, but on shoots of the current season. Fruit maturation may start in the middle of summer, and can last several weeks (Flaishman et al., 2008).

2.3 Horticultural classification

Figs are classified into four general horticultural types:

- a. Capri figs produce a small non-edible fruit; their flowers however, produce pollen. This pollen is required to fertilise flowers of Smyrna and San Pedro figs (Ferguson et al., 1990; McEachern, 1996).
- b. Smyrna figs (called Calimyrna figs in the United States of America) (Condit, 1948) produce large, edible fruit with viable seeds. Pollination is required for normal fruit development. Unless pollination takes place, the fruit will fall from the tree before maturation starts (McEachern, 1996).
- c. San Pedro figs bear two crops; a parthenocarpic breba crop (first crop) and a main crop requiring pollination (McEachern, 1996). The setting of a breba crop is one of the characteristics that define San Pedro type figs, although some common figs also produce a breba crop (Flaishman et al., 2008).
- d. The common fig, to which 'Bourjasotte Noire', 'Col de Dame Noire' and 'Noire de Caromb' belong, develops parthenocarpically and usually does not require the stimulus of pollination (Condit, 1955). Thus the fruit normally contains undeveloped, infertile pips (Dickson & Dickson, 1996). Some common fig cultivars, like Bourjasotte Noire, drop all or nearly all of the fruit buds of the breba crop and then mature a good main crop. Others, such as 'Noire de Caromb', have practically complete parthenocarpic development in both crops (Condit, 1955).

Cultivars newly introduced into the Western Cape

2.3.1 ‘Bourjasotte Noire’

‘Bourjasotte Noire’ (syns. ‘Bernissou Negra’, ‘Précoce Noire’, ‘Burjasotte Preto’, ‘Grosse Bourjasotte’, ‘Monacello’ (Condit, 1955), ‘Barnisotte Noire’, ‘Black Bourgasotte’, ‘Brogiotto Nero’, ‘Brogiotto fiorentino’, ‘Grosso figo’, ‘Bellagrade’ (Eisen, 1901), ‘Violette de Solliés’ (Roger & Khadari, 2003)) was described by Condit (1955) as widely grown in Italy, southern France and parts of Spain and Portugal in the 1950’s. Other names used include ‘Parisienne’ and ‘Negro Largo’. However, both Eisen (1901) and Condit (1955) describe ‘Negro Largo’ as a different cultivar, and from the description given of ‘Negro Largo’, it does appear to be a different cultivar.

In 1926, ‘Bourjasotte Noire’ was introduced into California from southern France. Condit (1955) describes the tree as being vigorous, although from personal observation the tree has moderate vigour (Figure 1). Terminal buds are brown; leaves are medium to large, glossy above, and three-to five-lobed (Eisen, 1901; Condit, 1955) (Figure 1). Breba fruit are rare, larger than the main crop fruit, with a pyriform shape, purplish black colour and strawberry- (Condit, 1955) to deep red coloured pulp (Eisen, 1901) (Figure 1). Main crop figs are variable in shape and size (Condit, 1955), are broader than long (Eisen, 1901), and have an average weight of 50 grams (Condit, 1955). Eisen (1901) describes the fruit as excellent and one of the very finest for fresh (table) consumption.



Figure 1: ‘Bourjasotte Noire’ tree (displaying growth habit), leafs and fruit.

‘Col de Dame Noire’

‘Col de Dame Noire’ (syns. ‘Col de Señora Negra’, ‘Col di Signora Nero’, ‘Cuello- de Dama Negra’ (Condit, 1955), ‘Col di Signora Nigra’ (Eisen, 1901)) is not as popular in Spain as Col de Dame, which is a light, or green- / yellow-skinned cultivar. In France, Col de Dame Noire is a late cultivar described to have fruit of excellent quality (Condit, 1955). Some discrepancies exist in literature on whether or not there are two crops. However, from personal observation the breba crop on relatively young trees is small. According to Condit (1955), the cultivar is widely grown in North-Africa, but on account of the thick skin is not used for commercial drying. ‘Col de Dame Noir’ was introduced into California from England in 1883 (Condit, 1955).

The cultivar typically displays large, spreading growth (Eisen, 1901) (Figure 2). Leaves are large, having three- to five-lobes with undulated margins (Figure 2). Fruit on average weighs 45 grams and are sub-globular to oval in shape (Figure 2). Ribbing is prominent and the skin is fine, but fairly resilient. The outside colour is dark violet and the flesh is white while the pulp is deep red and luscious (Condit, 1955 citing Simonet et al., 1945).



Figure 2: ‘Col de Damme Noire’ tree (displaying growth habit), leaves and fruit.

‘Noire de Caromb’

‘Noire de Caromb’ (syns. ‘Perroquière’, ‘Violette Perruquine’, ‘Argusela’, ‘Douqueira’, ‘Douqueira Negra’, ‘Peroquina’, ‘Monginenco’ (Condit, 1955; Eisen, 1901)) is regarded as one of the oldest and best known figs from the Nice district (Condit, 1955 citing Sauvaigo, 1889).

Two crops are produced, of which the first has highest importance (Condit, 1955). The leaves have three to five lobes and breba fruit have an elongated pyriform shape (Figure 3) (Condit, 1955 citing Simonet, 1945) and are very large (up to 10 cm long) with a sweet taste (Eisen, 1901). Their surface is finely pubescent with a reddish violet colour and red pulp (Figure 3). Main crop figs are smaller, with a pyriform shape and uniform violet-black colour. The quality of the main crop fruit is fair when fresh, but good when dried (Condit, 1955 citing Simonet, 1945).



Figure 3: ‘Noire de Caromb’ leaves, fruit and tree (displaying growth habit).

3. Factors related to tree complexity

3.1 Dormancy, apical dominance (AD) and acrotony

3.1.1 Mechanisms and factors involved

The dormant period of deciduous fruit crops starts with paradormancy followed by endodormancy and finishes with eco- and/or paradormancy (Crabbe, 1994; Faust et al., 1995, 1997). Paradormancy is synonymous with correlative inhibition as manifested in apical dominance (AD) (Crabbe & Barnola, 1996). Release from paradormancy does not require chilling. In contrast, endodormancy requires a period of cold to release buds (Faust et al., 1995). Terminal buds are easier to release from dormancy than auxiliary buds (Crabbé, 1994). This is probably due to lateral buds being inhibited by terminal buds through AD carried into late autumn and winter (Saure, 1985; Naor et al., 2003), since it was found that the reduced chilling requirement of lateral buds in apple after decapitation of the terminal bud corresponds roughly to the chilling requirement of the terminal buds (Faust et al., 1995). Apart from having to overcome AD, lateral buds still have to meet their specific chilling requirement (Faust et al., 1995). Depending on the strength of the AD generated by the terminal bud, or the receptiveness of lateral buds to this dominance effect (Faust et al., 1995), release from dormancy by chilling leads either to uniform outgrowth of all buds or to acrotony (Crabbe, 1994).

The mentioned establishment of AD during the dormant period probably mediates acrotony prior to bud burst in spring (Cook et al., 1998), causing distal buds to break first (Cook et al., 2001). Being slightly ahead in their development they are marginally better producers of auxin and quickly become established sinks for metabolites, thereby monopolising available growth substances (Oosthuyse et al., 1992 citing Jankiewicz, 1972). This leads to the formation of “blind wood” (Oosthuyse et al., 1992). Auxin could be responsible for preventing the movement of cytokinins (CK's) into lateral buds under the influence of AD (Cook, et al., 2001), and clearly plays a central role in correlative phenomena that causes acrotony and the resultant architecture of the tree. The CK associated with spring bud burst appears to originate from within the shoot (Cook et al., 2001). It is therefore likely that CK's associated with bud burst in spring are stored in the shoot before it becomes dormant (Cook et al., 2001; Van Staden, 1976).

3.1.2 Dormancy and AD characteristics in fig

According to Eisen (1901), *Ficus carica* is deciduous and drops its leaves even in countries with tropical weather and is never evergreen. However, according to Flaishman et al. (2008), figs grown in hot desert areas with winter temperatures above 6° to 10°C do not enter an endodormant period or shed their leaves. For instance, in hot tropical climatic conditions such as in Brazil, common figs are evergreen as a result of their low chilling requirement (Aksoy, personal communication; Flaishman et al., 2008). In areas with cold weather, the tree stops growth, sheds its leaves and enters a dormant period (Flaishman et al., 2008). When excised shoots of ‘Masui Dauphine’ were headed back and kept at 25°C under continuous fluorescent light, even in the deepest phase of endodormancy, it induced bud break and resulted in shoot growth (Kawamata et al., 2002). Fig trees therefore seem to have limited chilling requirements (Aksoy, personal communication) and the length of the dormant period likely depends on local climatic conditions (Flaishman et al., 2008 citing Erez & Shulman, 1982). Thus, figs can be grown in regions with little winter chilling, but bud break might be erratic and thereby compromise yield (Flaishman et al., 2008).

According to Aksoy (personal communication), many fig cultivars display strong AD, resulting in seasonal growth either from the terminal bud or the adjacent 1-2 buds. Lack of AD due to modification by pruning, can result in denser lateral growth, leading to less productive, bushy type trees. When a cultivar ordinarily (without pruning) has weak AD, like some breba cultivars, it naturally displays bushy type growth without pruning, yet still performs well in terms of productivity (Aksoy, personal communication). Given that AD is generally weaker amongst breba cultivars, this is not the case with all breba cultivars and they can still be categorised according to a 1 to 5 scale, indicating the intensity of AD as either very weak, weak, moderate, strong or very strong (Şahin & Balci, 1998).

3.1.3 The role of temperature

As mentioned in the previous section, bud break in fig can be erratic in regions with little winter chilling. It was found in apple that with a decline in chilling temperatures from 12° to 7.5°C, there was an increase in the number of lateral buds bursting. This effect could be accentuated with an increase in chilling hours (Naor et al., 2003). Given the erratic bud break of some fig cultivars in warmer regions, it seems that there are cultivars with higher chilling requirements that could benefit from more winter chilling. It is likely that cold accumulation

plays a role in the normalisation of bud growth potential (Cook et al., 1998). A lower level of bud break was also seen in apple trees with daily alternating temperatures, especially if the maxima exceeded 14°C (Naor et al., 2003). There are ways to partially substitute chilling where local climatic conditions are not ideally suited to a specific cultivar. Such methods will be discussed further on in this literature review.

4. Cultural practices used to manipulate tree architecture

4.1 Tree training systems

Open vase systems are normally used in fig production (Erez et al., 2003; Flaishman et al., 2008). The open vase usually has four or five structural limbs (Flaishman et al., 2008). This system supports the natural growth of a wide canopy. When it is trained low and open, it controls the growth and size of the tree. In California, young trees are trained to a modified open vase system (Ferguson et al., 1990). Another option is a perpendicular V-training system with two scaffold branches per tree. This type of system can be used for denser plantings of 2 x 5 m, instead of 4 x 5 m used for open vase systems (Erez et al., 2003).

Stub pruning methods have also been employed in fig production. Young trees are trained to produce four main branches, tied down to grow almost horizontally. New shoots are allowed to grow vertically from the horizontal shoots. Each year, the new growth is cut back to short stubs, almost similar to the practice used in grape production (Flaishman et al., 2008).

Fig tree canopies can reach up to 15 m when they are allowed to grow naturally. Allowing trees to reach this size is suitable when dry figs that are picked off the ground are being produced. However, in most modern orchards where figs are produced for fresh consumption, the height of trees are kept within three meters by means of pruning to allow easy access for fruit pickers (Flaishman et al., 2008).

In straight-line training systems used in Japan, a primary scaffold limb is grown from a 40 cm high trunk. The scaffold limb is orientated (assume bent down) along the direction of the row, its length equal to the interplant distance, and the spacing of new fruit bearing shoots on the scaffold limb is 20 cm (Yamakura et al., 2008). In greenhouse production trials on fig (cultivar Super fig 1) in Spain, main shoots from young fig trees grown in perlite furrows

were guided from the time the tree reached a height of 30 – 40 cm, up to a height of 1.95 m by use of guiding wires. Shoots were then pruned at this height, and any secondary proleptic shoots were removed by pruning through thinning cuts, thereby leaving one main shoot per tree. Plant density ranged from 26 666 to 34 293 plants per hectare and up to 81.4 tons of figs were produced from two annual crops (Melgarejo et al., 2006).

Whatever the training system used, fig trees should be grown in such a manner that the foliage is high enough off the ground as in other fruit crops (Eisen, 1901). According to Eisen (1901), the most natural growth habit of a fig tree is obtained by heading a young tree (just planted) close to the ground, and allowing three of the shoots that grow out to form the main limbs, in a similar fashion to the way wild fig trees grow.

4.2 Pruning

The literature on fig pruning is filled with differences of opinion and discrepancies. This could be the result of differences observed due to location, climate and cultivar influences and whether the breba or main crop was of interest. Even though the work of Eisen (1901) is old and not necessarily representative of modern trends, it is included here since it does offer insight into certain reactions of fig to pruning that are still relevant today.

Pruning of fig trees is cultivar dependant and varies between fresh and dry production (Flaishman et al., 2008). As with other fruit types, Eisen (1901) emphasises that pruning of fig trees should also be done according to the age of the tree, as very young (just planted) trees are pruned differently from trees that have been in the orchard a year or more. Fig trees require less pruning than most other fruit trees grown in temperate climates (Eisen, 1901), and annual dormant pruning should be done in order to stimulate adequate, but not excessive growth (Ferguson et al., 1990). The trees are to be pruned in order to admit light into the canopy. During early pruning, the ultimate form that the tree will be trained to should be kept in mind and pruning done accordingly (Eisen, 1901).

The branches of fig trees should never be headed back, since it could result in a reduction of the potential crop for some years (Eisen 1901). This statement is probably somewhat cultivar specific. Eisen (1901) recommends that after the first year, branches/shoots should only be thinned out. Fruit bearing shoots should not be headed back as new side shoots will

develop below the cut. It is advisable to rather remove the whole shoot at the inception with a thinning cut, in order for all remaining shoots to have a terminal bud (Eisen, 1901). Generally, the highly productive growth is from the terminal bud (Ersoy, 2008 citing Aksoy, 1997). Small shoots can also be removed with thinning cuts. Suckers originating at the base of the tree from the soil should be removed each year. Shoots that cross each other and shoots within the centre of the tree can be thinned out if necessary. Pruning should be done when the tree is most dormant (Eisen, 1901).

Diseased and broken branches should be removed in mature trees, and heavier winter pruning should be applied every three years. This will encourage enough new growth for renewal of fruit bearing wood (Flaishman et al., 2008).

4.2.1 Pruning for both crops

If both a breba crop and main crop are involved as is the case with ‘Noire de Caromb’, pruning can be challenging. If the breba crop is the most important economically (breba fruit are often larger than main crop fruit (Wang et al., 2003)), pruning after harvesting the breba crop will remove or delay the summer crop. It does however leave enough time to regenerate the tree canopy for a breba crop the following year. An alternative strategy is to adapt some sort of compromise, by pruning only some of the one-year-old shoots, thereby renewing only part of the shoots to produce new growth (Erez et al., 2003). Pruning can also be done immediately after the main crop is harvested (Flaishman et al., 2008), so that re-growth can take place on which the breba crop will be borne.

In China, strong branches along the only two limbs extending (in opposite directions) from a 30 cm high trunk are pruned back to 3 buds during the dormant period. Two to three shoots result from the cut shoot during spring, yielding a large number of mature fruit on the new growth during autumn. Wang et al. (2003) states that middle shoots (assumed to be medium sized shoots on this sort of training system, as compared to strong shoots) are left to produce a breba crop. Where these shoots are too crowded, some are removed by pruning. This pruning method, as in the previous example, is a compromise to accommodate both crops. Cultivars on this training system that do not produce a breba crop have all of their shoots reduced to three buds or otherwise completely removed (Wang et al., 2003).

4.2.2 Pruning for the main crop

When all one-year-old shoots are headed back to stubs or removed, it leads to the production of only a main crop, since the breba crop is borne on one-year-old shoots. An example of such a method is complete shoot renewal, where one-year-old shoots are headed back to 4 - 5 nodes to encourage the growth of new fruit-bearing shoots. Pruning encourages new growth, the main aim being for the tree to grow more fruit bearing wood. Another, similar type of practice is yearly heading back of one-year-old shoots to two buds (Singh, 1995).

Winter pruning is normally performed in the case of main crop cultivars, and will stimulate new growth that increases the yield thereby increasing productivity (Flaishman et al., 2008). Whether or not winter pruning will increase the crop is probably cultivar dependant.

4.2.3 Pruning for a breba crop

Breba producing cultivars bear the best fruit on small shoots (Erez et al., 2003; Puebla et al., 2003). Trees should therefore not be irrigated or fertilized excessively, since this may result in vigorous growth, leading to an unfavourable ratio between vegetative development and fruit weight (Erez et al., 2003).

A pruning trial on one-year-old 'White Adriatic' trees conducted by Maimon (1998) to evaluate pruning for a breba crop, showed that control trees yielded more fruit compared to trees receiving a severe summer pruning (trees cut back from 1.5 - 2.0 m above ground to 0.5 m). The summer-pruned trees had to grow new shoots for the following seasons' harvest, while in the control, all shoots since the beginning of the season remained for the next harvest. Control trees produced no new growth during summer, indicating that it is sufficient to produce growth for a breba crop during spring only. Thus, in young trees where the focus is on the breba crop, minimal pruning yields more fruit. Additional pruning should only be done to decrease height or clear alleyways between rows, by removing oversized branches at the base (Maimon, 1998).

Four summer pruning dates were evaluated in a study aimed at finding the best time to prune for a breba crop of San Pedro type figs, trained to a central axis (Puebla et al., 2003).

One-year-old shoots on trees were headed every 20 days starting 20 June (NH). Earlier pruning dates caused significantly larger yields as compared to later pruning dates, and lighter heading cuts, where only 2 buds were removed, caused larger yields as compared to heavier heading cuts. Fruit on trees receiving only a light pruning were heavier compared to fruit from the other pruning treatments. The number of new shoots produced increased as the intensity of the pruning cut was increased (Puebla et al., 2003). Unfortunately, the author did not compare the results to a control treatment.

Pinching can be done at the beginning of the season on all the fruit-bearing shoots. This should force both the axial buds and breba figs, and therefore a few days after pinching the terminal bud, the new developing vegetative shoots should be removed as well. Apply this technique only to selected shoots, the remainder of shoots being allowed to grow fruit-bearing wood for the following season (Eisen, 1901). This practice was used in cold areas in northern France where fig branches were buried underground each year to protect them from cold (Eisen, 1901).

4.2.4 Other deciduous fruit crops

Low complexity and a sub-optimal number of bearing positions ascribed to insufficient bud break is seen as a problem in apple production (Oosthuyse et al., 1992; Honeyborne, 1996 Cook et al., 1998, 2001) and other fruit crops such as peach (Erez, 1987), plum (Kriel, 1943), kiwi (McPherson et al., 2001) and grape (Iwasaki & Weaver, 1977). The problem has been studied and addressed in various ways (Cutting et al., 1991; Oosthuyse et al., 1992; Sagredo et al., 2005). As apple trees display an acrotonic (distal branching) growth habit, delayed heading is used to reduce the effects of apical control (Oosthuyse et al., 1992). When one-year old ‘Granny Smith’ shoots were headed back (removed 1/3 of total shoot length) from bud burst to shortly after full-bloom at 14 day intervals, it increased the number of shoots formed, leading to a reduction in the total length of new growth (Oosthuyse et al., 1992). Some of these shoots originate from buds that would have remained dormant, giving rise to “blind wood” (Oosthuyse et al., 1992; Cook et al., 2001). This condition is undesirable since the “blind wood” section of the shoot is unproductive (Oosthuyse et al., 1992).

Delayed heading allows buds in a shoot section with less available CK to burst. The buds are probably released, due to the pruning treatment causing less favourable conditions for AD to develop (Cook et al., 2001). Removal of the terminal bud (pinching) during summer and fall also releases lateral apple buds from AD (Faust et al., 1997). Wang and Faust (1993) found that after removal (pruning) of the paradormancy signal, all buds increase in size for up to 48 hours. However, only the top 2 - 3 buds resume growth, since AD is re-established by the distal buds/ developing shoots (Wang & Faust, 1993), emphasising the value of delayed heading. Yet, irrespective of the heading date, the number of buds that remain dormant in apple still exceed the number of buds that break (Oosthuysen et al., 1992).

4.3 Girdling

Girdling involves the removal of a strip of phloem around the circumference of a branch or tree trunk in order to interrupt phloem transport, theoretically without damaging the cambium (Davie et al., 1995; Theron & Steyn, 2008). This interruption in phloem transport leads to an interruption in the flow of IAA towards the roots. Interruption of polar auxin transport in turn purportedly causes a sharp rise in cytokinin leading to an increase in meristematic activity which can cause an increase in flower induction and initiation (Theron & Steyn, 2008). Girdling further causes an accumulation of carbohydrates above the girdle, and is mainly aimed at increasing yield (Davie et al., 1995).

A single trunk girdle during early summer (1 June – 15 July (NH)) has been used as a method to increase fruit size and yield of ‘Black Mission’ dried figs (Ferguson et al., 2003). Some of the treatments had a marked effect on yield and fig size, leading to an increase in both. The highest yields per tree were obtained with the earlier girdling dates, within the first five weeks of summer. The earlier girdling dates also increased the number of large and extra large figs. The previous year’s girdling treatment appeared to have a residual effect on the next year’s fruit size, yielding significantly larger fruit (Ferguson et al., 2003). This girdling response was not found by Flaishman (personal communication).

4.4 Bending

As mentioned earlier, bending is employed in fig production to create straight-line training systems (Yamakura et al., 2008). Maimon (1998) refers to bending as being one of numerous cultural practices to consider in successful fig production.

In apple, bud break was found to be much higher on horizontally positioned trees than on vertically positioned trees (Naor et al., 2003). Evidence indicates that methods that decrease auxin transport to the roots, such as bending (Wertheim, 2005), may also alter the maximum depth of dormancy (Crabbe, 1994). This emphasises the effect of AD on lowering the effectiveness of chilling for lateral apple buds (Naor et al., 2003). Bending one-year-old apple trees resulted in more shoots and increased total shoot length in comparison to control trees (Ouellette et al., 1996).

4.5 Notching

Notching involves cutting through or removing a strip of bark directly above a bud, thereby effectively disrupting transport in phloem (and differentiating xylem). During the period that the phloem (and differentiating xylem) remains severed, auxin transport in the direction of the bud is prevented, and the bud will not be inhibited, since bud inhibition is imposed by auxin transport from a shoot apex (Greene & Autio, 1994). Notching was successfully used in the fig ‘Brown Turkey’ to increase bud break, while notching and pruning combined as compared to pruning only resulted in higher fruit set (Valia et al., 1994). Notching, when used as a treatment to induce bud break on one-year-old apple trees, not only produced more shoots due to increased bud break, but also significantly increased total new shoot length (Ouelette et al., 1996).

5. Chemical means of manipulating tree architecture, with focus on dormancy and AD

5.1 Timing of chemical applications

The potential to skip endodormancy exists only prior to the development of membrane changes that blocks the communication between the buds and supporting tissues (Faust et al., 1997). During endodormancy, membranes are the structures that impose dormancy. The only factor that can re-establish the conditions required for the resumption of growth is the required amount of chilling for the specific plant (Faust et al., 1997). During the endodormant period, there is a loss of the normal connection and interaction between the various plant organs, causing a disruption of the normal intraplant communication. Loss of communication likely leads to a change in survival mechanism, leaving buds to operate on an individual basis. When these effects are alleviated during chilling exposure, CK’s have the

ability to cause bud break, while masked hormonal effects (paradormancy) also become apparent again (Faust et al., 1997).

According to Faust et al. (1997), rest breaking agents (RBA's) can only be used to supplement the chilling effect after the majority of cold-induced membrane changes have taken place. Faust et al. (1997) claims that it is during the last stage of endodormancy and during the ecodormant period that buds are sensitive to CK's and RBA's. This is then also the time period when under natural conditions, buds resume growth if exposed to sufficiently high temperatures (Faust et al., 1997). In apple production in low chill winter areas of South Africa, an ecodormant phase is not relevant since these cultivars receive fewer cold units than required.

Fuchigami and Nee (1987) characterised the aforementioned time period (shortly before spring bud break) as the quiescent phase. They reported that during this phase, hydrogen cyanamide (HC) was no longer effective in promoting bud break in 'Radian' crab apple. It either inhibited bud growth or severely injured the quiescent buds and stems. It might be that HC is an exception to the norm implied by Faust et al. (1997), at least for some genera, regarding the effective period for use of RBA's. In agreement with the results of Fuchigami and Nee (1987), Shulman et al. (1986) found that the best results are obtained for various fruit crops when HC is applied after the accumulation of some chilling, but still some weeks before the normal time of bud break, unlike other compounds that are more active at the bud swelling stage. Siller-Cepeda et al. (1992) obtained similar results in peach and reported that the best time to apply HC to peach trees is during the later stages of endodormancy, but before ecodormancy, since they found that it inhibited, delayed, and damaged buds and stems during ecodormancy.

Steffens and Stutte (1989) concluded from research on excised one-year-old shoots of three apple cultivars (low, medium and high chilling requirement) where they attempted to substitute chilling with thidiazuron (TDZ), that TDZ was most effective in promoting bud break when it was applied before the initiation of chilling (at 4°C). When TDZ was applied prior to chilling it also reduced the chill unit requirement (Steffens & Stutte, 1989). Consider that at the beginning of the dormant period a basitonic tendency has been observed on apple shoots. All buds have a lower developmental rate during this period (Cook et al., 1998). It might be that TDZ is more effective when applied earlier due to the basitonic gradient and

lower developmental rate of all buds, thereby having less correlative phenomena during this time which may contribute to making buds more receptive. Thus, despite TDZ's antagonistic role toward AD, it might not be as effective when forces of correlative inhibition are stronger than the TDZ stimulus (Faust et al., 1997).

Taking into account these notes on the effectiveness of RBA's in terms of time of application, it seems that RBA's are most effective later in winter when the majority of the chilling requirement has been satisfied, while TDZ is also effective during late fall (Erez, 1987; Steffens & Stutte, 1989). HC may be an exception, or the optimal time of application may be different for some genera and cultivars.

5.2 Rest-breaking agents (RBA's)

5.2.1 Hydrogen cyanamide (HC)

HC has been used to induce bud break in apples (Sagredo et al., 2005), pistachio (Pontikis, 1989), blueberry (Jaldo et al., 2009), grapes (Possingham, 2004), kiwi (McPherson et al., 2001), and peaches and nectarines (Dozier et al., 1990). According to LiLi and JinBao (2003), HC as Dormex® (49% HC (Jackson, 1997)) is the most popular agent used for breaking bud dormancy in fig. Applications of 0.5 – 2.5% HC applied to fig trees can cause early, uniform bud break (Shulman et al., 1986). The suggested mode of action for HC is that it reduces catalase activity, thereby inducing oxidation. Chilling is also suggested to reduce catalase activity. It is possible that oxidative processes are required to release buds from dormancy (Shulman et al., 1986).

Since earlier ripening of breba crops lead to higher prices in Israel, a trial was conducted to evaluate the effect of HC on bud break. Favourable results were obtained with regard to uniformity of cyconia development and bud break enhancement. A correlation was found between timing of HC application and bud break as well as fruit ripening in 'Nazareth' breba figs. By timing the HC treatment, using a rate of 3% Dormex®, bud break and fruit ripening was scheduled over the season (Yablowitz et al., 1998). The first treatments were applied as early as 15 December (NH), which resulted in bud break from 1 - 10 January. Earlier treatment dates compared to later treatment dates, resulted in the shortest time from application to bud burst (15+ days), whereas the latest treatment date (15 January), led to the longest time between treatment and bud break (30+ days) (Yablowitz et al., 1998).

In support of these results, Shulman et al. (1986) found that when HC was applied to fig 40 days before expected bud break, the treatment caused a high percentage and early bud break, as well as high breba fruit set (Shulman et al., 1986). It is no surprise then that HC is successfully used on a commercial scale in Israel for breba crop production. HC as 3% Dormex® is sprayed in late January to obtain high and uniform bud break, followed by a gibberellic acid (GA₃) application at 30 mg L⁻¹ to reduce fruit drop (Erez et al., 2003).

Apart from the success of HC to break dormancy or schedule harvest in fig, it was found in ‘Golden Delicious’ apple that although bud break increased with increasing rate of HC (from 1 – 2%), fruit set, yield efficiency and yield was reduced, leading to large increases in yield the next season (Sagredo et al., 2005). It is possible that vegetative growth increased as a result of increased bud break, thereby causing competition between vegetative and reproductive growth in the first season (Sagredo et al., 2005). Such an increase in vegetative growth does, however, increase the number of potential bearing positions, which may lead to a positive long term effect on yield.

5.2.2 Thidiazuron (TDZ)

TDZ (N-phenyl-N-1,2,3,-thidiazol-5-ylurea), a CK analogue, has been used as an exogenous application especially in apple, to overcome dormancy (Steffens & Stutte, 1989; Wang et al., 1991). Auxin plays a role in promoting correlative inhibition that causes AD, acting both during paradormancy and endodormancy (Faust et al., 1997). Conversely, endogenous CK's play an important role in stimulating bud break and overcoming AD in spring (Faust et al., 1997), by counteracting the inhibition of lateral buds caused by AD (Faust et al., 1995) and therefore the action of auxin. Then again, in the presence of an adequate supply of auxin, CK causes cell division (Van Staden & Cook, 1986), which in turn is associated with resumption of growth (Faust & Wang, 1993).

Exogenous TDZ application caused an increase in DNA, RNA and protein content in apple buds when used to stimulate bud break, suggesting that the mechanism through which TDZ releases buds from dormancy is dependent upon protein synthesis (Wang et al., 1985). It is possible that some of these proteins are enzymes or structural proteins which are needed for mitosis (Salisbury & Ross, 1992) during cell division.

In a trial studying the effects of TDZ on bud break in apple, it was shown that TDZ stimulated bud break at all used concentrations (50 – 1000 μM) by releasing buds from dormancy, while 100 μM was established to be the optimal concentration in this regard (Wang et al., 1985).

5.2.3 6-Benzylamino purine (BA)

BA was successfully used in tea crab apple (*Malus hupehensis*) to induce lateral bud break. It was found that two applications of 0.2% BA (plus 1% Tween 20 (wetting agent) and 5% dimethylsulfoxide (solvent)), 6 hours apart were most effective to induce bud break in both the upper and lower sections of young tea crab apple trees (Broome & Zimmerman, 1976).

5.2.4 Giberellic acid (GA_3)

In attempts to use GA_3 to set parthenocarpic figs (unfortunately the author did not include application dates), it was discovered that it broke the dormancy of terminal vegetative buds (Crane, 1962). In a prior experiment, GA_3 was applied two weeks after terminal shoot growth had ceased (14 June NH) (Crane & Campbell, 1959). The length and duration of resultant growth was directly proportional to the rate of GA_3 applied. Growth produced after application of 25 and 50 mg L^{-1} was 14.6 cm and 20.6 cm, respectively (Crane, 1962). When GA_3 (Giberel, potassium salt of gibberellic acid), used specifically to break the dormancy of terminal buds in fig, was applied at rates lower than 20 mg L^{-1} during the vegetative growth period, it had no effect on the number or length of internodes. When applied after shoot growth had ceased, there was no visible growth stimulating effect on the dormant terminal buds. However, concentrations of 25 mg L^{-1} and higher (50 - 1000 mg L^{-1}) released buds from dormancy, causing shoot extension growth. Higher rates of GA_3 resulted in more growth and more leaves per shoot and shortened the time between application and bud break. The higher rates, especially 1000 mg L^{-1} , yielded longer internodes (Crane & Campbell, 1959).

5.2.5 Promalin[®]

Promalin[®] (GA_{4+7} & N-(phenylmethyl)-1H-purine 6-amine) has been used to increase lateral shoot production of ‘Matsu’ apple nursery trees (Jackson, 1997), ‘Granny Smith’ and ‘Topred Delicious’ apple trees (Theron et al., 1987). Promalin[®] at 5% was applied to the

emerging central leader of ‘Matsu’ nursery trees when it reached a length of about 6 - 10 cm above the heading cut (at 60 cm) of the previously un-branched apple tree. On the same trees, Promalin[®] was not effective in breaking the dormancy of buds on the previous season’s wood (Jackson, 1997). However, in another study on two-year-old ‘Empire’ apple trees, Promalin[®] was found effective to increase bud break, but not branching on the previous seasons’ growth. Promalin[®] increased bud break and branching on current-seasons’ growth, and had no effect on two-year-old sections of the central leader (Quellette et al., 1996). When applied (close to bud break) in water-soluble latex-based paint to one-year-old wood of various sweet cherry cultivars, Promalin[®] increased the development of spurs and lateral shoots (Miller, 1983).

5.2.6 Mineral oil

Applications of 4, 6 or 8% mineral oil were effective in advancing and enhancing bud break in ‘Hosui’ pear, with 6 and 8% applications being most effective (De Oliveira et al., 2008). Mineral oil applied during the dormant period to pistachio caused a significant increase in the amount of vegetative growth, with the best results obtained when application was made two weeks before spring (mid-February NH) (Beede & Ferguson, 2002). In apple, 5% winter oil (mineral oil 826 g L⁻¹) was effective in causing vegetative bud break when applied between 5 and 12 September (SH) (Honeyborne, 1996).

5.2.7 Combinations of RBA’s

A combination of HC and mineral oil is used in apple to break dormancy when applied at the first visible signs of bud break. Sagredo et al. (2005) found no synergistic effect between HC and mineral oil, and found that mineral oil at 4% plus 1 to 2% HC was sufficient to break dormancy in apple. Effectiveness of mineral oil was not dependent on the rate applied as was the case with HC (Sagredo et al., 2005).

Combinations of TDZ (150 or 200 mg L⁻¹) plus 4% mineral oil or HC (0.25 or 0.5%) plus 4% mineral oil yielded good results in terms of improved bud break when applied to ‘Gala’ apple trees (Camelatto & Nachtigall, 1998).

6. Conclusions

The three cultivars newly introduced to South Africa are well known in Europe. They are described as having fruit of excellent quality, which serves to substantiate research that will develop commercial practices for effective, profitable cultivation of these cultivars. The occurrence of “blind wood” (Oosthuysen et al., 1992) and suggested sub-optimal yield related to this phenomenon (Oosthuysen et al., 1992), has been the initial factor that led to the initiation of a research program on these cultivars.

AD and the resultant acrotonic (distal branching) growth habit (Cook et al., 1998; 2001) of some deciduous fruit trees can be partly overcome by various chemical and pruning treatments as discussed. ‘Bourjasotte Noire’ and ‘Col de Dame Noire’ display strong AD, while ‘Noire de Caromb’, being a breba cultivar, displays less AD (Şahin & Balci, 1998). Of further importance with regard to possible treatments is the fact that ‘Noire de Caromb’ bears two crops, while ‘Bourjasotte Noire’ and ‘Col de Dame Noire’ bear only one crop. The number of crops affects the timing and type of treatments that can be used. The various existing commercial practices that have been used to modify fig tree architecture abroad should be investigated to examine the resultant effect on yield. Applicable commercial practices that are used on various other deciduous fruit crops should also be investigated.

Training system: It seems that traditional open vase training systems are being challenged by alternative methods such as the straight-line systems employed in Japan (Yamakura et al., 2008) and in greenhouses (Melgarejo et al., 2006), where the tree is treated more or less like a grapevine. However, the choice of a training system is dependent upon the characteristics of the cultivar and the relative importance of the different crops that it bears.

Pruning and related practices: Various suggestions related to pruning and the timing thereof in fig and other deciduous fruit crops have been discussed and should be evaluated and adapted to the specific cultivars. In fig, three ideas seem to be prominent in the literature; either minimal pruning (Maimon et al., 1998; Eisen 1901), renewal of branches (Wang et al., 2003), or shoot thinning (Eisen, 1901). Practices such as bending and notching can be used to overcome bud dormancy while girdling can be considered to improve fruit set and size.

RBA's: Various RBA's are available to overcome bud dormancy and their application should be timed for greatest effect as discussed in the text and also when no damage to buds, fruit or foliage is likely to occur. RBA's to consider include HC, TDZ, BA, GA₃, Promalin® and mineral oil, separately or in combination as described.

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Vegetative and reproductive phenology of three fig (*Ficus carica* L.) cultivars under South African conditions

Abstract. The European fig cultivars Bourjasotte Noire, Col de Damme Noire and Noire de Caromb were recently introduced to the Western Cape Province of South Africa. Producers struggle to implement effective commercial practices that will optimise yield of quality fruit. A phenological study was conducted to establish the optimum one-year-old shoot length to maximise yield and optimise fruit size. The number of fruit, bud break and shoot growth on one-year-old shoots comprising four different length categories ('Bourjasotte Noire': 10 - 15 cm, 25 - 40 cm, 50 - 65 cm and 75+ cm; 'Col de Damme Noire' & 'Noire de Caromb': 10 – 20, 30 – 50, 60 – 80 and 100+ cm) were evaluated. In 'Bourjasotte Noire', all four categories seem to be suited for reproduction and should also produce a fair yield the following season. In 'Col de Damme Noire', category four seems to be the best one-year-old shoot length for reproduction. However, yield on these shoots may not be optimal the following season, due to the fact that current season shoots are too short. In 'Noire de Caromb', category one shoots are very productive relative to their length. Categories two and three were also relatively productive, while category four was less productive, but developed a large number of current season shoots similar in length to category one, that should be productive the following season.

Introduction

The common fig (*Ficus carica* L.) is a subtropical, deciduous fruit tree (Botti et al., 2003) belonging to the Eusyce subgenus of the Moraceae (mulberry) family (Mars, 2003; Watson & Dallwitz, 2004). Figs are cultivated in most Mediterranean-type climates (Flaishman et al., 2008) with the Mediterranean basin of primary importance (Şahin, 1998). Despite possibly being the oldest cultivated fruit species (Brown, 1994), a lack of information pertaining to production practices as well as the low number of fig cultivars available commercially, limit hectares (Botti, 2003). Even so, the commercial production of figs has expanded to the Mediterranean-type climate Western Cape Province of South Africa, where three black, parthenocarpic, common type figs, 'Bourjasotte Noire', 'Col de Damme Noire' and 'Noire de

Caromb' have been established to provide fruit for the fresh market in South Africa and Europe.

Common type figs produce their main crop from buds in the axils of leaves on the current season's growth (McEachern, 1996; Flaishman et al., 2008). Harvest may start in the middle of summer and can last several months, until the onset of winter. At the end of the growth period, trees enter into a dormant period preceded by leaf-drop. Fig buds require little or no winter chilling to break endo-dormancy (Ferguson et al., 1990) and growth resumes in early spring (Flaishman et al., 2008). Fig shoots have one vegetative and two reproductive buds per node, the shoot terminating in a vegetative bud (personal observation).

Shoots on 'Bourjasotte Noire' display plagiotropic to weak orthotropic growth, resulting in open, drooping trees. 'Noir de Caromb' displays orthotropic growth resulting in a more upright but spreading tree, while 'Col de Dame Noire' shoots grow strongly orthotropic resulting in a more upright, compact, but large tree. 'Bourjasotte Noire' and 'Col de Damme Noire' display strong apical dominance (AD); therefore new proleptic (N+1) shoots develop mainly from the most distal vegetative buds of one-year-old (N) shoots. As a result, large sections of "blind wood" are found on strong N shoots (personal observation). 'Noire de Caromb' has less pronounced (moderate to strong) AD (as is often the case in breba cultivars) than the other two cultivars. 'Col de Damme Noire' grows extremely vigorously, followed by 'Noire de Caromb' and then 'Bourjasotte Noire' (personal observation).

In order to maximise yield of good quality fruit, the most productive shoot lengths (in terms of yield and fruit size) should be determined and strategies devised to maximise the number of these shoots on trees. It is therefore important to study the phenological characteristics of a cultivar to establish optimum shoot characteristics. The objective of this research was to identify the most suitable types of shoots by selecting distinctly different N shoots on the tree and doing a detailed, comparative study of phenological processes such as bud break, shoot growth and yield for each shoot length category.

Materials and methods

The trial was conducted on ‘Bourjasotte Noire’, ‘Col de Damme Noire’ and ‘Noire de Caromb’ trees during the 2008/2009 growing season in a 4-year-old commercial orchard in the Breede River valley (Mediterranean-type climate; 33°34'S, 19°16'E, 217 m) near Worcester in the Western Cape, South Africa. The area accumulated 541.5 chill units from 1 May 2008 until 31 August 2008 according to the Daily Positive Chill Unit model (Linsley-Noakes et al., 1995). The trees, on own roots, were planted in October 2004 at a spacing of 4 x 3 m.

Four different N shoot length categories were selected and tagged per tree (‘Bourjasotte Noire’: 10 - 15 cm, 25 - 40 cm, 50 - 65 cm and 75+ cm; ‘Col de Damme Noire’ & ‘Noire de Caromb’: 10 – 20 cm, 30 – 50 cm, 60 – 80 cm and 100+ cm), using twelve single trees. The length and basal diameter of each tagged shoot was measured. The average N shoot lengths of the four shoot categories from the shortest (category 1) to the longest (category 4) shoots were as follows: ‘Bourjasotte Noire’ - 14.0, 38.4, 60.8 and 85.3 cm, ‘Col de Damme Noire’ - 17.9, 44.3, 74.7 and 121.1 cm; and ‘Noire de Caromb’ - 16.8, 44.1, 73.0 and 113.6 cm.

All trees received standard commercial practices except that tagged shoots were left unpruned. The selected shoots were evaluated in terms of the following parameters: total number of vegetative buds on N shoots; bud break over time; number of N+1 shoots and their individual lengths; number of reproductive buds on N+1 shoots; number of fruit harvested per shoot; weight and diameter of harvested fruit; and fruit scars on N+1 shoots. Fruit scars were counted as a comparison to the number of harvested fruit, in case some fruits were inadvertently picked or lost.

Comparison of parameters per N shoot length category were done by analysis of variance using the general linear models procedure of SAS version 9.1.3 SP2 (SAS Institute, Cary, N.C., 2004). Single degree of freedom, orthogonal polynomial contrasts were fitted where applicable.

Results

‘Bourjasotte Noire’

The average number of N+1 shoots produced (which also represents bud break) per N shoot increased linearly from category one (C1) to four (C4), with C1 yielding an average of 1.6 shoots per N shoot compared to C4 yielding 8.8 shoots (Table 1). Bud break percentage on N shoots increased linearly from 24.5% to 39.2% from the shortest (10 – 15 cm) to the longest category (75+ cm) (Table 1).

The total length of new growth (N+1) increased linearly from C1 to C4. C1 shoots produced an average of 18 cm new growth as compared to C4 shoots which produced an average of 152 cm (Table 1). The average N+1 shoot length increased linearly from C1 (11.4 cm) to C4 (17.9 cm) (Table 1). The average length of N+1 shoots that yielded fruit likewise increased linearly from C1 to C4. There was a linear increase in internode length from C1 to C4 (Table 1). Figure 1 displays the typical morphological characteristics of the four ‘Bourjasotte Noire’ shoot lengths selected in this study and the N+1 shoots that it produced.

Total fruit per N shoot followed a linear ($p < 0.0001$) to slightly quadratic ($p = 0.0883$) trend with C1 producing only 2.3 fruit per shoot in comparison to C4 shoots producing 9.3. In fruit scars per N shoot, the quadratic trend is confirmed ($p = 0.0354$) and C1 produced significantly fewer fruit than all other categories. Yield (gram) per N shoot increased linearly from C1 to C4 shoots (Table 1). There were no significant differences between categories in the average number of fruit per N+1 shoot, or the average fruit- weight or diameter (Table 1).

All N+1 shoots from the four categories used in the study were pooled to investigate the correlation of shoot length and diameter with the number of fruit produced. The number of fruit per shoot increased linearly with increasing length ($R^2 = 0.861$) and diameter ($R^2 = 0.873$) of shoots (Figure 2).

The occurrence of N+1 shoots and their fruiting characteristics were evaluated per category and expressed in graphs (Figure 3, A - D). The length of shoots ranged from 0.1 – 30 cm on C1 (A) and C2 (B) shoots, 0.1 – 45 cm on C3 (C) and 0.1 – 55 cm on C4 (D)

shoots, (Figure 3). All of the N shoots used in this study from C2, C3 and C4 produced fruit (on new growth), while 83% of N shoots from C1 produced fruit (data not shown).

The following percentages of N+1 shoots on each N shoot category yielded fruit: 68% (C1), 76% (C2), 66% (C3) and 54% (C4) (data not shown). None of the four N shoot length categories produced fruit on N+1 shoots 0.5 – 4.9 cm long. In the four categories respectively, more than 60% of N+1 shoots of the following length ranges produced an average number of two or more fruit per shoot: 5 – 29.9 cm in C1 and C2, 5 – 45 cm in C3 and 10 – 40 cm in C4 (Figure 3).

C1 and C2 N shoots produced slightly more fruit on N+1 shoots 5.0 – 14.9 cm long than C3 and C4 (Figure 3). On average, C3 produced more fruit on shoots in the range 20.0 – 45.0 cm long than the other categories.

Of all N+1 shoots produced per category, 42%, 18%, 15%, and 10% (8, 8, 11 and 10 shoots) were of the same length as C1 N shoots (10 – 15 cm), on C1, C2, C3 and C4 respectively. The occurrence of N+1 shoots the length of C2 shoots (25 – 40 cm) was 5%, 11%, 22% and 26 % (1, 5, 17, 27 shoots) on C1, C2, C3 and C4, respectively. Only one N+1 shoot the length of a C3 shoots (50 – 65 cm) was produced (on a C4 shoot) on the selected shoots over twelve trees in this trial. No N+1 shoots the length of a C4 shoot were produced in this trial (Figure 3).

‘Col de Damme Noire’

The number of N+1 shoots (bud break) per N shoot increased linearly from C1 to C4 where C1 produced 1.1 and C4 8.7 shoots, respectively. The bud break percentage likewise increased linearly from the shortest to the longest category (Table 2).

Total new growth per N shoot increased linearly from C1 to C4. C1 produced 15 cm new growth compared to C4 which produced 191 cm new growth (Table 2). The average length of N+1 shoots increased quadratically ($p=0.0480$) from C1 to C3 and C4, while the average length of N+1 shoots yielding fruit increased linearly from C1 to C4. In C1, the average N+1 shoot length was 12.7 cm, while the combined average N+1 shoot length of C2 to C4 averaged 21.2 centimetres (Table 2). The average internode length of N shoots followed a

quadratic trend, increasing sharply from C1 to C2 and then more gradually to C4 (Table 2). Figure 4 displays the typical morphological characteristics of the four categories in this study and the N+1 shoots produced by each.

The total number of fruit per N shoot increased quadratically from C1 with a sharp increase from C3 to C4, where C4 produced 10.8 fruits per shoot, compared to C1 producing 2.0 fruits per N shoot. Fruit scars and total yield (grams) per N shoot followed the same pattern (Table 2). There were no significant differences between the four categories in terms of the average number of fruit per N+1 shoot (Table 2). Both average fruit weight and diameter increased linearly from C1 to C4 shoots, with C1 yielding fruit with an average weight and diameter 22.6 g and 32.1 mm, respectively, while C4 fruit averaged 31.3 g and 37.3 mm, respectively (Table 2).

When all N+1 shoots in the four categories were pooled, a positive linear correlation was found between shoot diameter ($R^2 = 0.986$) and- length ($R^2 = 0.821$) with the number of fruit per shoot (Figure 5).

N+1 shoots on C1 ranged mainly from 0.1 – 40 cm, with one shoot outside this range measuring 67 cm. On C2, shoots ranged from 0.1 – 35 cm, while on C3 and C4 they ranged mainly from 0.1 – 55 cm, while C4 developed an additional shoot measuring 64 cm (Figure 6)

In C1, 75% of the 12 N shoots produced fruit (on new growth), while 92% of N shoots in C2 and all N shoots in C3 and C4 produced fruit (data not shown). Of all the N+1 shoots produced in C1, 77% yielded fruit, followed by C4 with 74%, then C2 with 67% and C3 with 52% (data not shown).

C1 shoots yielded a high number of fruit on N+1 shoots ranging mainly from 5 – 40 cm in length, apart from one fruit yielding shoot outside this range measuring 67 cm. More than 60% of shoots in this range yielded fruit. C2 shoots produced fruit on a high percentage (60% and more) of N+1 shoots ranging from 15 – 35 cm long, while C3 shoots yielded fruit on more than 60% of N+1 shoots 25 – 30 cm long and 40 – 55 cm long. C4 shoots produced fruit on 60% and more of most shoots 5 – 55 cm long, and also on a 64 cm long N shoot (Figure 6).

C1 and C2 shoots produced a higher average number of fruit on N+1 shoots ranging in length from 5 – 10 cm as compared to C3 and C4. C4 shoots produced a high percentage of bearing shoots spanning a wide range of N+1 shoot length categories. Both C1 and C4 seem to produce productive shoots over a wide range of shoot lengths, whereas C2 and C3 were more varied in the percentage of shoots that yielded fruit.

Of all shoots produced per category, 31%, 44%, 25% and 15% were of the same length as C1 (10 – 20 cm), on C1, C2, C3 and C4 N shoots, respectively. The occurrence of N+1 shoots the length of C2 (30 – 50 cm) was 8%, 15%, 26% and 35% of the shoots produced per C1, C2, C3 and C4, respectively. Only two N+1 shoots in the length range of C3 N shoots occurred in this study, one in C1 and one in C4, while no N+1 shoots in the length range of C4 (100 + cm) were produced (Figure 6).

‘Noire de Caromb’

The number of N+1 shoots (bud break) and the bud break percentage both displayed a linear increase from C1 to C4. The average number of shoots on C1 was 1, as compared to 8.5 in C4 (Table 3). C1 had 15.5% bud break compared to C4 which displayed 28.4% bud break (Table 3).

The total new growth per N shoot increased linearly from C1 to C4, with C1 producing only 23 cm growth as compared to 207 cm growth produced by C4. There was no significant difference between the categories in the average N+1 shoot length produced, however there was a linear increase in the average length of fruit bearing shoots from C1 to C4 (Table 3). The average length of internodes on N shoots increased linearly from C1 to C4 (Table 3). Figure 7 thus displays the typical morphological characteristics of the four shoot categories and the resultant N+1 shoots.

The total number of fruit per N shoot increased linearly from C1 to C4, with C1 having on average 2.3 fruits per shoot as compared to C4 with 6.1. Fruit scars per N shoot displayed a quadratic trend with C1 and C2 producing significantly fewer fruit per shoot as compared to categories C3 and C4 (Table 3). The total yield (grams) per N shoot increased linearly from C1 to C4 (Table 3). The total number of fruit per N+1 shoot was significantly higher in C1 as compared to the other categories, decreasing linearly from C1 (2.3) to C4 (0.9). There

were no significant differences between categories in terms of average fruit- weight or diameter (Table 3).

As with the other two cultivars, all N+1 shoots in the four categories were pooled to correlate shoot diameter and length to number of fruit (Figure 8). It was found that the number of fruit increased linearly with an increase in shoot length ($R^2 = 0.978$) and diameter ($R^2 = 0.946$) (Figure 8).

The length of N+1 shoots of 'Noire de Caromb' ranged from 5 – 40 cm in C1, 0.1 – 40 cm in C2, 0.1 – 60 cm in C3 (with an additional shoot 72 cm long) and 0.1 – 60 cm long in C4 (Figure 9). In C1, C2 and C3, all selected N shoots produced fruit (on new growth), while in C4, 92 % of the N shoots produced fruit (data not shown). The following percentage of N+1 shoots in the four categories produced fruit: 100%, 74%, 72% and 50% on C1, C2, C3 and C4, respectively.

In C1, all N+1 shoots produced fruit. In C2, more than 60% of all shoots 5 – 40 cm long produced fruit. In C3, more than 60% of shoots 5 – 40 cm long and shoots 50 – 60 cm long, plus an additional shoot 71 cm long produced fruit. In C4, 60% and more of shoots 25 – 60 cm long produced fruit (Figure 9). C1 produced on average more fruit per N+1 shoot in the 20 – 40 cm range as compared to other categories (Figure 9).

Of all N+1 shoots produced per N shoot length category, 0%, 18%, 14% and 23% (0, 7, 9, 22 shoots) was within the length range of C1 shoots (10 – 20 cm), on C1, C2, C3 and C4 N shoots, respectively. The occurrence of N+1 shoots the length of C2 (30 – 50 cm) shoots was 25%, 21%, 28% and 33% (4, 8, 18, 31) of the N+1 shoots produced on C1, C2, C3 and C4 respectively (Figure 9). Only two shoots in the length range of C3 (60 – 80 cm) shoots occurred in this study, one on a C3 and one on a C4 shoot. C1 shoots produced N+1 shoots mostly longer than its' own length (Figure 9).

Discussion

A lower bud break percentage is expected on longer shoots, due to the high number of vegetative buds present in comparison to shorter N units. This was however not the case in any of the three cultivars observed (Tables 1 – 3). The shorter average internode length on short N shoots resulted in more vegetative buds per unit length on shorter shoots (Table 1 - 3) and this probably contributed to the lower bud break percentages on shorter shoots.

In ‘Bourjasotte Noire’, C4 produced the most new growth, even so, it did not produce more fruit than C3, despite producing 50 cm more growth (Table 1). C1, C2 and C3 produced fruit on a higher percentage of the N+1 shoots in comparison to C4. C4 seems to be the least productive per unit length when compared to the other categories, although the difference is small. This is probably due to more vigour resulting in less fruiting (Wertheim, 2005). Even so, C4 produced the highest number of N+1 shoots of similar lengths as C1, C2 and C3 N shoots which should be productive the next season. ‘Bourjasotte Noire’ did not produce many fruits on C1 shoots, yet this category is still productive relative to its length, when compared to other categories.

In ‘Col de Damme Noire’, C4 produced the most growth in comparison to the other categories. The total number of fruit and fruit scars followed a quadratic trend, increasing sharply from C1 and C2 to C3 and especially C4, which yielded the highest number of fruit. The longer C4 shoots seem to yield the highest number of fruit per N shoot (and unit length N shoot) and the fruit are larger making C4 the most suited for yield in ‘Col de Damme Noir’. C2 is unproductive relative to its size when compared to other categories, and C1 produces smaller fruit when compared to C3 and C4. A large percentage of the N+1 shoots produced by C4 were the length of C2 N shoots, the least productive N shoot length category. None of the categories produced N+1 shoots the length of C4 shoots.

As was the case in ‘Bourjasotte Noire’ and ‘Col de Damme Noire’, the most new growth was produced by C4 shoots in ‘Noire de Caromb’. Even so, the total number of fruit per N shoot and the number of fruit scars per N shoot did not differ significantly between C3 and C4. It appears that shoot vigour is not detrimental to yield in this cultivar as is the case in some other fruit crops such as apple (Wertheim, 2005). The increase in the number of fruit per N shoot between categories from C1 to C4 was low relative to the increase in shoot size.

There was no difference in the average number of fruit per N+1 shoot in ‘Bourjasotte Noire’ or ‘Col de Damme Noire’, yet in ‘Bourjasotte Noire’ C1 and C2 seem to be able to produce more fruit on a higher percentage of N+1 shoots 5 – 15 cm long in comparison to C3 and C4. ‘Bourjasotte Noire’ has a shorter average bearing shoot length in C1 and C2. C3 and C4 are mainly productive on N+1 shoots longer than 10 cm. In ‘Col de Damme Noire’ C1 and C2 seemed to produce more fruit (per shoot) on N+1 shoots 5 – 10 cm long compared to the other categories. C1 and C4 produced fruit more consistently on N+1 shoots in ‘Col de Damme Noire’ when compared to the other categories. C1 and C2 had the shortest average bearing shoot lengths, with the average- and average bearing shoot lengths of C1 being equal. In ‘Noire de Caromb’ it seems that C1 shoots can produce a higher number of fruit on shorter shoots as compared to the other categories, as seen in Figure 9 and the average ‘number of fruit produced per N+1 shoot’. The percentage of N+1 shoots that yielded fruit in ‘Noire de Caromb’ was 100, 74, 72 and 50% on C1, C2, C3 and C4 respectively, hence C1 to C3 seem to be more productive. Even so, C4 shoots produced the highest number of C1 and C2 shoots that should be productive the next season.

Conclusions

All shoot length categories evaluated yielded fruit in ‘Bourjasotte Noire’ and are likely to yield well the following season as well. In ‘Col de Damme Noire’, both C3 and C4, but especially C4 seem to be suited to reproduction, yet they might produce a poor yield the following season due to the fact that N+1 shoots are too short. Therefore, development of C4 shoots will have to be stimulated by selective pruning. C1 shoots of ‘Noire de Caromb’ are productive relative to their length, and yield a high average number of fruit per N+1 shoot. C2 and C3 are fairly productive (relative to their size), and C4 produced suitable shoot lengths for the following season. Not all fig cultivars bear fruit on the same shoot types, but in general it appears as if a wide range of shoot lengths are productive.

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Table 1: The effect of one-year-old shoot length on bud break, shoot growth and fruiting in four-year-old 'Bourjasotte Noire' in the Breede River valley (2008-2009). Means were separated by LSD (5%).

Shoot length category	No. of N+1 shoots	Bud break %	New growth (cm)	Avg N+1 shoot length (cm)	Avg bearing N+1 shoot length (cm)	Average internode length	Total fruit per N shoot	Fruit scars per N shoot	Yield per N shoot (g)	Total fruit per N+1 shoot	Avg fruit weight (g)	Avg fruit diameter (mm)
10 - 15 cm shoot	1.6 d	24.5 b ^Z	18 d	11.4 b	13.7 c	2.2 d	2.3 c	3 c	90 b	1.5 ^{NS}	35.1 ^{NS}	41.1 ^{NS}
25 - 40 cm shoot	3.8 c	27.1 b	54 c	14.7 ab	17.5 b	2.8 c	5.8 b	9 b	221 b	1.5	40.0	43.9
50 - 65 cm shoot	6.2 b	31.7 ab	102 b	17.2 a	22.9 a	3.2 b	10.0 a	14 a	385 a	1.6	36.8	41.7
75 + cm shoot	8.8 a	39.2 a	152 a	17.9 a	24.4 a	3.9 a	9.3 a	13 ab	363 a	1.1	37.9	42.0
Pr > F												
Treatment	<0.0001	0.0065	<0.0001	0.0018	<0.0001	<0.0001	0.0002	<0.0001	0.0004	0.2679	0.4606	0.1809
Shoot length linear	<0.0001	0.0007	<0.0001	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.1953	0.6788	0.9958
Shoot length quad	0.7232	0.4103	0.4071	0.2886	0.3014	0.5455	0.0883	0.0354	0.1150	0.2131	0.4238	0.1922

^Z categories with different letters differ significantly at p < 0.05

^{NS} no significant differences between categories

Table 2: The effect of one-year-old shoot length on bud break, shoot growth and fruiting in four-year-old 'Col de Damme Noire' in the Breede River valley (2008-2009). Means were separated by LSD (5%).

Shoot length category	No. of N+1 shoots	Bud break %	New growth (cm)	Avg N+1 shoot length (cm)	Avg bearing N+1 shoot length (cm)	Average internode length	Total fruit per N shoot	Fruit scars per N shoot	Yield per N shoot (g)	Total fruit per N+1 shoot	Avg fruit weight (g)	Avg fruit diameter (mm)
10 - 20 cm shoot	1.1 c	14.7 b ^Z	15 c	12.7 b	14.5 c	2.4 c	2.0 c	2 c	66 b	1.8 ^{NS}	22.6 b	32.1 b
30 - 50 cm shoot	2.3 c	16.7 b	42 c	17.7 ab	20.4 bc	3.4 b	1.8 c	3 c	63 b	1.1	26.6 ab	34.5 ab
60 - 80 cm shoot	5.4 b	26.5 a	114 b	23.0 a	23.3 ab	3.8 a	4.7 b	7 b	138 b	1.1	28.6 a	36.1 a
100 + cm shoot	8.7 a	30.9 a	191 a	22.9 a	28.8 a	4.3 a	10.8 a	17 a	339 a	1.4	31.3 a	37.3 a
Pr > F												
Treatment	<0.0001	0.0006	<0.0001	0.0011	0.0026	<0.0001	<0.0001	<0.0001	<0.0001	0.3530	0.0799	0.0471
Shoot length linear	<0.0001	<0.0001	<0.0001	0.0003	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	0.4621	0.0109	0.0060
Shoot length quad	0.7998	0.6906	0.7619	0.0480	0.4480	0.0212	0.0068	0.0103	0.0272	0.1216	0.5884	0.3899

^Z categories with different letters differ significantly at p < 0.05

^{NS} no significant differences between categories

Table 3: The effect of one-year-old shoot length on bud break, shoot growth and fruiting in four-year-old 'Noire de Caromb' in the Breede River valley (2008-2009). Means were separated by LSD (5%).

Shoot length category	No. of N+1 shoots	Bud break %	New growth (cm)	Avg N+1 shoot length (cm)	Avg bearing N+1 shoot length (cm)	Average internode length	Total fruit per N shoot	Fruit scars per N shoot	Yield per N shoot (g)	Total fruit per N+1 shoot	Avg fruit weight (g)	Avg fruit diameter (mm)
10 - 20 cm shoot	1.0 d	15.5 c ^Z	23 d	23.0 ^{NS}	23.0 b	2.5 c	2.3 c	3 b	76 b	2.3 a	30.0 ^{NS}	33.9 ^{NS}
30 - 50 cm shoot	3.2 c	20.6 bc	60 c	20.9	22.9 b	3.0 b	3.8 bc	5 b	127 ab	1.4 b	26.4	32.7
60 - 80 cm shoot	5.4 b	23.5 ab	134 b	26.5	29.8 a	3.2 b	5.8 ab	10 a	155 a	1.4 b	27.2	34.1
100 + cm shoot	8.5 a	28.4 a	207 a	25.1	32.7 a	3.8 a	6.1 a	9 a	191 a	0.9 b	27.4	33.3
Pr > F												
Treatment	<0.0001	0.0011	<0.0001	0.2703	0.0218	<0.0001	0.0042	<0.0001	0.0145	0.0023	0.3083	0.3662
Shoot length linear	<0.0001	<0.0001	<0.0001	0.2932	0.0048	<0.0001	0.0009	<0.0001	0.0020	0.0004	0.2932	0.8994
Shoot length quad	0.9268	0.6419	0.6993	0.7951	0.9838	0.9586	0.1786	0.0239	0.4533	0.4264	0.2628	0.9927

^Z categories with different letters differ significantly at p < 0.05

^{NS} no significant differences between categories

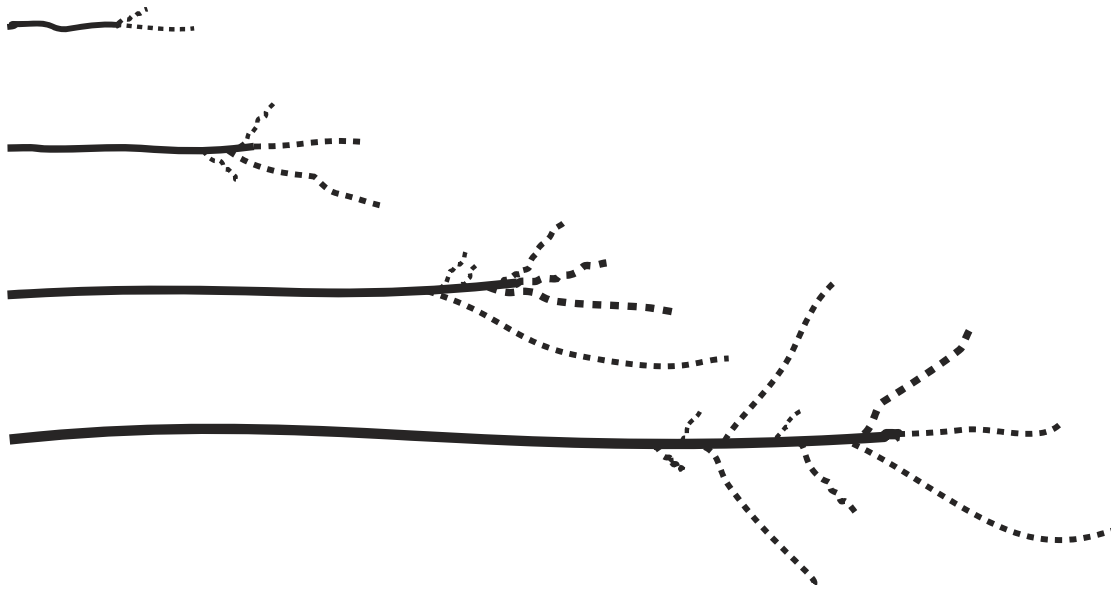


Figure 1: Typical morphological characteristics of category 1 (top) to category 4 (bottom) one-year-old- and current season shoots in 'Bourjasotte Noire' (orientation of one-year-old shoot not representative of on-tree orientation).

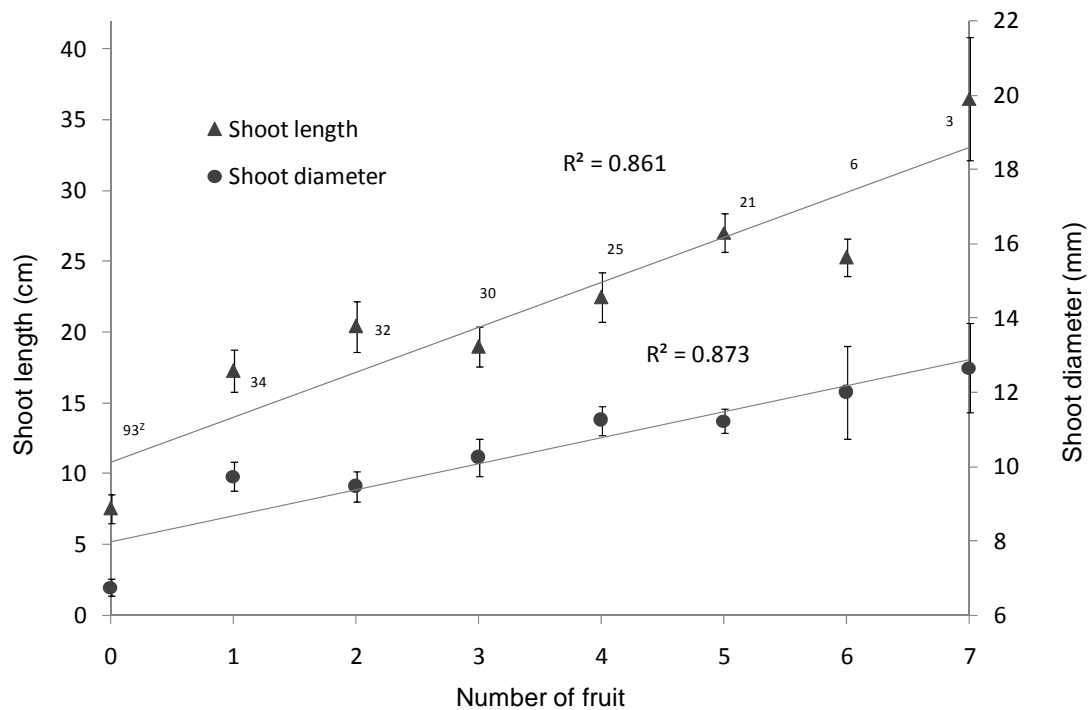


Figure 2: Response of fruit number to length and diameter of current season shoots in 'Bourjasotte Noire' (^znumber of shoots within x-axis category).

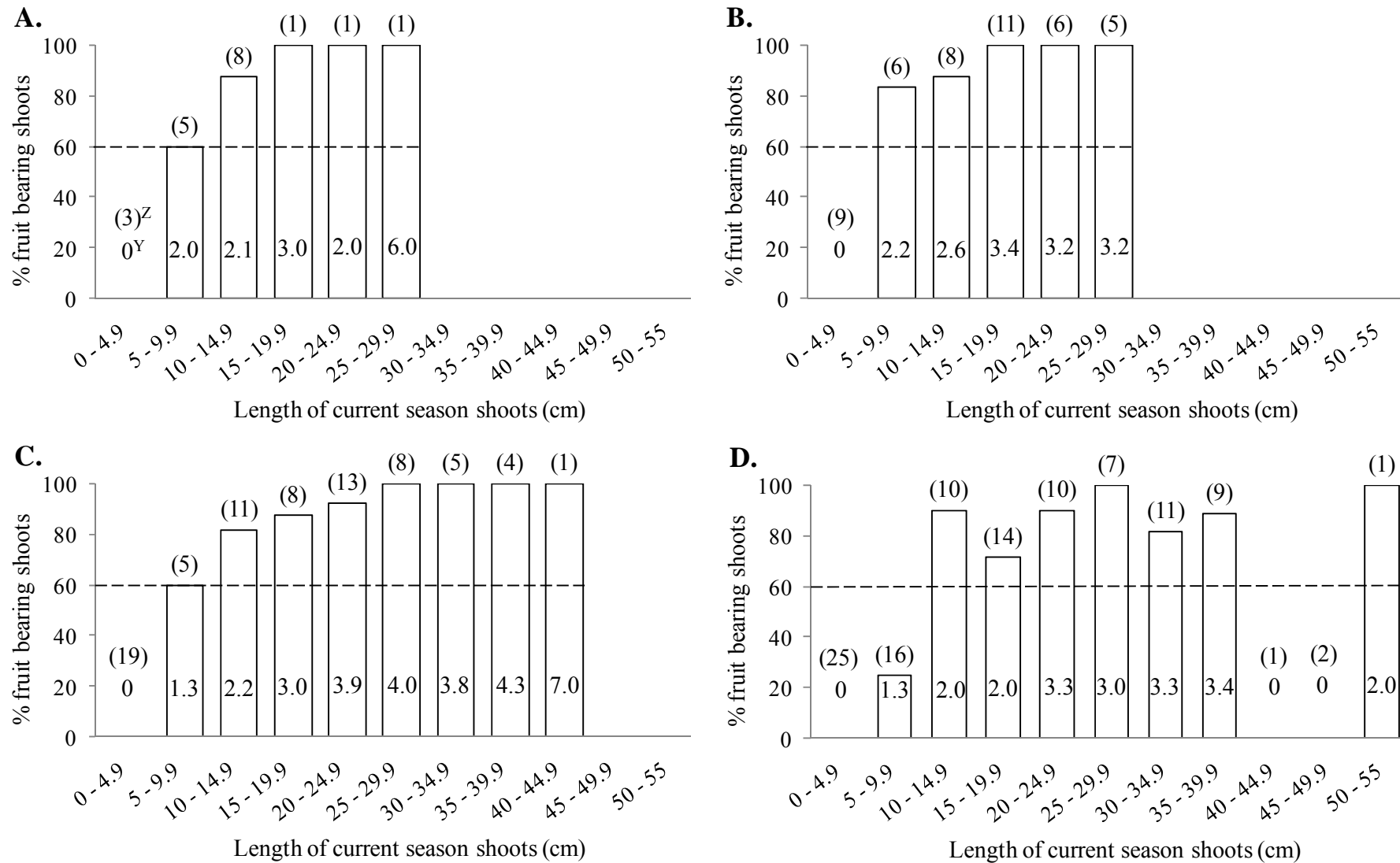


Figure 3: Characterization of various current season shoot parameters in 'Bourjasotte Noire' (Y average number of fruit per shoot; Z total number of shoots in specific category) per category one (A), two (B), three (C) and four (D) one-year-old shoot length categories.

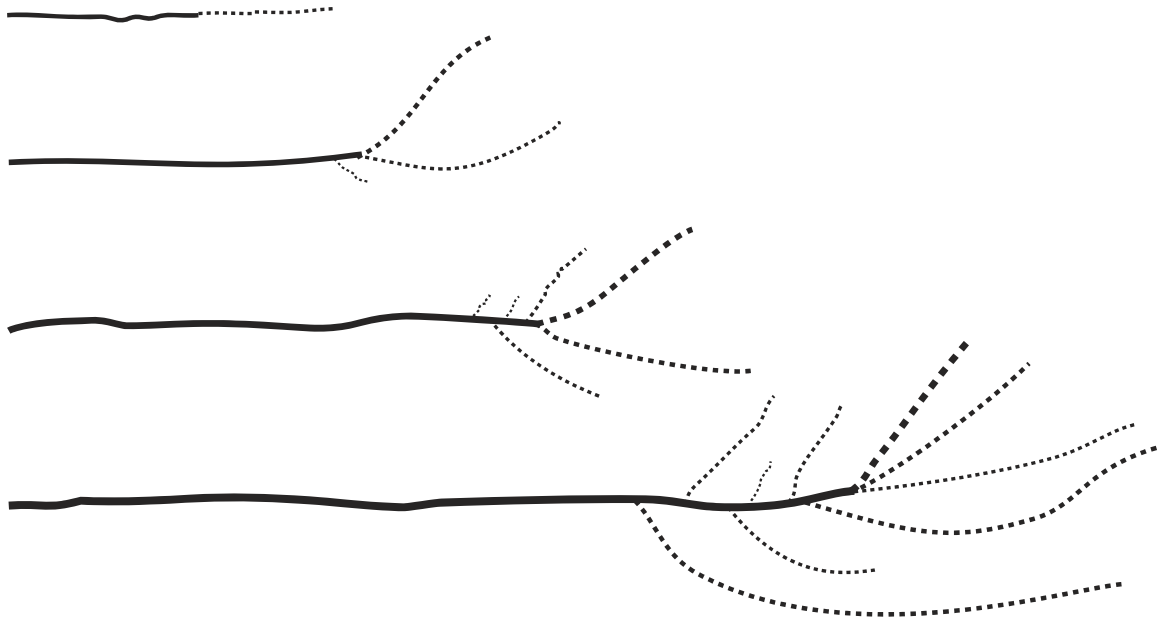


Figure 4: Typical morphological characteristics of category 1 (top) to category 4 (bottom) one-year-old- and current season shoots in 'Col de Damme Noire' (orientation of one-year-old shoot not representative of on-tree orientation).

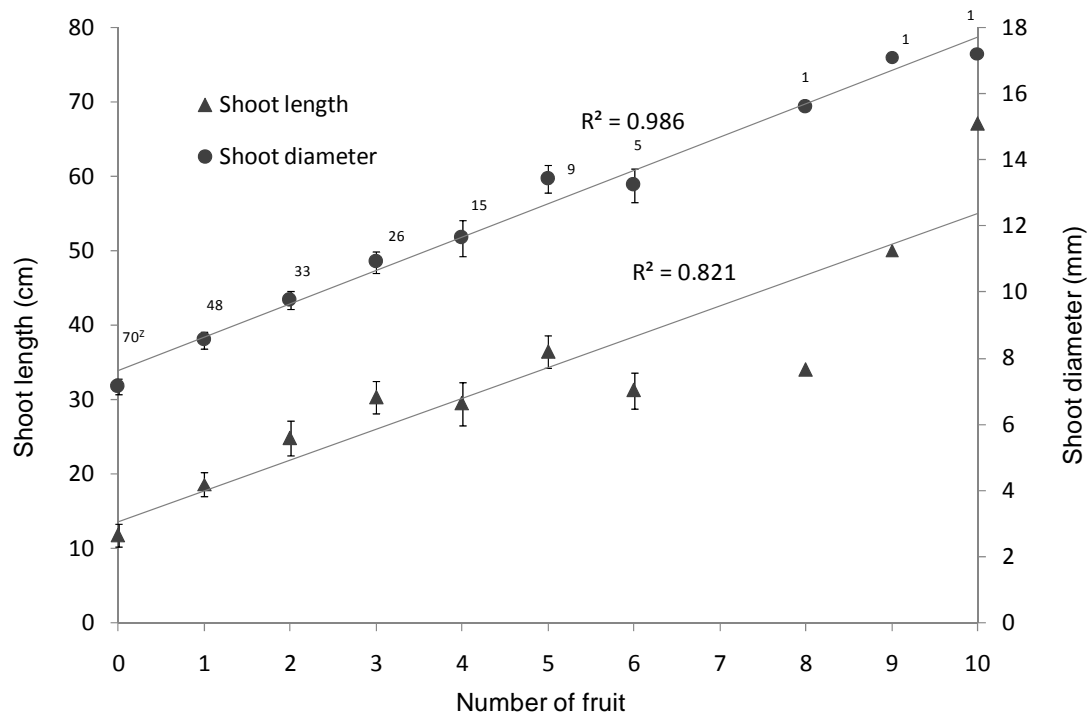


Figure 5: Response of fruit number to length and diameter of current season shoots in 'Col de Damme Noire' (^znumber of shoots within x-axis category).

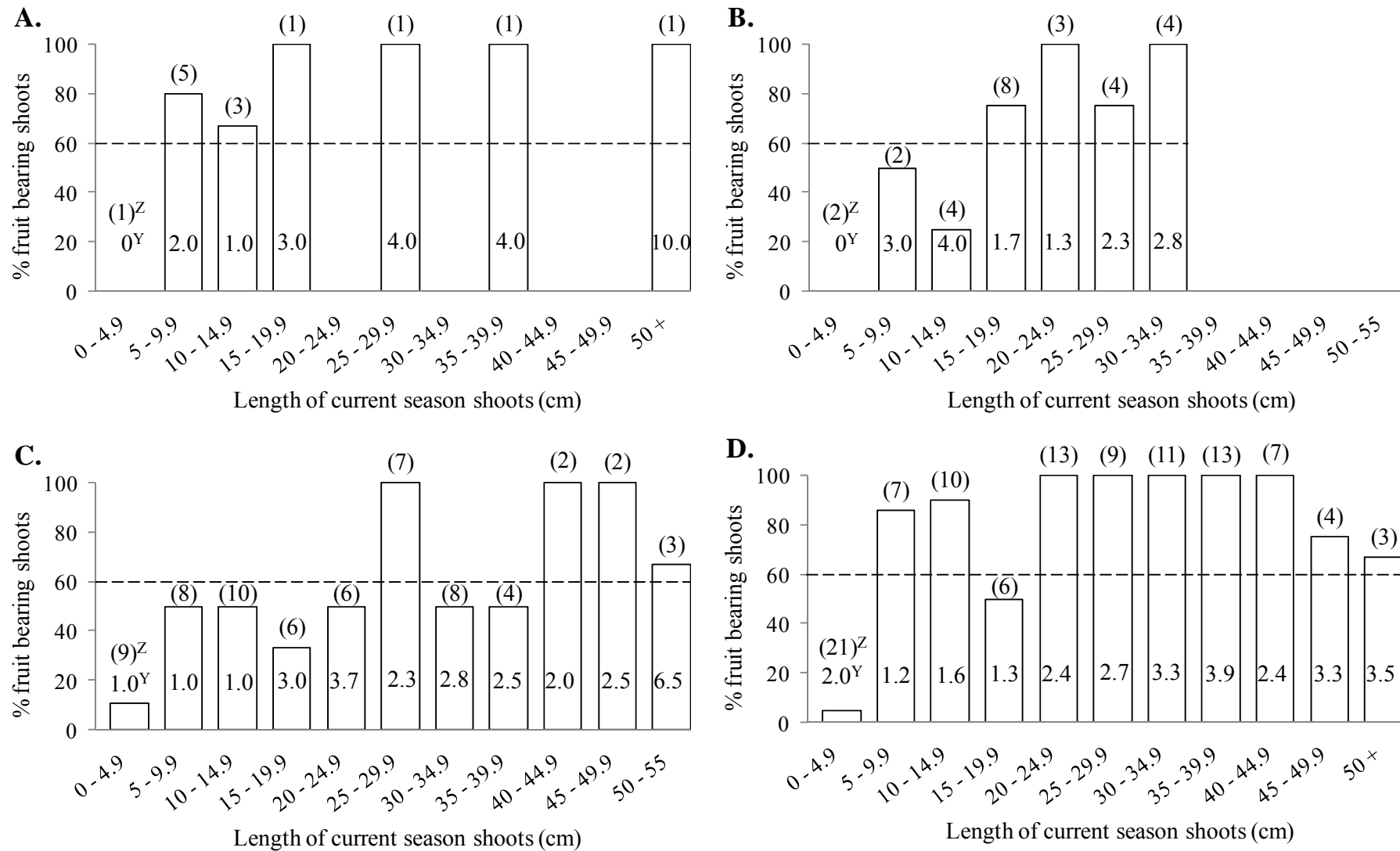


Figure 6: Characterization of various current season shoot parameters in 'Col de Damme Noire' (^Yaverage number of fruit per shoot; ^Ztotal number of shoots in specific category) per category one (A), two (B), three (C) and four (D) one-year-old shoot length categories.

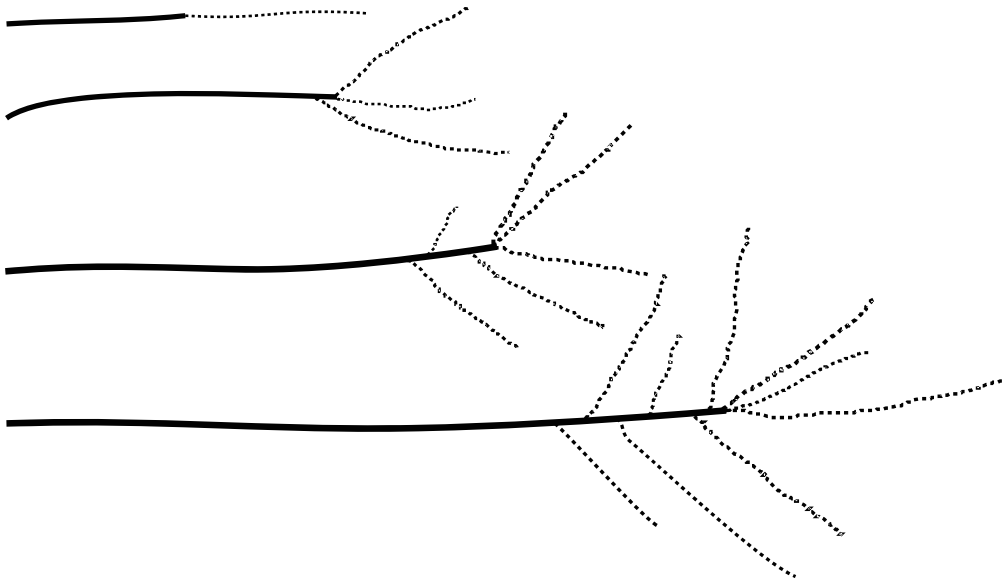


Figure 7 : Typical morphological characteristics of category 1 (top) to category 4 (bottom) one-year-old- and current season shoots in 'Noire de Caromb' (orientation of one-year-old shoot not representative of on-tree orientation).

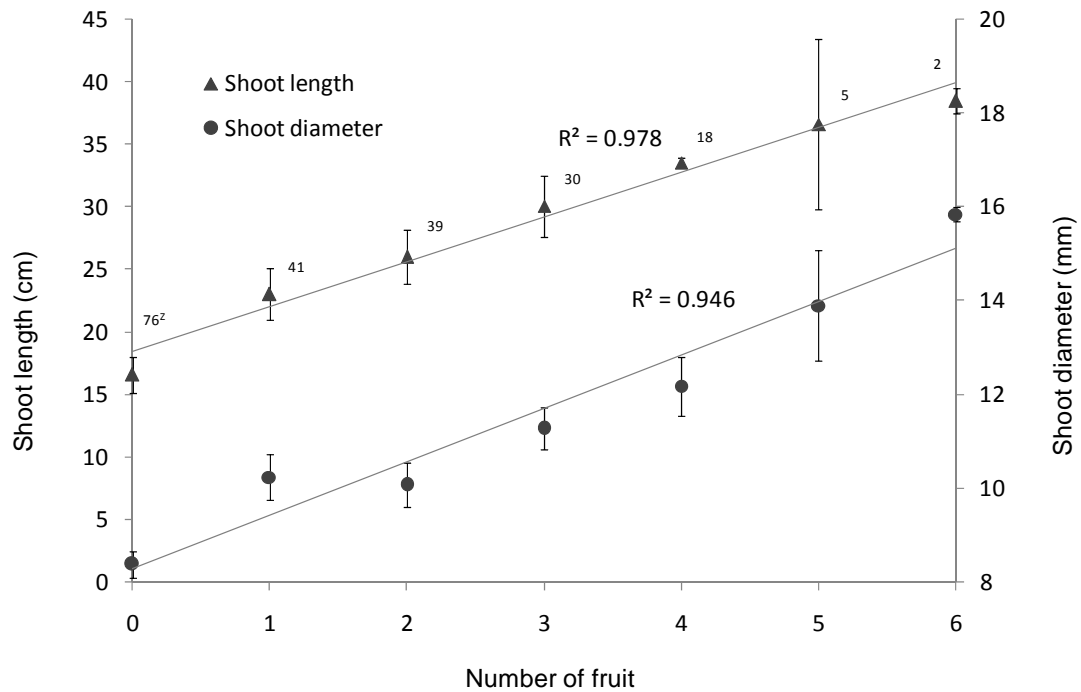


Figure 8: Response of fruit number to length and diameter of current season shoots in 'Noire de Caromb' (^znumber of shoots within x-axis category).

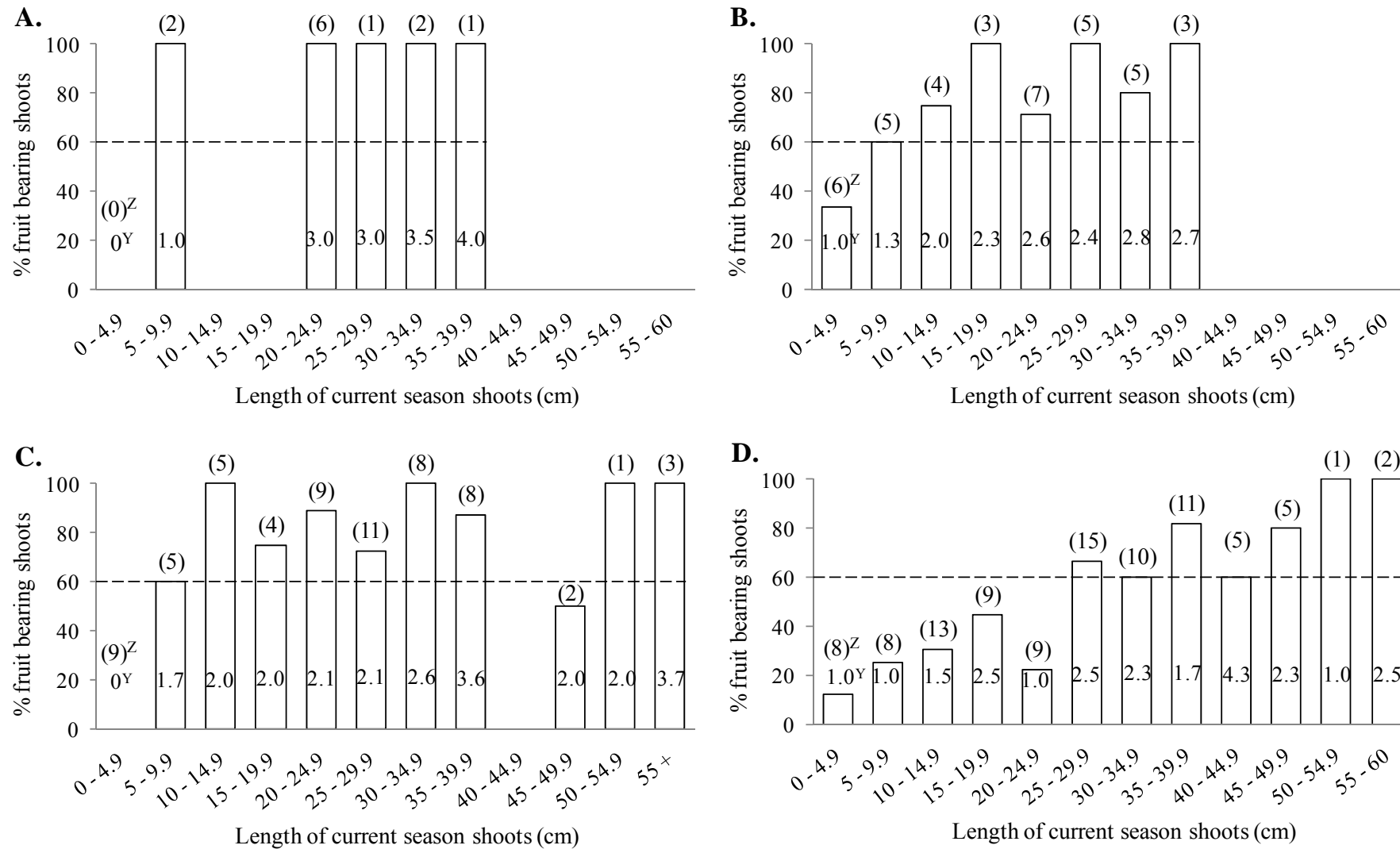


Figure 9: Characterization of various current season shoot parameters in 'Noire de Caromb' (^Yaverage number of fruit per shoot; ^Ztotal number of shoots in specific category) per category one (A), two (B), three (C) and four (D) one-year-old shoot length categories.

Developing pruning strategies for ‘Bourjasotte Noire’ and ‘Col de Damme Noire’ fig: Timing and intensity of pruning cuts

Abstract. Various pruning methods are described in fig production literature, depending on cultivar, crop of interest and climate. ‘Bourjasotte Noire’ and ‘Col de Damme Noire’ are European cultivars new to South Africa. Two experiments to establish pruning methods that will optimise yield in these cultivars were conducted in the Breede River Valley, Western Cape of South Africa. Experiment 1 comprised four treatments consisting of an unpruned control, removal of either one-third or one half of one-year-old (N) shoots, or cutting shoots back to three nodes. Treatments were applied to the whole tree, on 9 August 2008. Experiment 2 comprised six treatments: an unpruned control and five pruning dates (30 June 2008, 21 July 2008, 11 August 2008, 1 September 2008 or 22 September 2008) where one third of the shoot was removed by heading. One treatment was applied per tree, to three selected one-year-old shoots. In experiment 1 it was established that in ‘Bourjasotte Noire’, removal of one third of N shoots by heading should ensure the development of fair sized shoots for sustainable production, without a negative effect on yield. In ‘Col de Damme Noire’, heading N shoots back to three buds will produce current season (N+1) shoots longer than 60 cm, which is the optimal N shoot length for reproduction in this cultivar. Data from experiment 2 suggests that N shoots of ‘Bourjasotte Noire’ should be pruned on the 21st of July to produce long N+1 shoots for sustainable production, without having a negative effect on yield in the current season. Removal of one third of N shoots of ‘Col de Damme Noire’ on 30 June, 21 July, or 11 August can be used to produce long (40 cm and longer) N+1 shoots that should yield more and larger fruit per N shoot (but fewer per tree) in comparison to the control. These same pruning dates, but especially 30 June, should produce longer N+1 shoots in combination with heading N shoots back to three nodes.

Introduction

The aim of pruning is to regulate tree growth and development in a way that will ensure high annual yields of quality fruit from an early tree age. In addition to effects on yield,

pruning is employed in mature trees to maintain the tree in its allotted space and to allow adequate light penetration (Wertheim, 2005).

Various pruning methods are employed in fig, depending on cultivar, crop of interest and environmental conditions. Traditionally, as compared to other fruit trees grown in temperate climates, fig trees are believed to require less pruning (Eisen, 1901). Yet, it is suggested that at least some annual dormant pruning should be done in order to stimulate adequate, but not excessive growth (Ferguson et al., 1990). In Pune (India), light pruning is performed just after harvest (Singh, 1995).

Conversely, in more recent years, severe heading cuts have been employed in fig production, with young fig trees trained to grow on grapevine-type trellis systems. A number of main branches are tied down to grow horizontally, with current season (N+1) shoots growing vertically from these branches. As in grape production, shoots are cut back to short stubs each year (Flaishman et al., 2008).

A similar method is employed in China, where shoots on two main branches extending in opposite directions, are pruned back to three buds during the dormant period. Two to three shoots originating from each stub the following spring yield a large number of fruit on the new growth (Wang et al., 2003). In India, shoots are annually headed back in winter leaving only three to four buds, (Uttar Pradesh, India) or two buds (Karnataka, India), with the aim of stimulating the development of more fruit bearing wood (Singh, 1995).

Vigorous acrotonic (distal branching) fig shoots give rise to sections of unproductive “blind wood” as found in apple (Oosthuyse et al., 1992; Cook et al., 2001). Delayed heading (delaying the heading cut until after bud break) has been employed to overcome the effects of apical dominance and decrease the occurrence of “blind wood” in apple (Oosthuyse et al., 1992). When delayed heading was used to remove the distal one third of shoots in ‘Granny Smith’, there was an increase in the number of shoots developing, with a reduction in the total length of new growth (Oosthuyse et al., 1992). Delayed heading possibly releases buds under endogenous conditions less favourable for the development of dominance phenomena, allowing buds in a shoot section with less available cytokinin to break (Cook et al., 2001).

In this paper we present the results from two experiments. The first experiment was conducted to evaluate the effect of pruning intensity and the second experiment the effect of timing of the heading cut on the resultant vegetative and reproductive development of ‘Bourjasotte Noire’ and ‘Col de Damme Noire’. The pruning cuts will also be evaluated to determine what type and timing of cut is required to stimulate the growth of shoots of the same length as the shoots selected to be optimal for yield during the phenology studies of ‘Bourjasotte Noire’ and ‘Col de Damme Noire’ (Paper 1).

Materials and methods

Two experiments were conducted on both ‘Bourjasotte Noire’ and ‘Col de Damme Noire’ during the 2008/2009 growing season in a commercial orchard in the Breede River valley. For a complete description of the site and plant material, see Paper 1.

Treatments and trial design:

Experiment 1 comprised four pruning treatments viz., an unpruned control (T1), removal of either one-third (T2) or one half (T3) of one-year-old (N) shoots, or cutting the shoot back to approximately three nodes (T4). Treatments were applied on 9 August 2008 to the whole dormant tree. A randomised complete block design was used, using single tree plots replicated eight times. Three N shoots of more or less similar orientation, girth and length were selected and tagged on each tree. After pruning, the average N shoot lengths were 58, 38, 22 and 11 cm, respectively, from T1 to T4 in ‘Bourjasotte Noire’ and 77, 44, 36 and 17 cm, respectively, from T1 to T4 in ‘Col de Damme Noire’.

Experiment 2 consisted of six treatments replicated nine times, as single tree-plots in a randomised complete block design. One treatment was applied per tree, to each of three selected N shoots. An unpruned control (Control) and the following pruning dates were used as treatments: 30 June 2008 (Date 1), 21 July 2008 (Date 2), 11 August 2008 (Date 3), 1 September 2008 (Date 4) or 22 September 2008 (Date 5). Each treatment consisted of removing the distal third of the shoot on the specified date. Natural bud break commenced on 5 September in both cultivars. The average N shoot lengths after pruning was 55 cm (control), 36 cm (date 1), 34 cm (date 2), 34 cm (date 3), 38 cm (date 4) and 34 cm (date 5) in ‘Bourjasotte Noire’ and 67 cm (control), 47 cm (date 1), 51 cm (date 2), 45 cm (date 3), 53 cm (date 4) and 46 cm (date 5) in ‘Col de Damme Noire’.

Data recorded:

After leaf drop in autumn, the number of fruit scars and total number of vegetative buds (as present before bud break) on N shoots, the total number of N+1 shoots and total number of reproductive buds on N+1 shoots were counted. Fruit set percentage was calculated by expressing the number of fruit as a fraction of the total number of reproductive buds. Tree trunk circumference and the length and diameter of N+1 shoots were also measured. In ‘Col de Damme Noire’, the diameter of all fruit on selected shoots were measured with a calliper on 5 February 2008 as an indication of whether fruit maturation was advanced. Due to the method used, differences in diameter may indicate differences in maturity or fruit size.

Data analysis:

In both experiments, treatments were compared by analysis of variance using the general linear models procedure of SAS version 9.1.3 SP2 (SAS Institute, Cary, N.C., 2004). Where appropriate, single degree of freedom, orthogonal, polynomial contrasts were fitted and/or covariate analysis performed.

Results

Experiment 1:

Effect of pruning intensity on the number of new shoots and bud break percentage.

The number of N+1 shoots produced was significantly higher in the control treatment for both ‘Bourjasotte Noire’ (6.0) and ‘Col de Damme Noire’ (6.5) as compared to all other treatments (Table 1 & 2). T4 produced only 1.9 shoots in both cultivars. In ‘Bourjasotte Noire’, the bud break percentage was higher in the two most severe treatments, T3 (51%) and T4 (57%) as compared to the other treatments (T1: 43%; T2: 40%). T4 N shoots had an average of 3.4 vegetative buds whereas the control shoots (T1) had 15.4 vegetative buds (Table 1). In ‘Col de Damme Noire’, the bud break percentage was significantly higher in T4 as compared to the other treatments (Table 2). T2 and T3 did not differ significantly from each other, whereas T1 displayed the lowest bud break percentage, 29% as compared to 63% in T4. T4 N shoots had on average 3.0 vegetative buds while T1 had 21.9.

Effect of pruning intensity on N+1 shoot growth.

Pruning had no significant effect on the total new growth produced per N shoot in ‘Bourjasotte Noire’ (Table 1), while in ‘Col de Damme Noire’, removal of one-third of N shoots (T2) by heading resulted in the highest amount of total shoot growth (191 cm) per N shoot, as compared to the other three treatments which produced growth ranging from 137 to 138 cm (Table 2).

In ‘Bourjasotte Noire’, the average N+1 shoot length was significantly longer in T4 (35 cm) as compared to T1 (13 cm) and T2 (27 cm) (Figure 1). T3 (29 cm) did not differ significantly from either T2 or T4. When shoots were cut back to three nodes in ‘Col de Damme Noire’, the average N+1 shoot length was 72 cm (Figure 2). Heading shoots back halfway produced shoots with an average length of 61 cm, while removal of one third resulted in shoots with an average length of 57 cm. The unpruned control (T1) produced shoots with an average length of 24 cm (Figure 2). In both ‘Bourjasotte Noire’ and ‘Col de Damme Noire’ there were no significant differences in N+1 shoot internode length between pruning treatments T2, T3 and T4. Internodes on unpruned T1 shoots were significantly shorter compared to pruning treatments T2, T3 and T4 in ‘Col de Damme Noire’, and shorter compared only to T4 in ‘Bourjasotte Noire’ (Figure 1, 2).

In ‘Col de Damme Noire’, the average N+1 shoot diameter followed a similar trend to that of the average N+1 shoot length (Figure 3). T4 shoots were significantly thicker (17 mm) than in T2, T3 (both 14 mm) and T1 (10 mm), while in ‘Bourjasotte Noire’, T2 to T4 did not differ significantly from each other, but were thicker than T1 (Figure 3).

Effect of pruning intensity on yield.

There were significant differences between treatments in terms of total fruit per N shoot (as determined by fruit scars) in ‘Bourjasotte Noire’. T1 produced an average of 15 fruits per shoot, whereas T4 produced only eight (Table 1). The total number of fruit per N shoot in ‘Col de Damme Noire’ was significantly higher on unpruned shoots (T1) as compared to all pruned shoots which did not differ from each other (Table 2).

There were no statistically significant differences between treatments in the average number of fruit produced per N+1 shoot in ‘Bourjasotte Noire’, although pruning tended to increase the number of fruit produced ($p=0.0759$) (Table 1). In ‘Col de Damme Noire’ there

were no significant differences between treatments in the number of fruit per N+1 shoot (Table 2).

Set density (fruit per 30 cm N+1 shoot) in 'Bourjasotte Noire' shows no statistically significant differences between treatments, although pruning tended to decrease it ($p=0.0994$) (Table 1). In 'Col de Damme Noire', fruit density per 30 cm N+1 shoot was significantly higher on unpruned shoots (T1) as compared to pruned shoots (T2 – T4) (Table 2). The fruit set percentage was not significantly different between treatments in 'Bourjasotte Noire' (Figure 4), while in 'Col de Damme Noire' all pruned N shoots developed N+1 shoots with similar fruit set percentages, while unpruned shoots had a significantly higher average fruit set percentage (Figure 5).

Severe pruning (T3 and T4 in 'Col de Damme Noire'; T4 in 'Bourjasotte Noire') caused a reduction in the average number of reproductive buds on N+1 shoots per N shoot in both cultivars (Figure 4, 5). In 'Col de Damme Noire', T1 fruit had a significantly wider diameter as compared to T3 and T4 fruit, but not significantly different compared to T2 (Table 2).

Experiment 2:

Effect of time of pruning on total bud break, number of N+1 shoots and bud break percentage .

The control, had a significantly higher number of buds breaking, and therefore more N+1 shoots forming, in comparison to any other treatment in both cultivars (Table 3, 4). The number of buds breaking (and therefore shoots developing) increased linearly from date one to five (Table 3, 4).

Bud break percentage in 'Bourjasotte Noire' increased linearly with a delay in the pruning date ($P = 0.0012$) and a trend was observed in pruning increasing percentage bud break over that in the control ($p=0.0838$) (Table 3).

In 'Col de Damme Noire', there was a significant difference between the unpruned control and the pruned shoots in bud break percentage (higher in pruned shoots) and also in

this cultivar a significant linear increase was found in bud break percentage the later the pruning date (Table 4).

Effect of time of pruning on new growth.

There were no significant differences between the control and pruned shoots in the amount of growth per 30 cm N shoot in ‘Bourjasotte Noire’, but the total shoot growth was reduced by pruning (Table 3). On pruned shoots, growth per 30 cm N shoot followed a quadratic trend from date 1 to date 5, reaching the highest values following pruning on date 2 and date 3. Total new growth per N shoot followed a quadratic trend with dates two and three reaching the highest values (Table 3).

The means of total new growth per 30 cm N shoot in ‘Col de Damme Noire’ displayed a quadratic trend, with the last pruning date resulting in less growth per 30 cm N shoot than the earlier dates (Table 4). The control yielded less growth per 30 cm N shoot when compared to the average combined growth of pruned shoots (Table 4). This was not the case when looking at total new growth (Table 4).

The treatment date that produced the least growth per N shoot in both ‘Bourjasotte Noire’ and ‘Col de Damme Noire’ was date five (22 September 2008), the delayed heading treatment (Table 3 & 4).

Pruning resulted in longer shoots in ‘Bourjasotte Noire’ and ‘Col de Damme Noire’ except for the delayed heading pruning date (date 5) (Table 3 & 4). Pruning time resulted in a quadratic response in the average N+1 shoot length, increasing from date one to two and then decreasing to date five in ‘Bourjasotte Noire’ (Table 3), whereas in ‘Col de Damme Noire’ it decreased linearly from pruning date 1 to 5 (Table 4).

Effect of time of pruning on yield.

The yield per 30 cm N shoot of ‘Bourjasotte Noire’ displayed a quadratic response to pruning time decreasing from date one and two to date five, whereas in ‘Col de Damme Noire’ this decrease with pruning date was linear (Table 3 & 4). There was no significant difference between the control and combined average mean value of pruned shoots in ‘Bourjasotte Noire’ (Table 3) while pruning tended to decrease yield per 30 cm N shoot in ‘Col de Damme Noire’ ($p=0.0665$) (Table 4).

The mean values of fruit per 30 cm N+1 shoot decreased linearly from date one to five in ‘Bourjasotte Noire’ (Table 3) and this trend was also observed in ‘Col de Damme Noire’ ($p=0.0730$) (Table 4). The control treatment yielded significantly more fruit per 30 cm N+1 shoot as compared to the pruned shoots in both ‘Bourjasotte Noire’ and ‘Col de Damme Noire’ (Table 3 & 4).

The total number of fruit produced per N shoot in both cultivars was highest in the unpruned control, and lowest in pruning date five (Table 3 & 4). The total number of fruit per N shoot decreased linearly from pruning date one to five (0.0209) in ‘Col de Damme Noire’ (Table 4), whereas there was a quadratic response in ‘Bourjasotte Noire’, displaying a gradual decrease at first, before decreasing sharply from date four to five (Table 3). The total number of fruit produced per N+1 shoot decreased linearly in response to delaying the pruning date in both cultivars (Table 3 & 4).

The average fruit diameter in ‘Col de Damme Noire’ measured as a possible indication of fruit maturity, showed no significant differences between treatments (data not shown).

Discussion

Experiment 1:

The number of N+1 shoots declining in ‘Bourjasotte Noire’ and ‘Col de Damme Noire’ as the depth of heading cuts are increased is in agreement with the “Pruning rules of Koopmann” (Wertheim, 2005 citing Koopmann, 1896). After heading, vascular bundles in the remainder of the shoot need to supply fewer buds, which in turn leads to the production of vigorous side shoots (Wertheim, 2005). N+1 shoots resulting from heading cuts had significantly longer internodes as compared to those on unpruned shoots in both cultivars. Regardless of the intensity of the pruning cut, there was no difference in internode length on headed shoots and the number of reproductive buds were fewer in T4 on ‘Bourjasotte Noire’ and in T3 and T4 on ‘Col de Damme Noire’ when compared to the control (Figure 1, 3 & 4). In ‘Col de Damme Noire’, T3 and T4 displayed fruit set percentages and numbers of reproductive buds not significantly different in both these parameters (and no difference in fruit per N shoot). This seems to be contrary to the “Pruning rules of Koopman” which state

that stronger growth is less reproductive (Wertheim, 2005 citing Koopman, 1896), yet these rules were developed mainly for apple.

T2 in ‘Col de Damme Noire’ produced significantly more growth than all other treatments unlike in ‘Bourjasotte Noire’ where there were no significant differences (Table 1 & 2). Buds were more condensed in the distal part of the shoots of both cultivars, contributing to a loss of potential vegetative buds after pruning and is the main cause for an increased bud break percentage on more severely pruned shoots (Table 1 & 2).

Of the different intensities of heading cuts used in this experiment, removing one third (T2) of total shoot length had the least effect on the number of fruit per N shoot in ‘Bourjasotte Noire’, when compared to the control (T1). In T2, fewer N+1 shoots were produced in comparison to T1, but the average shoot length is twice as long. Even so, ‘Bourjasotte Noire’ trees can bear fruit effectively on N+1 shoots of any length N shoot longer than 10 cm (Paper 1). With tree complexity increasing annually, vigour of individual shoots is reduced (Borchert, 1976) as can also be seen in the average N+1 shoot length of unpruned N shoots which was only 13.3 cm in this experiment. Therefore some minimal level of pruning, as in T2, of some shoots may be necessary to maintain development of some longer N+1 shoots. Flaishman et al. (2008) similarly recommends light winter pruning, with a heavier winter pruning every three years to encourage enough new growth for sustainable production.

Heading back to three nodes in ‘Col de Damme Noire’ is the ideal intensity heading cut to produce the optimal N shoot length (60 cm and longer) (Paper 1). However, this treatment (and the other pruning treatments) produced N+1 shoots significantly less productive as compared to unpruned shoots and fruit may take longer to mature (Table 2). This result is in agreement with the observations of Eisen (1901) that heading cuts lead to a reduction in yield. Normally, with an increase in N+1 shoot length, there is an increase in the number of fruit per N+1 shoot on unpruned N shoots (Paper 1). However, this was not the case in this experiment. Due to the reduction in yield, heading cuts should be done selectively in ‘Col de Damme Noire’ in order to have both pruned and unpruned N shoots on the tree.

Thinning cuts in ‘Col de Damme Noire’ and ‘Bourjasotte Noire’, when done sparingly, are likely to have less- or no negative effect on yield per N shoot of remaining shoots (as

compared to heading cuts). On the contrary thinning cuts may even lead to a consistent and sustained high level of cropping of quality fruit. The reason being, that although there may be an increased supply of hormones and nutrients to remaining shoots after thinning, it is less pronounced compared to heading cuts, which may cause excessive shoot growth (Wertheim, 2005). In addition, the highly productive growth in fig is generally from the terminal bud (Ersoy, 2008 citing Aksoy, 1997), which remains in the case of thinning cuts (Eisen, 1901), leading to a more open and spreading growth habit (preferred in fig) as compared to more dense and compact growth induced by heading (Wertheim, 2005).

Experiment 2:

In ‘Bourjasotte Noire’, removal of a third of the N shoot length on 21 July is advised, thereby producing new growth (73 cm) not significantly less than on unpruned N shoots, yet producing the longest average N+1 shoot length (24.8 cm). This treatment yielded fewer fruit per N shoot compared to unpruned shoots. Alternatively, pruning on 11 August is expected to yield an average number of fruit per N shoot not significantly different from the control if the treatment is applied to the whole tree, as in experiment 1 where there was no significant difference between unpruned and pruned shoots in the number of fruit per N shoot. This may also apply to pruning on 21 July.

‘Col de Damme Noire’ produced fewer fruit per N shoot in all pruning treatments compared to the control. Pruning dates one to three, but especially date one, in conjunction with the removal of a third of the N shoot by heading, can be used to stimulate the production of longer N+1 shoots. These shoots will possibly produce larger fruit as seen in Paper 1, where there was an increase in fruit size with an increase in shoot length. However, these pruning dates will have to be combined with different intensity heading cuts to produce shoots within the optimal N shoot length range (Paper 1). It may be possible to stimulate the development of longer shoots by pruning on 30 June as compared to other treatment dates, but the negative effect on yield can be reduced by using less severe heading cuts.

Delayed heading had a negative effect on most parameters when compared to the control, as the control yielded more N + 1 shoots, more growth, more fruit, and an average N + 1 shoot length not significantly different from the delayed heading (date 5) treatment in both

cultivars (Table 3 & 4). Bud break increased linearly from pruning date 1 to 5 in both cultivars. Even so, the average bud break percentage as a result of pruning on 1 September, came very close to being significantly more than the bud break percentage in response to pruning on 22 September ($p=0.0898$; data not shown) in ‘Col de Damme Noire’ which is unexpected when compared to apple (Oosthuysen et al, 1992) and ‘Bourjasotte Noire’ (Table 3).

Unfortunately fruit size was not measured in experiment 1 to quantify the effect of heading cuts on fruit size. In experiment 2, pruning cuts should have been applied to the whole tree. Due to reductions in yield as a result of heading cuts in both cultivars, thinning cuts should be evaluated as an alternative to heading cuts, or used in combination with heading cuts. Thinning cuts also lead to a more open, spreading growth habit (Wertheim, 2005) similar to the natural growth habit of ‘Col de Damme Noire’ and especially ‘Bourjasotte Noire’.

Conclusions

In ‘Bourjasotte Noire’, removing one third of the total length of N shoots on 21 July by heading had the least negative effect on yield, while stimulating the development of more growth and longer N+1 shoots (when compared to other treatments), which are necessary to maintain annual yield. Heading back to three nodes in ‘Col de Damme Noire’ is required to stimulate the growth of N+1 shoots of the length of N shoots established in Paper 1 to be optimal for yield. By heading back on 30 June, it may be possible to produce the optimal shoot lengths without heading back to three buds, since longer N+1 shoots are produced on this date. However, in the first season, N+1 shoots as a result of pruning will be less productive and therefore heading should be done selectively in order to retain sufficient numbers of unpruned shoots maintaining yield.

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Table 1: The effect of different depths of heading cuts on number of vegetative buds, bud break, current season shoots and yield in 'Bourjasotte Noire'.

	No. of N+1 shoots	Bud break %	No. of V-buds per N shoot	New growth (cm)	Total fruit per N shoot	Total fruit per N+1 shoot	No. of fruit per 30 cm N+1 shoot
Control (T1)	6.5 a ^z	43 b	15.4 a	85 ^{NS}	15 a	2.4 ^{NS}	0.6 ^{NS}
1/3 off (T2)	3.3 b	40 b	8.5 b	90	14 ab	4.1	0.5
1/2 off (T3)	2.8 bc	51 a	5.4 c	82	10 bc	3.9	0.4
3 nodes remain (T4)	1.9 c	57 a	3.4 c	68	8 c	4.0	0.4
Pr > F							
Treatment	<0.0001	0.0028	<0.0001	0.3510	0.0102	0.0759	0.0994

^z means with different letters differ significantly at p < 0.05

^{NS} no significant differences between means

Table 2: The effect of different depths of heading cuts on number of vegetative buds, bud break, current season shoots and yield in 'Col de Damme Noire'.

	No. of N+1 shoots	Bud break %	No. of V-buds per N shoot	New growth (cm)	Total fruit per N shoot	Total fruit per N+1 shoot	No. of fruit per 30 cm N+1 shoot	Avg. fruit Ø (mm)
Control (T1)	6.0 a ^z	29 c	21.9 a	137 b	15 a	2.5 ^{NS}	0.33 a	27.6 a
1/3 off (T2)	3.3 b	40 b	8.6 b	191 a	9 b	2.7	0.15 b	26.3 ab
1/2 off (T3)	2.3 c	38 b	6.0 c	137 b	7 b	3.1	0.15 b	25.6 b
3 nodes remain (T4)	1.9 c	63 a	3.0 d	138 b	6 b	3.1	0.12 b	25.1 b
Pr > F								
Treatment	<0.0001	<0.0001	<0.0001	0.0006	0.0024	0.6761	<0.0001	0.0194

^z means with different letters differ significantly at p < 0.05

^{NS} no significant differences between means

Table 3: The effect of timing of heading cuts on bud break, shoot growth and yield in four-year-old 'Bourjasotte Noire' in the Breede River valley (2008-2009). Means were separated by LSD (5%).

Treatment	Total bud break	Bud break %	New growth / 30 cm N shoot (cm)	New growth (cm)	Avg N+1 shoot length (cm)	No. of fruit / 30 cm N shoot	No. of fruit / 30 cm N+1 shoot	Total fruit per N shoot	Total fruit per N+1 shoot
Control	5.7 a ^z	36 cd	48.6 bc	87 a	15.0 c	9.0 abc	5.6 ab	16 a	2.8 b
30-06-2008 (Date 1)	3.0 c	38 bcd	53.4 ab	64 b	20.7 b	10.0 ab	5.9 a	11 bc	4.0 a
21-07-2008 (Date 2)	3.0 c	34 d	62.0 a	73 ab	24.8 a	10.8 a	5.3 abc	12 b	4.1 a
11-08-2008 (Date 3)	3.6 bc	42 abc	64.0 a	74 ab	21.1 b	8.5 bc	4.0 cd	10 bc	2.8 b
01-09-2008 (Date 4)	3.4 bc	44 ab	54.5 ab	64 b	18.2 b	7.6 c	4.4 bc	9 c	2.5 b
22-09-2008 (Date 5)	3.8 b	46 a	38.1 c	46 c	12.3 c	3.8 d	3.1 d	4 d	1.2 c
Pr > F									
Initial shoot length	<0.0001	0.3127	0.2803	<0.0001	0.0047	<0.0001	<0.0001	0.7315	0.0026
Treatment	<0.0001	0.0044	0.0003	<0.0001	<0.0001	<0.0001	0.0003	<0.0001	<0.0001
Control vs. Pruning	<0.0001	0.0838	0.1699	0.0001	0.0009	0.2539	0.0254	<0.0001	0.7393
Pruning linear	0.0077	0.0012	0.0025	0.0055	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Pruning quadratic	0.9117	0.4703	0.0001	0.0013	<0.0001	0.0063	0.8322	0.0118	0.0571

^z means with different letters differ significantly at p < 0.05

Table 4: The effect of timing of heading cuts on bud break, shoot growth and yield in four-year-old 'Col de Damme Noire' in the Breede River valley (2008-2009). Means were separated by LSD (5%).

Treatment	Total bud break	Bud break %	New growth / 30 cm N shoot (cm)	New growth (cm)	Avg N+1 shoot length (cm)	No. of fruit / 30 cm N shoot	No. of fruit / 30 cm N+1 shoot	Total fruit per N shoot	Total fruit per N+1 shoot
Control	5.5 a ^z	29 d	55.3 b	134 a	26.5 c	4.4 a	2.6 a	9 a	2.0 a
30-06-2008 (Date 1)	2.9 c	35 cd	85.6 a	131 a	47.2 a	3.8 a	1.3 b	5 b	2.0 a
21-07-2008 (Date 2)	3.1 bc	38 bc	84.9 a	131 a	43.4 ab	3.7 a	1.4 b	6 b	2.0 a
11-08-2008 (Date 3)	3.2 bc	37 bc	79.7 a	129 a	41.0 ab	3.4 a	1.3 b	5 bc	1.5 ab
01-09-2008 (Date 4)	3.6 bc	45 a	89.9 a	142 a	39.3 b	2.7 ab	0.8 b	5 bc	1.2 bc
22-09-2008 (Date 5)	3.7 b	40 ab	63.6 b	104 b	28.0 c	1.5 b	0.8 b	2 c	0.7 c
Pr > F									
Initial shoot length	0.0011	0.0188	0.0982	<0.0001	0.0093	0.1853	0.1359	0.6614	0.2188
Pruning	<0.0001	<0.0001	<0.0001	0.0471	<0.0001	0.0446	0.0013	0.0004	0.0030
Control vs. Pruning	<0.0001	<0.0001	0.0001	0.4981	<0.0001	0.0665	<0.0001	<0.0001	0.0971
Pruning linear	0.0198	0.0037	0.0096	0.1020	<0.0001	0.0073	0.0730	0.0209	0.0001
Pruning quadratic	0.8215	0.3211	0.0407	0.0431	0.1445	0.3121	0.5652	0.2343	0.4047

^z means with different letters differ significantly at p < 0.05

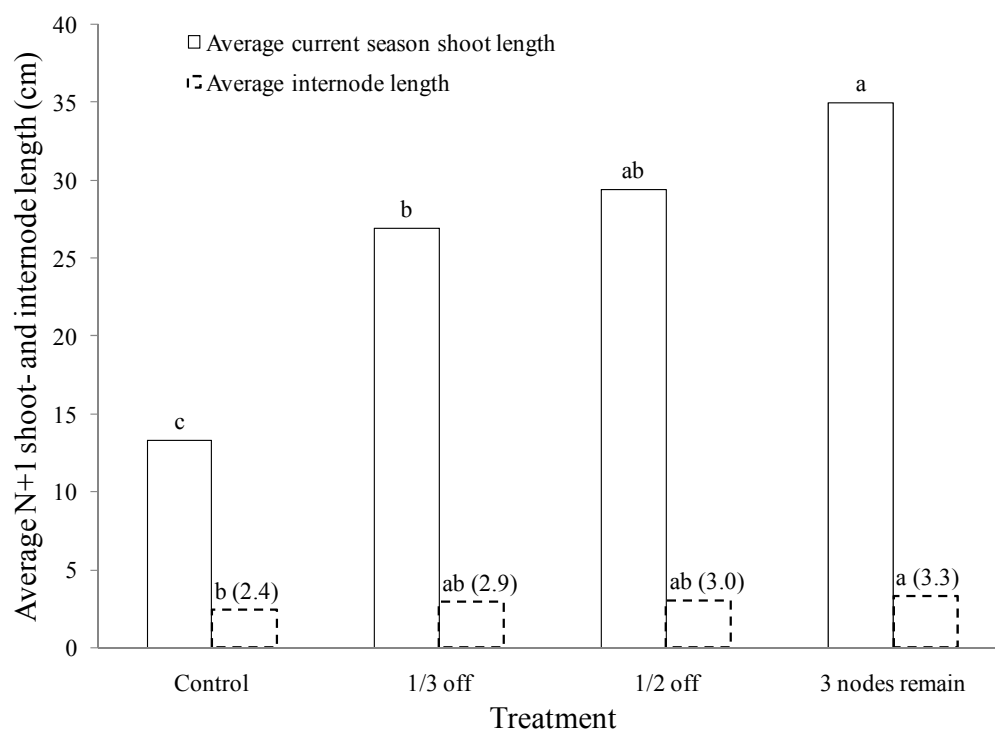


Figure 1: Average current season shoot- and internode length expressed as a function of pruning intensity in 'Bourjasotte Noire'.

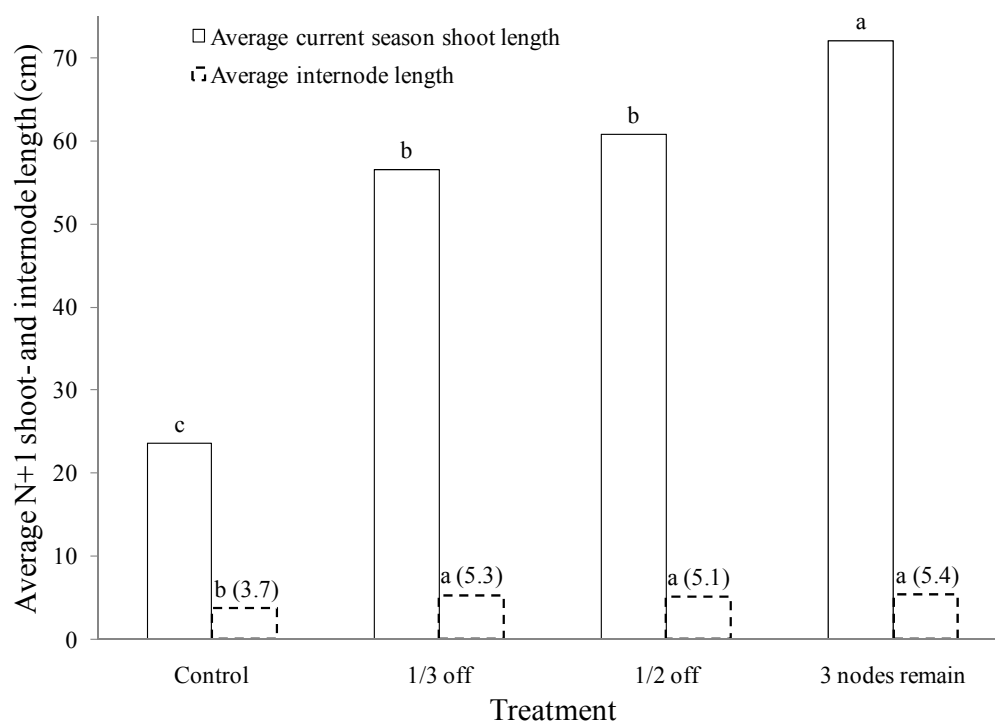


Figure 2: Average current season shoot- and internode length expressed as a function of pruning intensity in 'Col de Damme Noire'.

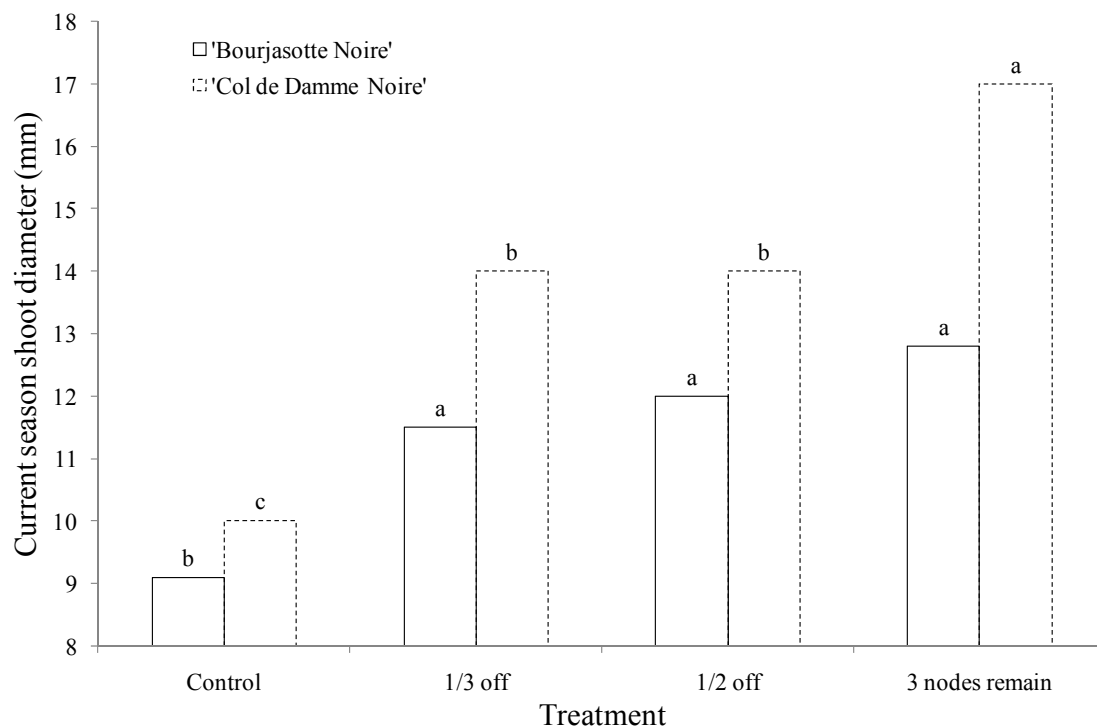


Figure 3: Average current season shoot diameter as a function of pruning treatment in 'Bourjasotte Noire' and 'Col de Damme Noire'.

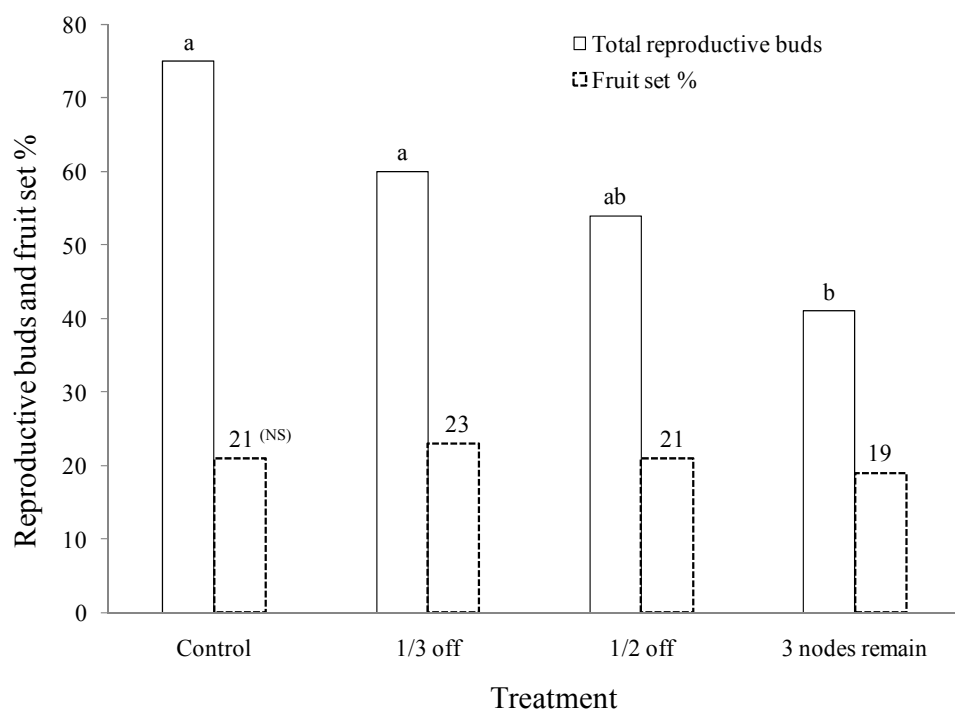


Figure 4: Fruit set percentage and average number of reproductive buds on new growth, per N shoot, as a function of pruning intensity in 'Bourjasotte Noire'.

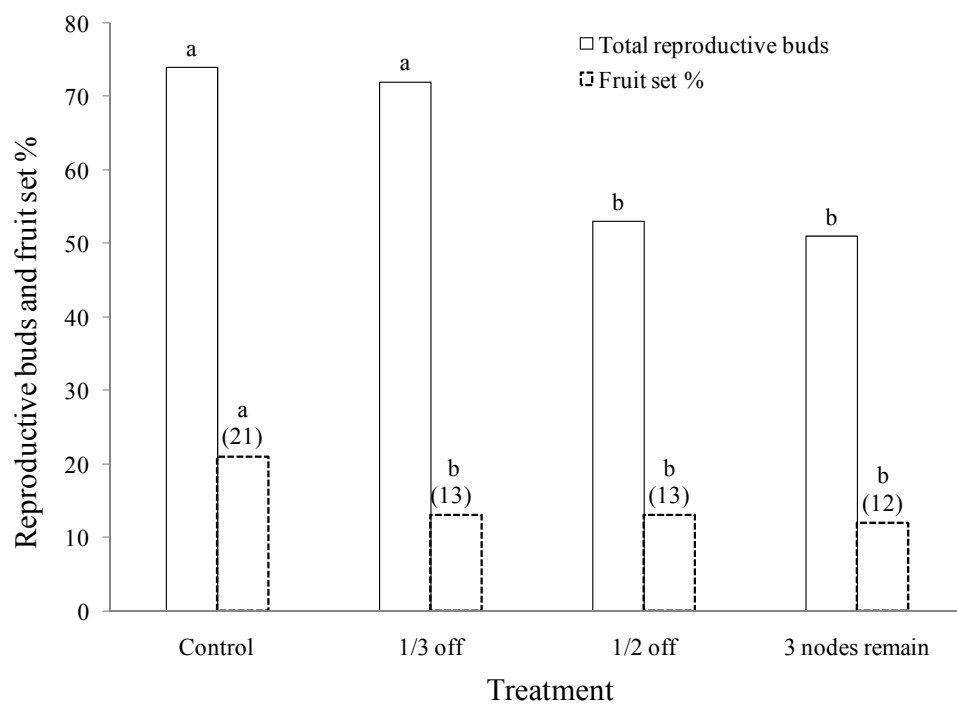


Figure 5: Fruit set percentage and average number of reproductive buds on current season shoots, per N shoot, as a function of pruning intensity in 'Col de Damme Noire'.

Effect of Hydrogen Cyanamide, Mineral Oil and Thidiazuron in Combination with Tip Pruning on Bud Break, Shoot Growth and Yield in ‘Bourjasotte Noire’, ‘Col de Damme Noire’ and ‘Noire de Caromb’ Figs

Abstract. Commercial fig production is relatively new to the Mediterranean-type climate Western Cape Province of South Africa. Very little research on fig production has been conducted in South Africa and producers struggle to implement effective commercial practices to ensure adequate yields of quality fruit. The chemical rest breaking agents, Lift® (thidiazuron $3 \text{ g}\cdot\text{L}^{-1}$) at 6%, Dormex® (hydrogen cyanamide, $520 \text{ g}\cdot\text{L}^{-1}$) at 4%, mineral oil at 4% and a combination of mineral oil and Dormex® at 2% each were evaluated in a split plot design in combination with tip-pruning versus no-pruning to overcome apical dominance and increase complexity (Experiment 1). During the 2008/2009 season, an additional investigation was conducted to evaluate the use of thidiazuron and hydrogen cyanamide for harvest scheduling (Experiment 2). Dormex® at 3% and Lift® at 6%, were applied to dormant trees on 30 June 2008, 3 August 2008, 15 August 2008 or 30 August 2008. In Exp. 1, Lift® increased and tip-pruning decreased bud break in ‘Bourjasotte Noire’, while tip-pruning caused a reduction in the amount of new growth and yield in ‘Noire de Caromb’. In Exp. 2, Lift® applied 3 August and 15 August and Dormex® applied 30 June, shortened the number of days to bud break in ‘Bourjasotte Noire’. Dormex® applied 3 August and 15 August and Lift® applied 30 June, decreased the number of days to 50% bud break in ‘Col de Damme Noire’. Dormex® and oil and oil alone, combined with no-pruning increased bud break in ‘Noire de Caromb’. Both Lift® and Dormex® applied 30 June decreased the number of days to 50% bud break leading to a reduction in the number of days to 50% harvest of the breba crop in ‘Noire de Caromb’. These treatment dates also increased the number of fruit in both the breba and main crop of ‘Noire de Caromb’, but decreased fruit size of the breba crop.

Introduction

Fruit tree cultivars have specific genetic chilling requirements to break endodormancy (Erez, 1995), a period that starts after paradormancy and which ends with ecodormancy or bud break (Crabbe, 1994; Faust et al., 1995, 1997). Correlative inhibition, which is synonymous with paradormancy, gives rise to apical dominance (AD) (Crabbe & Barnola, 1996). The establishment of AD during the dormant period probably mediates acrotony, a distal branching growth habit (Cook et al., 2001), (common in many tree species), prior to bud burst in spring (Cook et al., 1998).

Lateral buds are inhibited by terminal buds through paradormancy (Saure, 1985; Naor et al., 2003), and therefore terminal buds are released more easily from dormancy (Crabbé, 1994). After alleviation of endodormancy by exposure to chilling, cytokinins (CK's) have the ability to induce bud break (Faust et al., 1997) either resulting in uniform outgrowth of all buds or in acrotony (Crabbe, 1994), depending on the strength of the AD generated by the terminal bud and the receptiveness of lateral buds to the dominance effect (Faust et al., 1995).

Fig cultivars generally have low chilling requirements (Flaishman et al., 2008; Aksoy, personal communication). The difference between a high- and low chill (apple) cultivar lies in both the strength of AD during paradormancy and the length of the endodormant period (Faust et al., 1995). According to Flaishman et al. (2008), figs grown in hot desert areas with winter temperatures above 6° to 10°C, do not enter an endodormant period or shed their leaves. Buds on excised shoots of the fig cultivar Masui Dauphine were induced to break (80% bud break within three weeks) by heading back the shoots (at 25°C), even in the deepest phase of endodormancy (Kawamata et al., 2002). It is likely that local climatic conditions dictate the length of the dormant period (Flaishman et al., 2008 citing Erez & Shulman, 1982). According to Flaishman et al. (2008), figs can be grown in regions with little winter chilling, but bud break might be erratic and thereby compromise yield (Flaishman et al., 2008). Fig cultivars with higher chilling requirements would benefit from more winter chilling. While having potentially low chilling requirements, the fig cultivar Bourjasotte Noire displays strong apical dominance and epitonic growth (Bell, 1991), Col de Damme Noire display strong apical dominance (AD) and acrotonic growth and Noire de

Caromb displays moderate- AD and acrotonic growth (personal observation). According to Aksoy (personal communication), many fig cultivars display a type of seasonal growth where only the terminal bud or the adjacent 1-2 buds break as a result of strong AD. In apple, this condition results in long unproductive sections of “blind wood” (Oosthuyse et al., 1992).

Since an acrotonic bud pattern, which gives rise to “blind wood”, causes distal buds to break first, they are marginally better producers of auxin. The distal buds quickly become established sinks for metabolites, thereby monopolising available growth substances (Oosthuyse et al., 1992 citing Jankiewicz, 1972). Auxin is possibly responsible for this growth (and therefore the architecture of the tree) by preventing the movement of cytokinins (CK's) into lateral buds under the influence of AD (Cook, et al., 2001), since endogenous CK's play an important role in stimulating bud burst in spring (Faust et al., 1997). These endogenous CK's have been suggested to originate from within the shoot (Cook et al., 2001) and it is therefore likely that they are stored in the shoot before it becomes dormant (Cook et al., 2001; Van Staden, 1976).

Various methods have been used to supplement chilling and to manipulate bud break in fruit trees. Hydrogen cyanamide (HC) has been used to induce bud break in various fruit crops such as apple (Sagredo et al., 2005), pistachio (Pontikis, 1989), blueberry (Jaldo et al., 2009), grape (Possingham, 2004), kiwi (McPherson et al., 2001), peaches and nectarines (Dozier et al., 1990) and fig (Shulman et al., 1986; LiLi & JinBao, 2003). Rates of 0.5 – 2.5% HC causes early, uniform bud break in fig (Shulman et al., 1986).

In Israel, a rate of 3% Dormex® has been used successfully to schedule bud break and fruit ripening over the season (Yablowitz et al., 1998). The earliest treatment date was 15 December (NH), which resulted in bud break from 1 to 10 January. Earlier treatment dates resulted in the shortest time from application to bud break (15+ days) compared to later treatment dates (15 January) resulting in the longest time (30+ days) between treatment and bud break (Yablowitz et al., 1998).

Applications of 4, 6 or 8% mineral oil was effective in advancing and enhancing bud break in ‘Hosui’ pear (De Oliveira et al., 2008), while mineral oil at 4% plus 1% to 2% HC sufficiently breaks dormancy in apple trees (Sagredo et al., 2005). Exogenous application of thidiazuron (TDZ), a cytokinin analogue, has been used to overcome dormancy in apples

(Steffens & Stutte, 1989; Wang et al., 1991). TDZ released buds from dormancy causing bud break at all used rates (0.01 ml L^{-1} – 0.22 ml L^{-1}), while 0.02 ml L^{-1} TDZ was found to be the optimal rate (Wang et al., 1985).

According to Faust et al. (1997), buds are sensitive to CK's and rest breaking agents (RBA's) during the last stage of endodormancy and during the ecodormant phase. This is also the period during which buds will resume growth if exposed to sufficiently high temperatures (Faust et al., 1997). According to Shulman et al. (1986), the best time to apply HC is after the accumulation of some chilling, but before (1 – 5 weeks) the normal time of bud break, unlike other compounds which are more active at the bud swelling stage. Steffens and Stutte (1989) found TDZ to be most effective to promote bud break in excised apple shoots before the initiation of endodormancy. It seems therefore that most RBA's are most effective in late fall and then again later in winter when most of the chilling requirement has been satisfied (Erez, 1987; Steffens & Stutte, 1989).

The first aim of this research was to establish whether RBA's in combination with tip-pruning can increase tree complexity by improving bud break in 'Bourjasotte Noire', 'Col de Damme Noire' and 'Noire de Caromb', and whether increased complexity would increase yield in 'Bourjasotte Noire'. The second aim of this research was to evaluate harvest scheduling using rest breaking agents to advance bud break.

Materials and methods

Both experiments were conducted on 'Bourjasotte Noire', 'Col de Damme Noire' and 'Noire de Caromb' in commercial orchards in the Breede River valley. Experiment 1 was conducted on 'Bourjasotte Noire' and 'Col de Damme Noire' during the 2007/2008 season while in the 2008/2009 season all three cultivars were included. Experiment 2 was conducted on all three cultivars during the 2008/2009 season. RBA's were applied with a motorised spray gun until run-off.

Experiment 1 consisted of a split-plot design with 5×2 treatments, replicated five times on 'Bourjasotte Noire' and ten times on 'Col de Damme Noire' during 2007/2008 and six times on all three cultivars during 2008/2009 in randomized, complete blocks. Treatments

were as follows: (1) an untreated control; (2) 4% Dormex® (HC); (3) 2% Dormex® plus 2% BudBreak® (mineral oil); (4) 4% BudBreak®; and (5) 6% Lift® (TDZ). A further pruning treatment of removing the apical ± 2.5 cm of shoots (tip-pruning) was randomly applied to one of the two trees in each subplot. Treatments were applied when terminal buds reached green tip (7/09/07 and 11/09/08, respectively). The average lengths of the selected one-year-old (N) shoots of all three cultivars did not differ markedly between treatments (Table 1).

On 5/10/07 and 10/10/08, the number of buds breaking on tagged shoots were counted in both 'Bourjasotte Noire' and 'Col de Damme Noire', while 'Noire de Caromb' was evaluated only on the latter date. On 04/02/08, 07/02/08, 14/02/08 ('Bourjasotte Noire') and 03/03/08, 13/03/08, 20/03/08 ('Col de Damme Noire'), the following data were collected during the first season: number and length of new (N+1) shoots, basal diameter of N shoots, number of fruit and fruit diameter. In the second season, the same data was collected on 05/02/09 for all three cultivars.

Experiment 2 was conducted during the 2008/2009 season as an augmented factorial, randomised complete block design using nine treatments, replicated six times. An untreated control and two RBA's, TDZ (Lift®, 6%) and HC (Dormex®, 3%) were applied on different dates ((30/06/2008 (mid winter), 3/08/2008, 15/08/2008 or 30/08/2008 (bud swell)). Single tree plots were used, on which three relatively uniform dormant shoots were selected, tagged and evaluated in terms of the following parameters: shoot length and basal diameter, total number of vegetative buds, bud break over time, number of new shoots, new shoot length, number of fruit, and the weight, diameter and harvest dates of individual fruit. The average lengths of the selected one-year-old shoot lengths are displayed in Table 2.

Comparison of parameters was performed by analysis of variance using the general linear models procedure of SAS version 9.1.3 SP2 (SAS Institute, Cary, N.C., 2004). Where appropriate, single degree of freedom, orthogonal, polynomial contrasts were fitted and/or covariate analysis performed.

Results

Experiment 1

‘Bourjasotte Noire’

In ‘Bourjasotte Noire’ there were significant differences between rest breaking treatments in the initial number of buds breaking per N shoot during the 2007/2008 and 2008/2009 seasons, with Lift® inducing a higher number of buds to break when compared to the control and all other RBA treatments (Table 3 & 4). Dormex® in combination with oil decreased initial bud break compared to the control in both seasons. Oil decreased bud break compared to all other treatments during 2008/2009. A higher number of buds broke initially on shoots that were left unpruned during both seasons. There were no significant differences in the final number of buds breaking in ‘Bourjasotte Noire’ during the 2007/2008 season, yet during the 2008/2009 season, both the Lift® and no-tipping resulted in higher numbers of buds breaking whereas Dormex® in combination with oil decreased final bud break, similar to the initial bud break results (Table 3 & 4).

RBA’s had no effect on the average N+1 shoot length in ‘Bourjasotte Noire’ during the first season, while the combination of Dormex® and oil resulted in a higher average N+1 shoot length than the other RBA’s during the second season, although not significantly different from the control. Lift® decreased the average N+1 shoot length compared to the control and the Dormex® and oil combination. During both seasons, tip-pruning caused an increase in the average N+1 shoot length. There were no significant differences in total new shoot growth or the number of N+1 shoots longer than 5 cm in either season (Table 3 & 4).

During the 2007/2008 season, there were no significant differences in ‘Bourjasotte Noire’ between treatments in the number of fruit produced per N shoot, while during the 2008/2009 season, tip-pruning decreased the number of fruit per N shoot (Table 3 & 4). There were no significant differences in the number of fruit per N+1 shoot in the first season (Table 3), whereas the combination of Dormex® and oil produced N+1 shoots with more fruit in comparison to the other treatments in 2008/2009, while the pruning treatment again had no significant effect on yield (Table 4). None of the RBA’s had any significant effect on fruit size during either season (Table 3 & 4).

‘Col de Damme Noire’

In ‘Col de Damme Noire’, Lift® caused the highest number of buds to break initially during the first season when compared to the control and other RBA’s. Dormex® in combination with oil decreased initial bud break compared to Dormex® on its own and Lift®. During the second season, tip pruning decreased initial bud break. There were no significant differences in final bud break in either of the two seasons (Table 5 & 6).

Dormex® and oil combined stimulated significantly longer average N+1 shoots in ‘Col de Damme Noire’ during the first season, in comparison to all treatments except for Dormex® on its own, while Lift® induced the shortest average N+1 shoot length although not significantly different from the control and oil (Table 5 & 6). Tip pruning increased the average N+1 shoot length in the first- and second season, while the RBA’s had no significant effect in the second season. RBA treatments had no significant effect on the total amount of N+1 growth in either of the seasons, while tip-pruning increased the amount of growth in both seasons. There were no significant differences in the number of N+1 shoots longer than 5 cm in either season (Table 5 & 6).

The RBA’s caused no significant differences in ‘Col de Damme Noire’ in the number of fruit per N- or N+1 shoot during either season, while tip pruning decreased the number of fruit for both parameters during the second season. There were no significant differences in fruit size as a result of the RBA’s in either season, while tip-pruning decreased fruit size when compared to unpruned shoots (Table 5 & 6).

‘Noire de Caromb’

In ‘Noire de Caromb’ there was significant interaction between tip-pruning and RBA treatments in both initial and final bud break during the 2008/2009 season. In the control, Dormex® and Lift®, tip pruning tended to slightly increase initial bud break, while for oil, this trend was inverted. With the Dormex® and oil combination, tip pruning significantly decreased initial bud break. The Dormex® and oil combination on unpruned N shoots caused the highest number of buds to break, significantly higher than the control although not significantly higher than oil and no-tip and Lift® and tip or no-tip. Dormex® and oil combined with no-tip again caused an increase in the final number of buds breaking, although not significantly different from ‘oil and no-tip’ (Table 7). This latter treatment also increased final bud break compared to the control treatments.

There were no significant differences in ‘Noire de Caromb’ in the average N+1 shoot length in 2008/2009 (Table 8). RBA’s had no significant effect on the total amount of new growth produced by N shoots, while tip-pruning decreased the amount of new growth (Table 8). There was significant interaction between the pruning treatment and RBA’s in the number of shoots longer than 5 cm, where the Dormex® and oil combination on unpruned shoots produced significantly more shoots longer than 5 cm when compared to the other treatments (Table 7). Unpruned Lift® shoots also produced more shoots compared to pruned Lift® shoots. The number of new shoots >5 cm did not differ between pruned and unpruned shoots in other RB treatments.

There were no significant differences in ‘Noire de Caromb’ in the total number of fruit per N- or N+1 shoot as a result of RBA application; however, pruning decreased the number of fruit for both parameters (Table 8). Significant interaction occurred between tipping and RBA treatments in fruit maturity, where all of the combinations except ‘control and no-tip’, ‘Dormex® and oil and tip’, ‘oil and tip or no-tip’ and ‘Lift® and tip’ had larger fruit on the day measurements were taken, in comparison to the control (Table 8). Unpruned shoots had larger fruit than pruned shoots in the case of oil and Lift®.

Experiment 2

‘Bourjasotte Noire’

In ‘Bourjasotte Noire’, the RBA treatments increased initial bud break compared to the control (Table 9). Lift® caused a higher initial number of buds to break compared to Dormex®. There was no significant difference between Lift® and Dormex® in the final number of buds that broke, while the RBA treatments tended to increase bud break relative to the control ($p=0.0991$). RBA treatments had no significant effect on the total amount of new growth per N shoots, but the average N+1 shoot length was decreased by Lift® compared to Dormex®, and later application dates of both RBA’s also caused a decrease in the average N+1 shoot length (Table 9). None of the treatments affected the number of fruit per N shoot, while Lift® decreased the number of fruit per N+1 shoot relative to Dormex® (Table 9). Treatments were not significantly different from the control for this parameter, and later RBA application dates tended to decrease the number of fruit per N+1 shoot ($p=0.0761$) (Table 9).

RBA treatments decreased the average fruit mass ($p=0.0102$) and diameter ($p=0.0575$) at harvest compared to the control (Table 9).

The RBA treatments did not have any harvest scheduling effect relative to the control (data not shown). Even so, Lift® prolonged the period until 25% ($p=0.0283$) and 50% ($p=0.0689$) of total harvest relative to Dormex®. However there was no significant effect on the time period until 75 % and 100 % of total harvest (data not shown). There was quadratic interaction between RBA's and time of application with regard to the dates until 25%, 50% and 75% bud break was achieved (Figure 1). Early application (30 June) of Dormex® decreased the number of days to 25%, 50% and 75% of bud break relative to the control. Lift® applied on 3 August had the biggest effect on decreasing the number of days to the respective bud break percentages,

‘Col de Damme Noire’

In ‘Col de Damme Noire’, there was quadratic interaction between the RBA's and application date, where Lift® application on 30 August significantly increased initial bud break relative to Dormex® (Figure 2A). RBA treatments tended to increase initial bud break relative to the control ($p=0.0953$). The final number of buds breaking decreased linearly from the earliest to the latest application dates, but there were no significant differences between treatments and the control, or between Lift® and Dormex® (Table 10).

There was a quadratic interaction between the RBA's and application date, with the earliest application date of Dormex® (30 June) and the second application date of Lift ® (3 August) shortening the number of days to 50% bud break to 28 and 29 days, respectively, in comparison to the control (47 days) (Figure 3).

Linear interaction was displayed between RBA and application date in the total amount of new growth produced (Figure 2B). Total growth decreased with later application in the case of Lift®, while in Dormex® the response did not differ with date of application. With regard to average N+1 shoot length, there was linear interaction between RBA and application date, where Lift® applied 30 June increased average N+1 shoot length relative to Dormex®. Later application dates displayed no significant differences (Figure 2C). There were no significant differences between treatments in yield or fruit size (Table 10), and RBA's had no significant harvest scheduling effect in ‘Col de Damme Noire’ (data not shown).

‘Noire de Caromb’

In ‘Noire de Caromb’, both initial and final bud break displayed a quadratic trend, increasing from the first- (30 June) to the second (3 August) application date and then decreasing to the last application date (Table 11). Lift® initially caused a higher number of buds to break in comparison to Dormex®, yet there were no significant differences between the two RBA’s in the final number of buds breaking. Both treatments increased initial and final bud break relative to the control (Table 11). There was a quadratic interaction between RBA and application date in the total amount of new growth produced, where Dormex® induced significantly less growth after the second application date (3 August) while the first two dates did not differ from Lift®, although producing more growth compared to the control (Figure 4A). Similarly, a quadratic response was seen in the number of N+1 shoots > 2cm, where all applications except Dormex® applied 30 June produced more shoots longer than 2 cm compared to the control (Figure 4B). The average length of N+1 shoots decreased in reaction to RBA treatments (Table 11). RBA treatments caused an increase in the number of fruit per N shoot relative to the control, and Dormex® increased the number of fruit relative to Lift® (Table 11). RBA applications were most effective in increasing the number of fruit when applied on 30 June. There was a quadratic interaction between RBA’s and application date in the number of fruit per N+1 shoot due to significantly more fruit developing following the last Dormex® application date (Figure 4C). There were no significant differences in the average fruit mass or weight between RBA’s and the control, yet Dormex® caused bigger fruit in both mass and diameter relative to Lift® (Table 11).

RBA’s were effective in shortening the number of days from 1 August to 50% bud break (Figure 5). Both RBA’s displayed a quadratic trend, with the first application date of Dormex® and the second application date of Lift® attaining the lowest values from 1 August to 50% of bud break. The number of breba fruit decreased linearly from the earliest to the latest application dates (Table 12). There was linear interaction between the RBA’s and application date, in both breba fruit diameter ($p=0.0908$) and breba fruit weight ($p=0.0242$). Lift® decreased diameter and fruit weight relative to Dormex®, and the average fruit weight tended to be higher ($p=0.0512$) in control as compared to treated trees. RBA’s shortened the number of days from 1 December to the date on which 50% of breba fruit were harvested, relative to the control. The earliest application dates of both Dormex® and Lift® were most effective, since the number of days to when 50 % of fruit had been harvest increased linearly

with later application dates (Table 12). RBA's had no significant effect on scheduling the harvest of main crop fruit (data not shown).

Discussion

Experiment 1

The difference between initial- and final bud break during the 2007/2008 season in 'Bourjasotte Noire' and 'Col de Damme Noire' especially following Lift® application is due to a relatively high number of buds aborting. The reason for this could be the re-instatement of apical dominance or the trees' inability to supply all of these buds with metabolites (Abbot, 1986). During the second season in 'Bourjasotte Noire', despite this reduction in the number of buds breaking (between initial and final bud break), the final number of buds breaking following Lift® application remained highest. The N shoots used in the second season in 'Bourjasotte Noire' and 'Col de Damme Noire' were shorter than those used in the first season (Table 1) possibly due to increased tree complexity between the two seasons (Borchert, 1976). It is possible that it was easier for the tree to supply metabolites to maintain increased bud break on the shorter shoots in 'Bourjasotte Noire' or the difference might be due to varying climatic conditions. Tip pruning also had a significant negative effect on yield in the second season on these shorter shoots when compared to the first season as was seen in the phenology trials (Papers 1) and pruning trials (Paper 2).

In the second season, tip-pruning decreased the number of initial and final buds breaking in 'Bourjasotte Noire', possibly due to the removal of distally concentrated buds (Paper 2). It is also known that after pruning, fewer shoots that are more vigorous develop (Wertheim, 2005; Paper 2). The fact that there was no significant difference in the final number of buds breaking as a result of pruning in the first season might be due to the shoots being longer with more internodes as compared to the second season, or it may have been caused by climatic conditions. In the second season, Dormex® and oil combined decreased bud break, thereby increasing the average shoot length which led to a higher number of fruit per N+1 shoot as compared to the other treatments.

In ‘Noire de Caromb’, the combination of Dormex® and oil, but also oil on its own was the most effective in increasing bud break when combined with no-pruning, contrary to the other cultivars where Lift® was more effective.

Experiment 2

In ‘Bourjasotte Noire’, the use of RBA’s caused a reduction in fruit size relative to the control. RBA’s seemed to be effective in increasing bud break relative to the control, but the application date did not have a significant effect. Even though the treatments effectively decreased the number of days from 1 August to 25%, 50% and 75% of total bud break there was no significant harvest scheduling effect.

In ‘Col de Damme Noire’, the first application date for Dormex® and dates one and two for Lift® decreased the number of days to 50% bud break, however there was no significant harvest scheduling effect.

In ‘Noire de Caromb’, the RBA’s caused an increase in the number of shoots per N shoot relative to the control. Earlier application dates were more effective. The average N+1 shoot length was shorter compared to the control. Lift® decreased fruit size relative to Dormex®. Dormex® was also more effective in increasing the amount of new growth as well as the number of fruit per N+1 shoot relative to Lift® and the control. Earlier application dates of both Lift® and Dormex® led to a reduction in the number of days from 1 August to 50% bud break. The number of days from 1 December to 50% harvest of breba fruit was decreased by application dates one and two in the case of Dormex® and date one for Lift®.

These results are in agreement with the findings of Shulman et al. (1986) and Yablowitz et al. (1998) that early application of HC caused earlier bud break and harvest of the breba crop, while also increasing the number of breba figs. Steffens and Stutte (1989) found that early application of TDZ caused early bud break relative to the control (on excised apple shoots), as was the case here on fig.

Conclusions

Lift® can be used to increase the number of buds breaking in ‘Bourjasotte Noire’, while tip pruning decreased bud break with a resultant increase in shoot length. Dormex® and oil combined decreased bud break, leading to an increase in N+1 shoot length. Lift® applied on 3 August and 15 August and Dormex® applied on 30 June can be used to shorten the number of days from 1 August to 25%, 50% and 75% bud break in ‘Bourjasotte Noire’. In ‘Col de Damme Noire’, none of the RBA’s were effective in increasing bud break, while tip-pruning increased the total amount of new growth and average N+1 shoot length although reducing yield. Dormex® applied on 30 June and Lift® applied on 3 August can be used to decrease the number of days to 50% bud break in ‘Col de Damme Noire’. Dormex® and oil and oil alone, both treatments combined with no pruning, increased bud break in ‘Noire de Caromb’. Dormex® and oil increased the number of N+1 shoots longer than 5 cm. Tip-pruning caused a reduction in the amount of new growth and yield in ‘Noire de Caromb’. Both Lift® and Dormex® applied on 30 June decreased the number of days to 50% bud break leading to a reduction in the number of days to 50% harvest of the breba crop. These treatments also increased the number of fruit in both the breba and main crop of ‘Noire de Caromb’, but decreased fruit size of the breba crop.

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Table 1: Average length of the selected treatment shoots in Experiment 1 for 'Bourjasotte Noire', 'Col de Damme Noire' and 'Noire de Caromb' in the Breede River valley (2007-2009).

Treatment	'Bourjasotte Noire'		'Col de Damme Noire'		'Noire de Caromb'	
	2007/2008	2008/2009	2007/2008	2008/2009	2008/2009	
	(cm)	(cm)	(cm)	(cm)	(cm)	
Control	65.9 ± 3.8	59.1 ± 2.9	112.3 ± 6.1	64.4 ± 1.8	65.2 ± 4.0	
Dormex [®] (4%)	60.7 ± 8.8	48.5 ± 4.3	114.7 ± 5.9	63.7 ± 4.8	61.8 ± 3.0	
Dormex [®] (2%) & Oil (2%)	53.0 ± 4.3	49.0 ± 3.6	111.4 ± 6.0	64.9 ± 4.4	60.9 ± 4.6	
Oil (4%)	58.5 ± 5.3	49.1 ± 3.5	114.5 ± 3.8	65.9 ± 3.7	62.5 ± 3.1	
Lift [®] (6%)	57.4 ± 5.1	47.6 ± 4.6	112.0 ± 4.7	61.5 ± 3.2	61.1 ± 3.5	

Table 2: Average length of the selected treatment shoots in Experiment 2 for 'Bourjasotte Noire', 'Col de Damme Noire' and 'Noire de Caromb' in the Breede River valley (2007-2009).

Treatment	'Bourjasotte Noire'		'Col de Damme Noire'		'Noire de Caromb'	
	2008/2009		2008/2009		2008/2009	
	(cm)		(cm)		(cm)	
Untreated control	55.5	± 5.0	58.1	± 6.4	71.4	± 4.9
3% Dormex – 30 June	44.2	± 2.3	49.9	± 3.6	76.2	± 3.9
3% Dormex – 03 Aug	45.9	± 2.5	49.2	± 3.8	78.8	± 3.7
3% Dormex – 15 August	49.3	± 2.3	55.4	± 2.8	70.9	± 4.4
3% Dormex – 30 August	43.7	± 1.9	60.3	± 6.0	72.6	± 4.4
6% Lift – 30 June	68.7	± 4.3	57.4	± 6.2	78.4	± 4.6
6% Lift – 03 Aug	54.5	± 5.7	65.4	± 5.3	70.2	± 2.5
6% Lift – 15 August	54.4	± 7.0	51.0	± 2.8	70.8	± 5.5
6% Lift – 30 August	45.4	± 3.7	55.4	± 2.6	69.6	± 4.4

Table 3: The effect of RBA's in combination with tip-pruning on bud break, new growth and yield on three-year-old 'Bourjasotte Noire' trees in the Breede River valley (2007-2008). Means were separated by LSD (5%).

Treatment	Bud break ^Y per N shoot		Avg N+1 shoot length	New growth	N+1 shoots > 5 cm	Total fruit per N shoot	Total fruit per N+1 shoot	Fruit maturity (Avg. Fruit Ø) (mm)
	Initial	Final	(cm)	(cm)				
<u>Rest break</u>								
Control	12 b ^z	9 ^{NS}	19 ^{NS}	156 ^{NS}	7.8 ^{NS}	15 ^{NS}	1.8 ^{NS}	35 ^{NS}
Dormex [®] (4%)	11 b	8	19	156	7.3	14	1.9	37
Dormex [®] (2%) & Oil (2%)	9 c	8	19	140	6.6	14	1.8	36
Oil (4%)	9 c	7	19	137	6.3	13	1.9	35
Lift [®] (6%)	17 a	9	18	158	7.6	13	1.5	35
<u>Pruning</u>								
Tip	10 b	8 ^{NS}	20 a	155 ^{NS}	6.9 ^{NS}	13 ^{NS}	1.8 ^{NS}	36 ^{NS}
No-Tip	12 a	8	17 b	143	7.3	14	1.8	35
Pr > F								
Rest break	0.0022	0.6731	0.9728	0.9131	0.5988	0.9646	0.7167	0.5897
Pruning	0.0173	0.6927	0.0004	0.0829	0.4706	0.5650	0.9725	0.0686
Rest break x Pruning	0.2782	0.2550	0.1892	0.1558	0.3410	0.8328	0.8320	0.4031

^Y initial bud break counted 27/09/07, final bud break counted 08/02/08

^z categories with different letters differ significantly at p < 0.05

^{NS} no significant differences between treatments

Table 4: The effect of RBA's in combination with tip-pruning on bud break, new growth and yield on four-year-old 'Bourjasotte Noire' trees in the Breede River valley (2008-2009). Means were separated by LSD (5%).

Treatment	Bud break ^Y per N shoot		Avg N+1 shoot length (cm)	New growth (cm)	N+1 shoots > 5 cm	Total fruit per N shoot	Total fruit per N+1 shoot	Fruit maturity (Avg. Fruit Ø) (mm)
	Initial	Final						
<u>Rest break</u>								
Control	6.8 b ^z	6.3 b	14 ab	90 ^{NS}	4.6 ^{NS}	10 ^{NS}	1.5 b	33 ^{NS}
Dormex [®] (4%)	6.6 b	5.8 b	13 bc	80	3.9	9	1.6 b	33
Dormex [®] (2%) & Oil (2%)	4.4 c	4.1 c	17 a	70	3.4	9	2.2 a	34
Oil (4%)	5.7 b	5.6 b	14 bc	70	4.1	9	1.6 b	34
Lift [®] (6%)	10.0 a	7.4 a	11 c	70	3.7	8	1.2 b	33
<u>Pruning</u>								
Tip	5.7 b	5.2 b	15 a	80 ^{NS}	3.7 ^{NS}	8 b	1.6 ^{NS}	33 ^{NS}
No-Tip	7.5 a	6.5 a	12 b	80	4.1	10 a	1.7	33
<u>Pr > F</u>								
<i>Rest break</i>	<i>0.0002</i>	<i>0.0053</i>	<i>0.0116</i>	<i>0.3825</i>	<i>0.0735</i>	<i>0.8614</i>	<i>0.0543</i>	<i>0.7579</i>
<i>Pruning</i>	<i>0.0001</i>	<i>0.0011</i>	<i>0.0011</i>	<i>0.6209</i>	<i>0.1590</i>	<i>0.0377</i>	<i>0.6419</i>	<i>0.9169</i>
<i>Rest break x Pruning</i>	<i>0.0955</i>	<i>0.1948</i>	<i>0.2230</i>	<i>0.5064</i>	<i>0.5174</i>	<i>0.8549</i>	<i>0.9902</i>	<i>0.9068</i>

^Y initial bud break counted 26/09/08, final bud break counted 06/02/09

^z categories with different letters differ significantly at p < 0.05

^{NS} no significant differences between treatments

Table 5: The effect of RBA's in combination with tip-pruning on bud break, new growth and yield on three-year-old 'Col de Damme Noire' trees in the Breede River valley (2007-2008). Means were separated by LSD (5%).

Treatment	Bud break ^Y per N shoot		Avg N+1 shoot length (cm)	New growth (cm)	N+1 shoots > 5 cm	Total fruit per N shoot	Total fruit per N+1 shoot	Fruit maturity (Avg. Fruit Ø) (mm)
	Initial	Final						
<u>Rest break</u>								
Control	12 bc ^z	10.7 ^{NS}	28 bc	274 ^{NS}	9 ^{NS}	6.8 ^{NS}	0.8 ^{NS}	27.5 ^{NS}
Dormex [®] (4%)	13 b	11.2	29 ab	315	10	8.0	0.8	26.2
Dormex [®] (2%) & Oil (2%)	11 c	9.9	32 a	295	8	6.7	0.9	28.3
Oil (4%)	13 bc	11.8	27 bc	306	10	6.9	0.6	28.1
Lift [®] (6%)	17 a	11.7	24 c	272	8	6.1	0.6	27.2
<u>Pruning</u>								
Tip	14 ^{NS}	11.4 ^{NS}	29 a	316 a	9 ^{NS}	6.8 ^{NS}	0.7 ^{NS}	26.8 b
No-Tip	13	10.7	27 b	269 b	8	7.0	0.8	28.1 a
Pr > F								
<i>Rest break</i>	<i><0.0001</i>	<i>0.1498</i>	<i>0.0162</i>	<i>0.4512</i>	<i>0.1236</i>	<i>0.8410</i>	<i>0.3616</i>	<i>0.2355</i>
<i>Pruning</i>	<i>0.1442</i>	<i>0.2417</i>	<i>0.0496</i>	<i>0.0009</i>	<i>0.0687</i>	<i>0.6840</i>	<i>0.2653</i>	<i>0.0260</i>
<i>Rest break x Pruning</i>	<i>0.9447</i>	<i>0.8675</i>	<i>0.3458</i>	<i>0.3090</i>	<i>0.9878</i>	<i>0.2263</i>	<i>0.4694</i>	<i>0.3670</i>

^Y initial bud break counted 27/09/07, final bud break counted 08/02/08

^z categories with different letters differ significantly at p < 0.05

^{NS} no significant differences between treatments

Table 6: The effect of RBA's in combination with tip-pruning on bud break, new growth and yield on four-year-old 'Col de Damme Noire' trees in the Breede River valley (2008-2009). Means were separated by LSD (5%).

Treatment	Bud break ^Y per N shoot		Avg N+1 shoot length (cm)	New growth (cm)	N+1 shoots > 5 cm	Total fruit per N shoot	Total fruit per N+1 shoot	Fruit maturity (Avg. Fruit Ø) (mm)
	Initial	Final						
<u>Rest break</u>								
Control	5.4 ^{NS}	4.8 ^{NS}	33 ^{NS}	150 ^{NS}	3.92 ^{NS}	11 ^{NS}	2.3 ^{NS}	27.0 ^{NS}
Dormex [®] (4%)	5.5	5.2	24	125	4.03	7	1.4	26.5
Dormex [®] (2%) & Oil (2%)	6.0	5.2	25	129	4.19	9	1.8	26.8
Oil (4%)	6.7	5.7	28	150	4.40	8	1.5	26.8
Lift [®] (6%)	5.9	4.6	25	117	3.64	7	1.5	26.8
<u>Pruning</u>								
Tip	5.5 b ^z	4.8 ^{NS}	30 a	144 a	3.94 ^{NS}	7 b	1.4 b	26.2 b
No-Tip	6.3 a	5.3	23 b	123 b	4.10	10 a	2.0 a	27.4 a
Pr > F								
<i>Rest break</i>	<i>0.2529</i>	<i>0.1868</i>	<i>0.1452</i>	<i>0.4087</i>	<i>0.3378</i>	<i>0.2184</i>	<i>0.0707</i>	<i>0.9412</i>
<i>Pruning</i>	<i>0.0214</i>	<i>0.0909</i>	<i>0.0004</i>	<i>0.0402</i>	<i>0.5691</i>	<i>0.0002</i>	<i>0.0035</i>	<i>0.0016</i>
<i>Rest break x Pruning</i>	<i>0.8976</i>	<i>0.9844</i>	<i>0.9634</i>	<i>0.8076</i>	<i>0.8644</i>	<i>0.3792</i>	<i>0.6160</i>	<i>0.4372</i>

^Y initial bud break counted 26/09/08, final bud break counted 06/02/09

^z categories with different letters differ significantly at p < 0.05

^{NS} no significant differences between treatments

Table 7: The effect of RBA's in combination with tip-pruning on bud break, number of shoots longer than 5 cm and fruit maturity on four-year-old 'Noire de Caromb' trees in the Breede River valley (2008-2009). Means were separated by LSD (5%).

Treatment	Bud break ^Y per N shoot		N+1 shoots > 5 cm	Fruit maturity (Avg. Fruit Ø) (mm)
	Initial	Final		
Control & tip	6.0 bcde ^z	5.2 c	4.2 bcde	25.0 b
Control & no-tip	5.8 cde	5.3 c	4.7 bcd	26.1 ab
Dormex [®] (4%) & tip	6.1 bcde	5.6 bc	4.0 de	26.4 a
Dormex [®] (4%) & no-tip	5.7 de	5.2 c	4.6 bcde	26.9 a
Dormex [®] (2%), Oil (2%) & tip	5.4 e	5.0 c	4.1 cde	26.4 ab
Dormex [®] (2%), Oil (2%) & no-tip	7.3 a	7.0 a	6.3 a	26.8 a
Oil (4%) & tip	6.0 bcde	5.6 bc	4.3 bcde	23.0 c
Oil (4%) & no-tip	6.6 abcd	6.2 ab	4.9 b	26.1 ab
Lift [®] (6%) & tip	6.9 ab	5.2 c	4.0 e	23.1 c
Lift [®] (6%) & no-tip	6.7 abc	5.4 bc	4.8 bc	27.0 a
Pr > F				
<i>Initial shoot length</i>	<i><0.0001</i>	<i><0.0001</i>	<i><0.0001</i>	<i>0.0424</i>
<i>Rest break</i>	<i>0.0603</i>	<i>0.0383</i>	<i>0.0290</i>	<i>0.0277</i>
<i>Pruning</i>	<i>0.1594</i>	<i>0.0301</i>	<i><0.0001</i>	<i><0.0001</i>
<i>Rest break x Pruning</i>	<i>0.0150</i>	<i>0.0082</i>	<i>0.0096</i>	<i>0.0117</i>

^Y initial bud break counted 26/09/08, final bud break counted 06/02/09

^z categories with different letters differ significantly at p < 0.05

Table 8: The effect of RBA's in combination with tip-pruning on new growth and yield on four-year-old 'Noire de Caromb' trees in the Breede River valley (2008-2009). Means were separated by LSD (5%).

Treatment	Avg N+1 shoot length (cm)	New growth (cm)	Total fruit per N shoot	Total fruit per N+1 shoot
<u>Rest break</u>				
Control	19.8 ^{NS}	106 ^{NS}	3.8 ^{NS}	0.7 ^{NS}
Dormex [®] (4%)	20.8	113	4.2	0.8
Dormex [®] (2%) & Oil (2%)	20.4	124	5.8	0.9
Oil (4%)	17.4	105	3.9	0.7
Lift [®] (6%)	19.6	105	3.6	0.7
<u>Pruning</u>				
Tip	19.0 ^{NS}	104 b ^z	2.9 b	5.6 b
No-Tip	20.2	117 a	5.6 a	9.6 a
<u>Pr > F</u>				
Initial shoot length	<0.0001	<0.0001	0.9060	0.1158
Rest break	0.2897	0.1210	0.1827	0.5572
Pruning	0.1272	0.0205	<0.0001	<0.0001
Rest break x Pruning	0.3159	0.5776	0.4638	0.5885

^z categories with different letters differ significantly at p < 0.05

^{NS} no significant differences between treatments

Table 9: Effect of rest breaking agents on bud break, new growth, average shoot length, yield and fruit size in 'Bourjasotte Noire' trees in the Breede River valley (2008-2009).

Treatment	Bud break per N shoot ^Y		New growth (cm)	Avg N+1 shoot length (cm)	Total fruit per N shoot	Total fruit per N+1 shoot	Avg fruit mass (g)	Avg fruit Ø (mm)
	Initial	Final						
Control	5.7	5.2	76	15	8.2	1.7	42	44
Dormex®	7.2	5.8	85	15	9.9	1.8	37	42
Lift®	9.5	6.3	76	12	8.6	1.4	37	42
Date: 30-Jun	8.2	6.0	88	14	9.9	1.7	35	41
03-Aug	7.7	5.5	78	14	10.2	1.9	38	43
15-Aug	8.7	6.4	82	12	8.9	1.4	37	42
30-Aug	8.9	6.3	74	12	7.9	1.3	37	42
Pr > F								
One-year-old shoot length	<0.0001	<0.0001	<0.0001	<0.0001	0.0091	0.3425	0.8708	0.9984
Treatment	<0.0001	0.1524	0.4911	0.0078	0.2125	0.0899	0.2478	0.3654
Control vs Treatment	0.0001	0.0991	0.6416	0.1521	0.4164	0.8155	0.0102	0.0575
Dormex vs Lift	<0.0001	0.2570	0.1428	0.0028	0.1418	0.0491	0.9403	0.8657
Date linear	0.2803	0.4070	0.1446	0.0191	0.1029	0.0761	0.3387	0.2791
Date quadratic	0.1453	0.2211	0.9906	0.3360	0.1729	0.1284	0.1975	0.5013
RBA*Date linear	0.4393	0.5588	0.7894	0.6439	0.1290	0.2537	0.6900	0.6827
RBA*Date quadratic	0.6313	0.5899	0.3798	0.4377	0.9914	0.9366	0.9025	0.7630

^Y initial bud break counted 29/09/08, final bud break counted 10/02/09

Table 10: Effect of rest breaking agents on final bud break, yield and fruit size in ‘Col de Damme Noire’ trees in the Breede River valley (2008-2009).

Treatment	Final bud break ^Y per N shoot	Total fruit per N shoot	Total fruit per N+1 shoot	Avg fruit mass (g)	Avg fruit Ø (mm)
Control	3.6	4.2	1.2	33	37
Dormex®	3.9	4.8	1.2	31	36
Lift®	3.6	4.0	1.2	30	36
Date: 30-Jun	4.3	5.0	1.2	32	37
03-Aug	3.9	3.6	1.0	30	36
15-Aug	3.2	4.6	1.4	30	35
30-Aug	3.6	4.3	1.3	30	35
Pr > F					
One-year-old shoot length	0.7180	0.1103	0.3020	0.7842	0.5676
Treatment	0.0708	0.1596	0.7432	0.8244	0.8534
Control vs Treatment	0.7183	0.8533	0.9901	0.2372	0.3634
Dormex vs Lift	0.1274	0.1879	0.9129	0.3712	0.6047
Date linear	0.0115	0.4243	0.6559	0.2122	0.1817
Date quadratic	0.4912	0.3035	0.4771	0.6937	0.8111
RBA*Date linear	0.6839	0.6504	0.7397	0.7020	0.3887
RBA*Date quadratic	0.3114	0.2821	0.5259	0.7821	0.6979

^Yfinal bud break counted 10/02/09

Table 11: Effect of rest breaking agents on bud break, average N+1 shoot length, yield per N shoot and fruit size in ‘Noire de Caromb’ trees in the Breede River valley (2008-2009).

Treatment	Bud break per N shoot ^Y		Avg N+1 shoot length (cm)	Total fruit per N shoot	Avg fruit mass (g)	Avg fruit Ø (mm)
	Initial	Final				
Control	6.4	7.2	24	4.2	27.5	33.7
Dormex®	8.8	8.8	21	6.8	28.6	34.2
Lift®	12.6	9.2	20	5.6	24.8	32.2
Date: 30-Jun	10.8	9.5	20	7.3	28.0	33.8
03-Aug	12.3	10.0	19	6.1	27.3	33.1
15-Aug	10.3	8.6	20	5.3	25.1	32.5
30-Aug	9.5	7.9	21	6.1	26.5	33.2
Pr > F						
One-year-old shoot length	0.0352	0.0019	0.0010	0.0400	0.3934	0.1507
Treatment	<0.0001	<0.0001	0.0237	0.0322	0.1786	0.1463
Control vs Treatment	0.0001	0.0002	0.0022	0.0165	0.6977	0.5733
Dormex vs Lift	<0.0001	0.2184	0.2587	0.0191	0.0089	0.0037
Date linear	0.2125	0.0004	0.4785	0.0425	0.2720	0.3182
Date quadratic	0.0230	0.0017	0.1079	0.1753	0.7498	0.4349
RBA*Date linear	0.6970	0.4486	0.1399	0.7144	0.9040	0.9885
RBA*Date quadratic	0.5234	0.5407	0.8259	0.6695	0.7042	0.4622

^Y initial bud break counted 29/09/08, final bud break counted 10/02/09

Table 12: Effect of rest breaking agents on the number of breba fruit and breba fruit size in 'Noire de Caromb' trees in the Brede River valley (2008-2009). Means were separated by LSD (5%).

Treatment	Number of breba fruit per tree	Breba fruit diameter (mm)	Breba fruit weight (g)	Days to 50 % harvest
Untreated control	5.0 b ^Z	43.3 a	56.2 a	23 a
3% Dormex – 30 June	17.5 a	40.4 ab	43.0 bc	15 cd
3% Dormex – 03 Aug	5.3 b	44.2 a	49.3 ab	19 bc
3% Dormex – 15 August	7.7 b	43.1 a	53.1 ab	22 ab
3% Dormex – 30 August	5.0 b	44.3 a	52.8 ab	23 a
6% Lift – 30 June	11.8 ab	41.9 ab	49.1 ab	14 d
6% Lift – 03 Aug	6.5 b	33.2 c	30.3 d	21 ab
6% Lift – 15 August	6.7 b	43.5 a	52.1 ab	22 ab
6% Lift – 30 August	6.2 b	37.0 bc	36.8 cd	24 a
Pr > F				
<i>Treatment</i>	0.0754	0.0058	0.0026	<0.0001
<i>Control vs Treatment</i>	0.2935	0.3685	0.0512	0.0480
<i>Dormex vs Lift</i>	0.6067	0.0070	0.0189	0.3973
<i>Date linear</i>	0.0025	0.8053	0.7503	<0.0001
<i>Date quadratic</i>	0.2242	0.6182	0.6795	0.6041
<i>Chemical*Date linear</i>	0.2535	0.0908	0.0242	0.4467
<i>Chemical*Date quadratic</i>	0.6700	0.2805	0.4376	0.3152

^Z categories with different letters differ significantly at p < 0.05

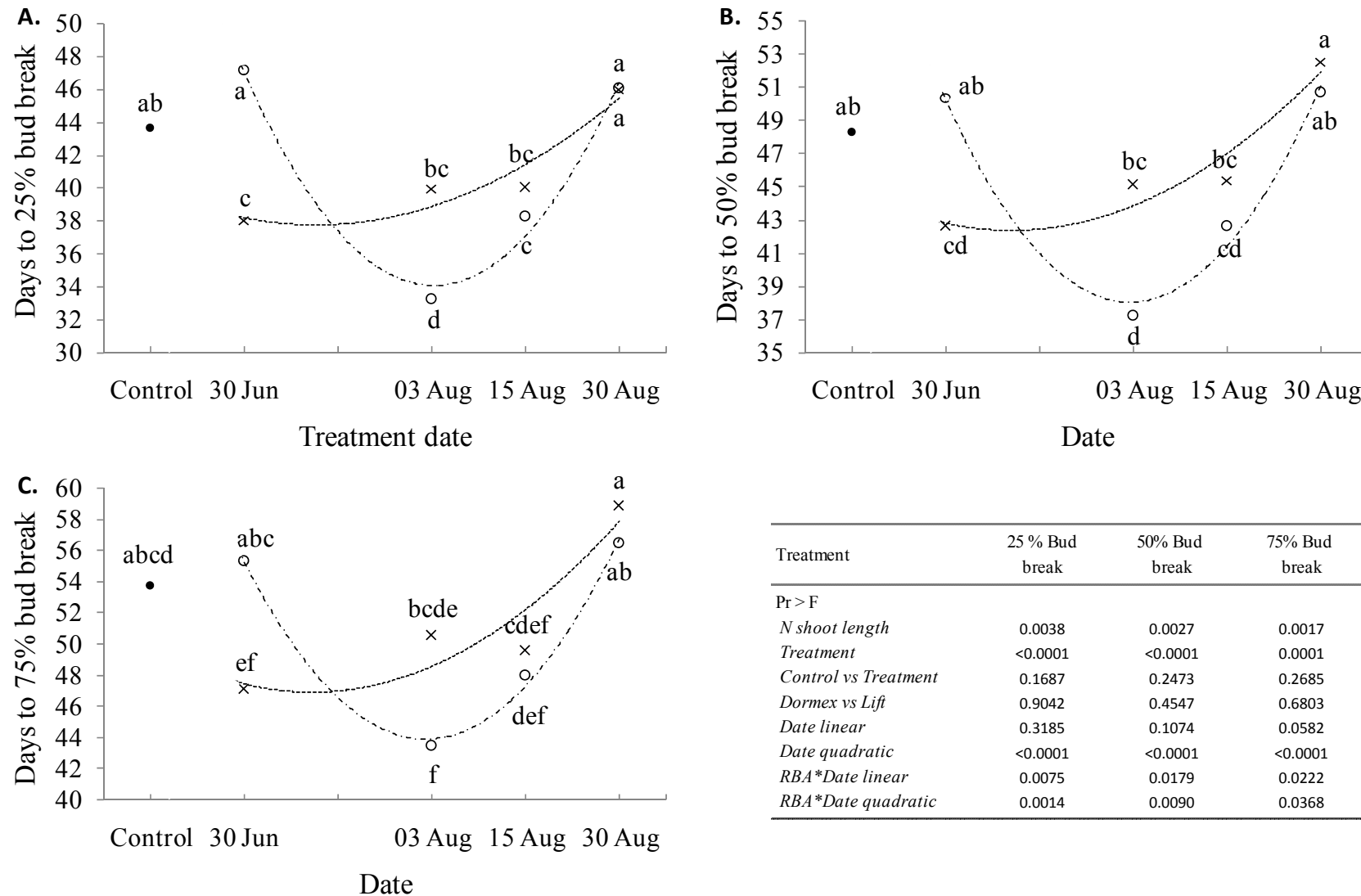


Figure 1: The effect of rest breaking agents (RBA's) on the duration of time to 25%, 50% and 75% of bud break, in 'Bourjasotte Noire'. Means were separated by LSD (5%) (RBA's: Lift® ○---○; Dormex® ×---×).

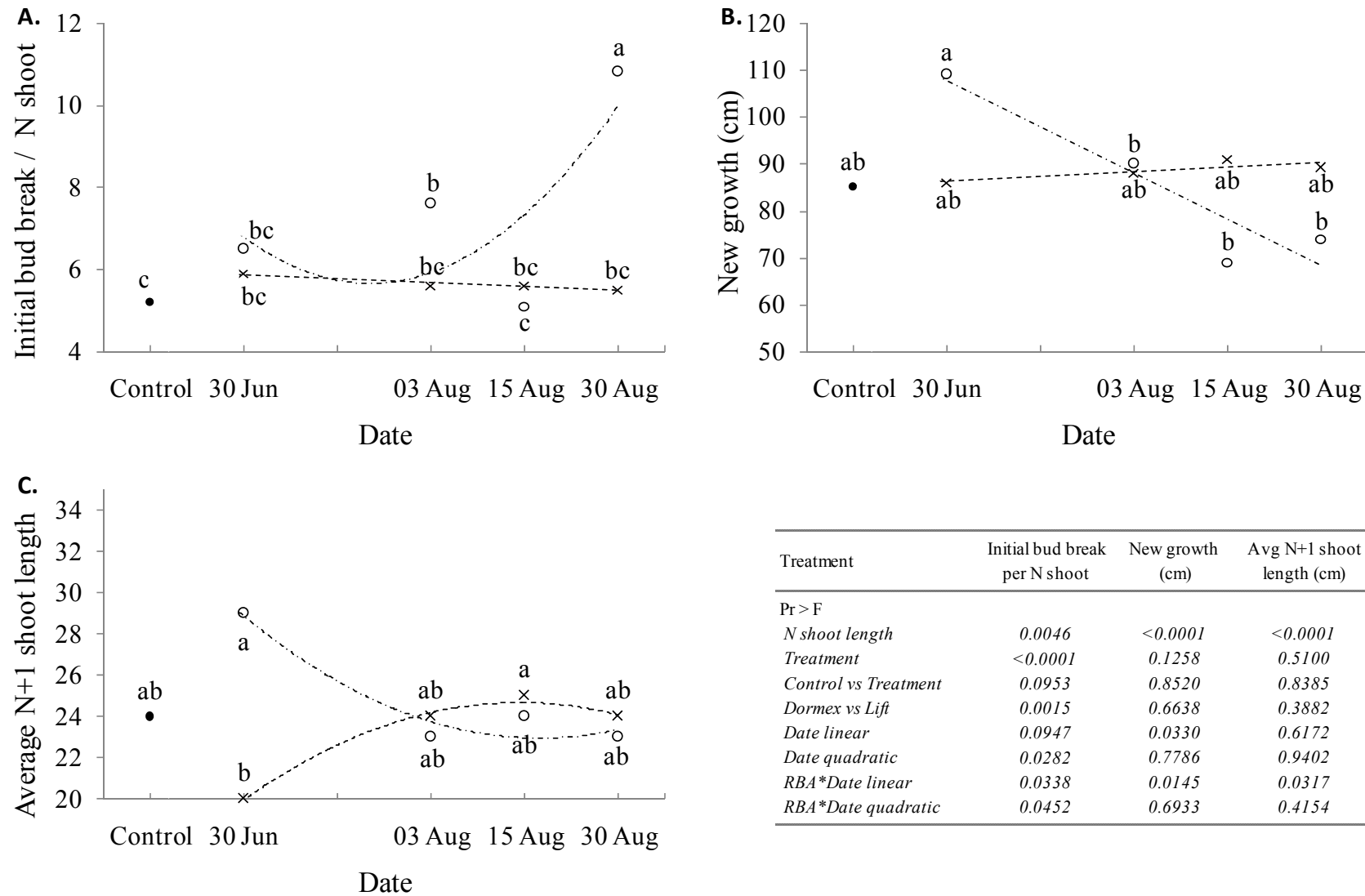
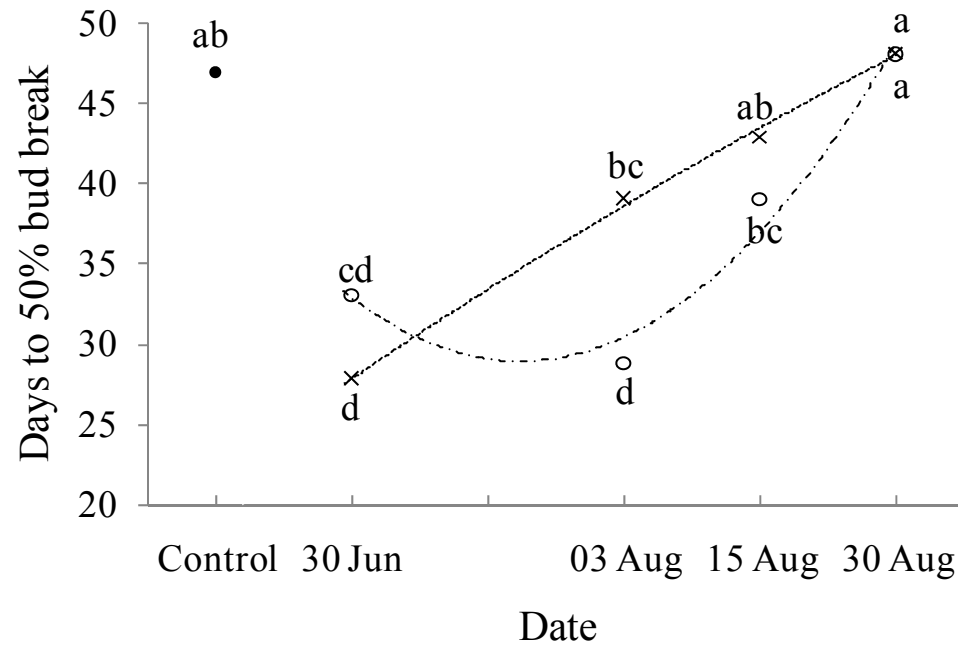


Figure 2: The effect of rest breaking agents (RBA's) on initial bud break, new growth, and average N+1 shoot length in 'Col de Damme Noire'. Means were separated by LSD (5%) (RBA's: Lift® ○---○; Dormex® ×---×) (Initial bud break was counted 29/09/08).



Treatment	50% Bud break
Pr > F	
<i>N shoot length</i>	0.2047
<i>Treatment</i>	<0.0001
<i>Control vs Treatment</i>	0.0005
<i>Dormex vs Lift</i>	0.1535
<i>Date linear</i>	<0.0001
<i>Date quadratic</i>	0.0023
<i>RBA*Date linear</i>	0.1137
<i>RBA*Date quadratic</i>	0.0030

Figure 3: The effect of rest breaking agents (RBA's) on the duration of time to 50% bud break in 'Col de Damme Noire'. Means were separated by LSD (5%) (RBA's: Lift® ○---○; Dormex® ×---×).

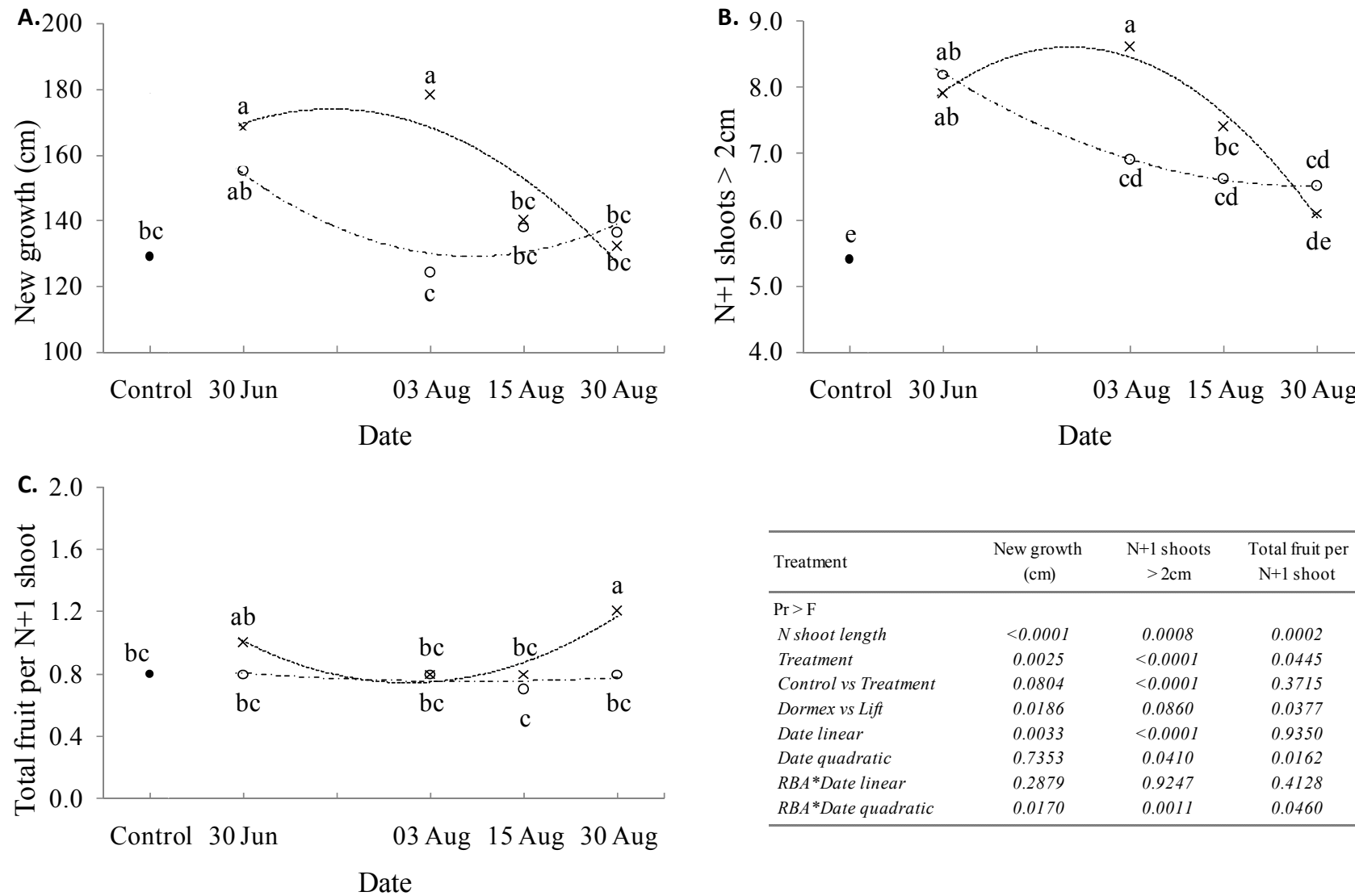
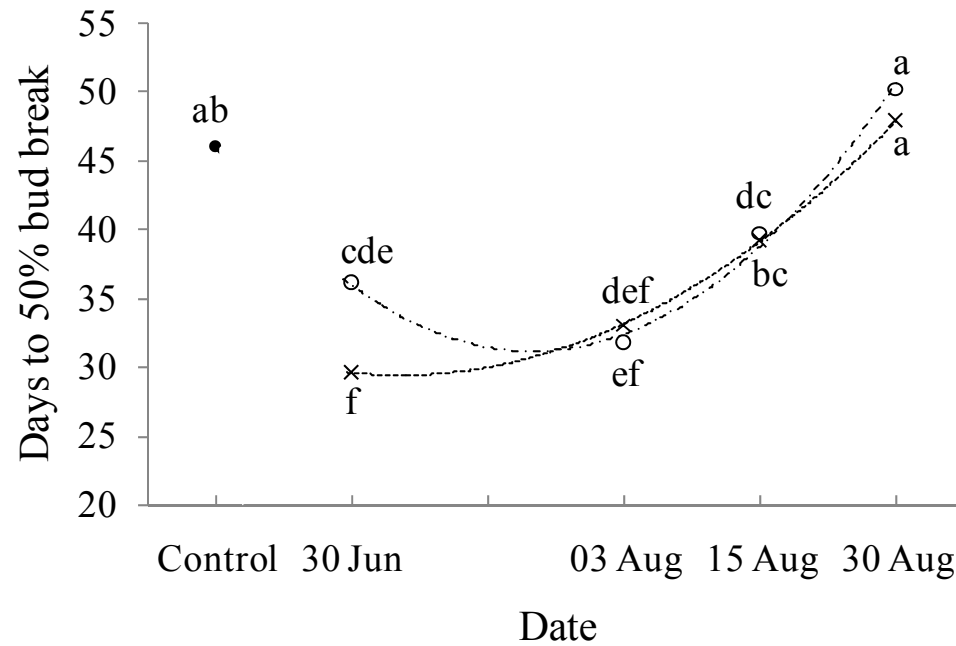


Figure 4: The effect of rest breaking agents (RBA's) on new growth, shoots longer than 2cm and number of main crop fruit per N+1 shoot in 'Noire de Caromb'. Means were separated by LSD (5%) (RBA's: Lift® ○---○; Dormex® ×---×).



Treatment	50% Bud break
Pr > F	
<i>N</i> shoot length	0.5159
Treatment	<0.0001
Control vs Treatment	0.0027
Dormex vs Lift	0.2035
Date linear	<0.0001
Date quadratic	<0.0001
RBA*Date linear	0.2713
RBA*Date quadratic	0.1629

Figure 5: The effect of rest breaking agents (RBA's) on the duration of time to 50% bud break in 'Noire de Caromb' trees in the Breede River valley (2008-2009). Means were separated by LSD (5%) (RBA's: Lift® ○---○; Dormex® ×---×).

GENERAL DISCUSSION AND OVERALL CONCLUSIONS

An understanding of the phenology of ‘Bourjasotte Noire’, ‘Col de Damme Noire’ and ‘Noire de Caromb’ figs under South African conditions is essential to optimise yield of quality fruit. This knowledge is also required for effective tree training and the development of pruning strategies. Apart from selecting the optimal one-year-old shoot (N shoot) lengths for yield in the current season, their productivity during the following season should also be considered, in order to maintain regular high yields of quality fruit. According to our data, in ‘Bourjasotte Noire’, all one-year-old shoots longer than 10 cm are suited for reproduction and should also produce a fair yield the following season. In ‘Col de Damme Noire’, one-year-old shoots longer than 60 cm seem to be the best for reproduction. However, yield on these shoots may not be optimal the following season, due to the fact that current season shoots are too short. In ‘Noire de Caromb’, all shoots longer than 10 cm are suited for reproduction, although shoots longer than 100 cm were less productive, but produced a high number of current season shoots suitable for reproduction the following season.

In order to prune the trees effectively, the effect of different intensity heading cuts and different application dates of the same heading cuts were evaluated. Growth of shoots of the lengths identified in the phenological study need to be stimulated or maintained, while also pruning in a way that restricts the tree to its allotted space without a negative effect on yield. In ‘Bourjasotte Noire’, removal of one third of one-year-old shoots by heading on 9 August should ensure the development of fair length shoots for sustainable production, without a negative effect on yield, while pruning on 21 July produces longer shoots with a slight negative effect on yield. In ‘Col de Damme Noire’, one-year-old shoots can be headed back to three buds to produce current season shoots longer than 60 cm, which is the optimal length for reproduction in this cultivar. Removal of one third of one-year-old shoots of ‘Col de Damme Noire’ on 30 June, 21 July, or 11 August can be used to produce long (40 cm and longer) current season shoots that should yield more and larger fruit per N shoot (but fewer per tree) in comparison to the control. These same pruning dates, but especially 30 June, should produce longer current season shoots in combination with heading N shoots back to three nodes.

‘Bourjasotte Noire’, ‘Col de Damme Noire’ and ‘Noire de Caromb’ display strong apical dominance, leading to a distal branching growth habit with a subsequent production of “blind wood” (Oosthuyse et al., 1992). The main crop of these cultivars have an extended, labour intensive harvest period. The plant growth regulators, hydrogen cyanimide and thidiazuron, has been used to induce early, increased bud break in fig and apple respectively (Shulman et al. 1986; Steffens & Stutte, 1989; Yablowitz et al. 1998). According to our data from experiments where rest breaking agents were applied at different times or in combination with tip-pruning, Lift® can be used to increase bud break in ‘Bourjasotte Noire’. Lift® applied 3 August and 15 August and Dormex® applied 30 June shortens the number of days to bud break in ‘Bourjasotte Noire’. Dormex® applied 3 August and 15 August and Lift® applied 30 June decreases the number of days to 50% bud break in ‘Col de Damme Noire’. Dormex® and oil and oil alone increases bud break in ‘Noire de Caromb’. Both Lift® and Dormex® applied 30 June decreases the number of days to 50% bud break leading to a reduction in the number of days to 50% harvest of the breba crop in ‘Noire de Caromb’. These treatment dates also increase the number of fruit in both the breba and main crop of ‘Noire de Caromb’, but decrease fruit size of the breba crop.

This study increased our insight into the vegetative and reproductive phenology of ‘Bourjasotte Noire’, ‘Col de Damme Noire’ and ‘Noire de Caromb’, helping to identify the optimal length of fruit bearing shoots in each cultivar, which enabled us to establish suitable pruning strategies to produce these shoots. Our results from the use of RBA’s confirm previous results (Shulman et al. 1986; Steffens & Stutte, 1989; Yablowitz et al. 1998) that early bud break and early harvest of breba fruit can be induced by using rest breaking agents in fig. A further evaluation of pruning strategies, especially the use of thinning cuts, should help to refine pruning strategies in order to reduce negative effects on yield.

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APPENDIX

Preliminary trials on fruit peel cracking in fig

Materials and methods

Two experiments were conducted on ‘Bourjasotte Noire’, ‘Col de Damme Noire’ and ‘Noire de Caromb’ during the 2008/2009 growing season in a commercial orchard in the Breede River valley. Trees were planted on own roots during 2005. For a complete description of the site, see Paper 1.

Treatments and trial design:

Experiment 1 comprised four treatments (in a randomized complete block design) replicated ten times, viz., an untreated control, 1% CaCl_2 (Stopit®), 1% $\text{Ca}(\text{NO}_3)_2$ (granular) and 1% KCl (granular). All applications were made to the whole tree during growth phase two of the fruit (fruit 2.5 – 3 cm diameter), using a motorised knapsack sprayer. A wetting agent, Bladwet® (5ml per 15L), was used to improve chemical uptake.

Experiment two comprised seven treatments replicated six times in a randomized complete block design. Treatments consisted of an unsprayed control and 25, 50 or 100 mg.l^{-1} GA_3 (granular ProGibb®) applied during growth phase one (fruit 2 cm diameter) or two (fruit 2.5 – 3 cm diameter), respectively.

Data collection

In both experiments, mature fruit were picked every five days over a period of six weeks and were scored according to the amount of visible cracking from 1 to 5, where fruit receiving a score higher than two was deemed unacceptable (Figure 1).

Data analysis:

Treatments were compared by analysis of variance using the general linear models procedure of SAS version 9.1.3 SP2 (SAS Institute, Cary, N.C., 2004).

Table 1: Effect of nutrient applications on the incidence of fruit peel cracking in 'Bourjasotte Noire', 'Col de Damme Noire' and 'Noire de Caromb' figs in the Breede River valley (2008-2009). Means were separated by LSD (5%).

Treatment	Percentage unacceptable fruit		
	'Bourjasotte Noire'	'Col de Damme Noire'	'Noire de Caromb'
Control	30.54 ^{NS}	49.72 ^{NS}	17.92 b ^Z
1% CaCl ₂	37.24	46.75	23.89 b
1% Ca(NO ₃) ₂	33.59	50.28	35.37 a
1% KCl	32.62	48.20	21.78 b
Pr > F			
Treatment	0.6972	0.9195	0.0002

^Z categories with different letters differ significantly at p < 0.05

^{NS} no significant differences between treatments

Table 2: Effect of nutrient applications on fruit size in 'Bourjasotte Noire', 'Col de Damme Noire' and 'Noire de Caromb' figs in the Breede River valley (2008-2009). Means were separated by LSD (5%).

Treatment	Average fruit mass		
	'Bourjasotte Noire'	'Col de Damme Noire'	'Noire de Caromb'
Control	44.16 ^{NS}	36.27 ab ^Z	32.72 ^{NS}
1% CaCl ₂	44.72	36.79 ab	32.75
1% Ca(NO ₃) ₂	43.51	38.13 a	33.57
1% KCl	43.62	33.83 b	33.17
Pr > F			
Treatment	0.9556	0.1638	0.9132

^Z categories with different letters differ significantly at p < 0.05

^{NS} no significant differences between treatments

Table 3: Effect of GA₃ on the incidence of fruit peel cracking in 'Bourjasotte Noire', 'Col de Damme Noire' and 'Noire de Caromb' figs in the Breede River valley (2008-2009). Means were separated by LSD (5%).

Treatment	Percentage unacceptable fruit		
	'Bourjasotte Noire'	'Col de Damme Noire'	'Noire de Caromb'
Control	7.50 c ^Z	37.6 ^{NS}	24.4 a
GA ₃ 25 ppm phase 1	29.50 a	37.14	20.00 ab
GA ₃ 50 ppm phase 1	14.00 bc	20.90	12.20 bc
GA ₃ 100 ppm phase 1	4.50 c	25.50	8.50 c
GA ₃ 25 ppm phase 2	27.80 a	27.98	12.90 bc
GA ₃ 50 ppm phase 2	24.80 ab	31.77	10.30 bc
GA ₃ 100 ppm phase 2	5.7 c	37.65	4.30 c
Pr > F			
<i>Treatment</i>	0.0003	0.5950	0.0093

^Z categories with different letters differ significantly at p < 0.05

^{NS} no significant differences between treatments

Table 4: Effect GA₃ on fruit size in 'Bourjasotte Noire', 'Col de Damme Noire' and 'Noire de Caromb' figs in the Breede River valley (2008-2009). Means were separated by LSD (5%).

Treatment	Average fruit mass		
	'Bourjasotte Noire'	'Col de Damme Noire'	'Noire de Caromb'
Control	41.3 a ^Z	34.7 a	36.5 ^{NS}
GA ₃ 25 ppm phase 1	36.20 ab	30.80 ab	34.80
GA ₃ 50 ppm phase 1	34.20 b	26.70 bc	31.40
GA ₃ 100 ppm phase 1	26.50 c	24.65 c	30.60
GA ₃ 25 ppm phase 2	39.60 ab	33.67 a	35.00
GA ₃ 50 ppm phase 2	38.90 ab	30.18 ab	32.00
GA ₃ 100 ppm phase 2	25.40 c	30.82 ab	29.20
Pr > F			
<i>Treatment</i>	<0.0001	0.0066	0.0645

^Z categories with different letters differ significantly at p < 0.05

^{NS} no significant differences between treatments

A.**B.****C.****D.**

Figure 1: Examples of fruit used for scoring, where A – D represents 2 – 5 respectively.