ADVANCING FULL PRODUCTION AND INCREASING YIELD IN YOUNG ‘TRIUMPH’ PERSIMMON ORCHARDS

By

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DECLARATION

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SUMMARY

Persimmon production is new to South Africa with about 700 ha planted to the dioecious, parthenocarpic Triumph cultivar since 1998. Little local expertise is available to assist growers in achieving high yields of high quality fruit and previous research has shown that recipes that are followed in Israel, from where 'Triumph' was introduced to South Africa, do not necessarily have any beneficial effect in South Africa.

'Triumph' orchards in South Africa are often late in reaching full production. Persimmon trees are generally vigorous and prone to excessive fruit drop, partly due to excessive vegetative growth, especially when young and grown on the very vigorous *Diospyros lotus* seedling rootstock. The first objective of this study was to evaluate the use of growth retardants and various severities of girdling to increase flower formation, fruit set and yield in vigorous, young 'Triumph' orchards. Scoring and girdling improved fruit set and yield in two such orchards and are recommended as tools to improve yield in 'Triumph' in South Africa. Strapping, prohexadione-Ca (P-Ca) and paclobutrazol (PBZ) did not increase yield whereas 5 mm bark removal was too severe a treatment and decreased fruit quality in the current season and yield in the following season. None of the treatments had an effect on flower formation or decreased vegetative growth. PBZ, especially as foliar spray, appears to advance fruit maturity. P-Ca at 125 mg L^{-1} and 250 mg L^{-1} induced phytotoxicity symptoms and decreased yields in both orchards. However, further research is required before P-Ca and PBZ are completely discarded as treatments to manage vigor in 'Triumph' persimmon in South Africa.

In contrast to the negative effect of excessive vigor on fruit production, the profitability of orchards is dependent on the rapid growth of trees after planting in order to fill the allotted canopy volume and achieve full production as quickly as possible. Hence, the second objective of this study was to determine optimum levels of irrigation and fertilizer application rates to attain early, high yields in newly planted 'Triumph'. Fertigation was applied at three levels, viz. ½X, 1X and 2X with 1X being the commercial standard application rate. Irrigation was also applied at these levels without addition of fertilizer. In addition, fertilizer was applied at 0X, ½X and 1X at

1X irrigation level. Tree size increased with an increase in water application rate. Yield also increased linearly with an increase in water application rate due to a linear increase in fruit size. Fertigation and ½X water as well as an increase in fertilizer application rate at 1X irrigation substantially delayed fruit ripening. Hence, careful management of fertilizer and water application rate could be used to extend the harvesting period and, therefore, the marketing window of South African ‘Triumph’. We recommend that the trial be continued for a further few seasons so that the effect of water and fertilizer application rates on fruit quality and storability can be assessed. Fruit set may also be affected as trees reach their mature size with a concomitant increase in shading.

OPSOMMING

Persimmonverbouing is ‘n nuwe bedryf in Suid-Afrika met ongeveer 700 ha van die tweeslagtige, partenokarpiese Triumph cultivar wat sedert 1998 aangeplant is. Min plaaslike kundigheid is beskikbaar om produsente van raad te bedien oor hoe om te werk te gaan om hoë opbrengste van hoë kwaliteit te verkry. Vorige navorsing het getoon dat resepte wat ‘Triumph’ van Israel na Suid-Afrika gevolg het, nie noodwendig suksesvol hier toegepas kan word nie.

‘Triumph’ boorde in Suid-Afrika neig om lank te neem alvorens hul hul maksimum produksievermoë bereik. Persimmons is oor die algemeen baie groeikragtig en geneig tot hoë vrugval, deels as gevolg van hul geil groei, en veral terwyl hulle jonk is en op die uiters groeikragtige *Diospyros lotus* saailingonderstam geënt is. Die eerste doelwit van hierdie studie was om die invloed van groei inhibeerders en verskillende grade van strafheid van ringelering op blomvorming, vrugset en oesopbrengs in jonk, sterk-groeiende ‘Triumph’ boorde te evalueer. Insnyding en ringelering met ‘n handsaag het vrugset en oeslading in twee groeikragtige boorde verbeter en word aanbeveel as geskikte ingrepe om die oeslading van ‘Triumph’ te verhoog. Draad-ringelering, en aanwending van prohexadione-Ca (P-Ca) en paclobutrazol (PBZ) het nie die opbrengs verhoog nie terwyl die verwydering van `n 5 mm strook bas té aggresief was en die vrugkwaliteit in die seisoen van toediening en opbrengs in die daaropvolgende seisoen verlaag het. Geen van die behandelings het blomvorming geaffekteer of vegetatiewe groei verminder nie. Dit wil voorkom asof PBZ, veral as blaartoediening, vrugrypwording kan versnel. Blare het tekens van fitotoksisiteit getoon na aanwending van P-Ca teen 125 mg L^{-1} en 250 mg L^{-1}. P-Ca het ook die opbrengs in beide boorde aansienlik verlaag. Verdere navorsing is egter nodig alvorens P-Ca en PBZ sondermeer verwerp word as behandelings om die groei van ‘Triumph’ te beheer.

Die winsgewendheid van boorde is afhanklik daarvan dat bome aanvanklik vinnig groei ten einde die toegekende boomryvolume so spoedig moontlik te vul en sodoende so vinnig as moontlik hul vol produksievermoë bereik. Bogenoemde is natuurlik teenstrydig met die negatiewe effek van uitermatige geil vegetatiewe groei op vrugproduksie. Die tweede doelwit van hierdie studie was dus om die optimale vlakke van besproeiing en bemesting te bepaal wat die vroeë aanvang van hoë opbrengste in nuwe 'Triumph' boorde sal verseker. Vloeibare bemesting is in kombinasie met besproeiing teen drie vlakke toegedien nl. ½X, 1X en 2X met 1X die kommersiële standaard vlak van toediening. Besproeiing is ook teen hierdie vlakke toegedien sonder dat kunsmis bygevoeg is. Addisioneel hiertoe is bemesting ook toegedien teen ½X, 1X en 2X teen 1X besproeiing. Boomgrootte het toegeneem met `n toename in die vlak van besproeiing. `n Lineêre toename in vruggrootte met 'n toename in die vlak van besproeiing het 'n oorsaaklike lineêre toename in opbrengs tot gevolg gehad. Bemesting in kombinasie met besproeiing, ½X besproeiing sonder bemesting, asook `n toename in die bemestingsvlak by 1X besproeiing het vrugrypwording substansieel vertraag. Die omsigtige bestuur van bemesting- en besproeiingsvlakke kan moontlik gebruik word om die oesperiode, en dus die bemarkingsvenster, vir Suid-Afrikaanse 'Triumph' te verleng. Ons beveel aan dat die proef vir 'n vêrdere aantal seisoene voortgesit word sodat die effek van bemesting- en besproeiingsvlakke op vrugkwaliteit en -houvermoë bepaal kan word. Verhoogde oorskaduwing soos wat bome van sekere behandelings hul toegekende spasie bereik en oorskry, kan ook in die toekoms 'n invloed op vrugset uitoefen.

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TABLE OF CONTENTS

GENERAL INTRODUCTION

Since 1998, about 700 ha of ‘Triumph’ persimmon (*Diospyros kaki* Thunb.) has been established in South Africa, mostly in the Mediterranean-type climate Western Cape region (Rabe, 2003). Production is aimed at the export markets of Europe, Asia, the Middle East and Canada. Since persimmon culture is new to South Africa, little local expertise is available on how to achieve precocious high yields. Results from our research program have shown that methods used to enhance fruit set in Israel, from where ‘Triumph’ came to South Africa, do not necessarily have any beneficial effect in South Africa (Steyn *et al*., 2008).

Being accustomed to high density planting of stone and pome fruit, the South African persimmon industry opted for fairly high planting densities (800-1111 trees per ha). ‘Triumph’ is a vigorous tree, especially when planted on the vigorous *D. lotus* seedling rootstock. Many ‘Triumph’ orchards are overly vigorous, slow to come into production and low-yielding when mature due to excessive shading and low fruitfulness. Hence, the first aim of this study was to investigate the effectiveness of various techniques (viz. strapping, scoring, girdling and application of the plant growth retardants prohexadione-Ca and paclobutrazol) to decrease vegetative growth and improve flowering, fruit set and yield in ‘Triumph’ persimmon under South African conditions.

When establishing new orchards, the first goal is to fill the allotted tree space as soon as possible to achieve positive cash flow (Lang, 2001). Since fruit compete with shoot growth, too early onset of high yields may curtail growth and delay the attainment of full bearing volume, thereby decreasing cumulative yield over the lifetime of the orchard. The supply of nutrients, especially nitrogen (N), and water are arguably the two most important external factors that influence the vegetative growth rate of plants and that can be controlled by the grower. Hence, the second aim of the study was to determine optimum levels of fertigation to achieve rapid growth to fill the allotted space as well as precocious fruit production.

The experimental part of the study is underpinned by a literature review on vigor control in fruit trees, with emphasis on persimmon.

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LITERATURE STUDY: VIGOR CONTROL IN FRUIT TREES WITH REFERENCE TO JAPANESE PERSIMMON, *DIOSPYROS kaki* Thunb.

1 INTRODUCTION

The cultivated or Japanese persimmon is a deciduous fruit tree that belongs to the genus *Diospyros* within the family *Ebenaceae*. The persimmon has its origins in China, but has most intensively been grown and researched in Japan (George *et al*., 1997). China, South Korea and Japan are the major producers of persimmon in the world, while sizeable industries exist in Brazil, Spain, Italy, Israel, New Zealand, Iran, Mexico and Turkey (Llacer & Badenes, 2002; FAOSTAT, 2010). Total world production amounts to about 3.6 million tons (2.5 million tons by China) produced on an estimated 762 500 hectares (FAOSTAT, 2010). Persimmon consumption in China, Japan and Korea constitutes about 92% of world production, which creates opportunities for counter season marketing of Southern Hemisphere produce in the Northern Hemisphere (Nissen *et al*., 2008).

The persimmon industry in South Africa is still in its infancy, with about 700 ha established mostly in the Mediterranean-type climate Western Cape region (32-34º S, 17-20º E, 200-800 m above sea level) (Rabe, 2003). Production is aimed at the export markets of Europe, Asia, the Middle East and Canada. The South African industry is based on the pollination variant, astringent, parthenocarpic cultivar Triumph because of its supposedly higher sugar levels, better yield and good shelf life compared to non-astringent cultivars, such as Fuyu, of which limited hectares have also been planted in South Africa (Hill, personal communication).

Persimmon trees are vigorous growers and attain a size of 7 to 8 m if left untrained (Kitigawa & Glucina, 1984). To accommodate their vigor, persimmons are traditionally planted at low densities (312-400 trees per ha) and trained to the free standing vase or central leader forms (George *et al.,* 2003; Ullio, 2003; Bellini, 2002). Higher planting densities (>740 trees per ha) are used when trees are trained to the palmette system (George *et al*., 2003; Bellini, 2002). Being accustomed to high density planting of stone and pome fruit, the South African persimmon industry has opted for fairly high planting densities (800-1111 trees per ha at a spacing of 4.5 – 5.0 m x 2.0 – 2.5 m) and training to the central leader form (Ungerer, personal communication). Excessive vigor and reduced fruitfulness due to shading are increasingly becoming problematic as trees reach their mature size and exceed their allotted row volume.

‘Triumph’ sets fruit parthenocarpically, thus vegetative growth can easily dominate reproductive growth as pointed out by Wright (1989). Persimmon fruit frequently drop after flowering (Kitigawa & Glucina, 1984). The most severe fruit drop occurs during the 2-3 weeks after petal fall followed by another two drop periods that are less severe (Kitigawa & Glucina, 1984). Fruit drop is greatly reduced by pollination, but is not an option in ‘Triumph’ since fruit have to remain seedless. Other factors causing fruit drop are insufficient sunlight and excessive shoot growth (Kitigawa & Glucina, 1984). According to George *et al*. (1997), low light levels, water stress and excessive vegetative growth are the most important environmental factors causing fruit drop in persimmon.

The main techniques used to control vigor of fruit trees and thereby increasing their fruitfulness are grafting on dwarfing rootstocks, tree training and pruning systems and the use of growth retardants (Jackson, 1989). Cultural techniques such as girdling, scoring (Autio & Greene, 1992) and strapping (Hasegawa *et al.*, 2003) can also be used to restrict vegetative growth and improve fruit set. Irrigation management methods such as regulated deficit irrigation (RDI) and partial root zone drying (PRD) are also effective in controlling vegetative growth (Kirda *et al.*, 1999). The purpose of this literature review is to provide insight into the current situation regarding the use of various techniques to control vigor in fruit trees and to what extent these methods have been used in persimmon culture.

2 ALTERNATE BEARING AND FRUIT DROP IN PERSIMMON

Alternate bearing is a major production constraint that affects the profitability of various fruit crops (Monselise and Goldschmidt, 1982). The occurrence of alternate bearing in persimmon has been well documented (Miller, 1984; Mowat & George, 1994; Collins & George, 1997). Miller (1984) evaluated 23 persimmon cultivars including Triumph and found that all cultivars were prone to biennial bearing. 'Off' season cropping was characterized by either sparse bloom or heavy fruit drop during fruit development. This was directly related to heavy crop loads during the previous season. According to Monselise and Goldschmidt (1982), the heavy crop produced during an 'on' season is universally recognized to be the main cause of alternation in various fruit kinds. According to Mowat and George (1994), over cropping in the one season results in competition for assimilates between fruit and shoots in that season. The resulting low carbohydrate status of a tree in the 'on' season can reduce flower initiation and may also cause pre-bloom flower bud abscission in the following season. Excessively high yields in the 'on' season also reduce vegetative growth, thus decreasing potential bearing positions for the next season (Miller, 1984; Ooshiro *et al.* 2001). Accumulation of reserves during the 'off' season promotes heavy flowering in the following season (Mowat & George, 1994).

Alternate bearing in persimmon is easily controlled by fruit thinning after flowering (Collins & George, 1997). Thinning in an 'on' season significantly increased starch reserves in the tree at flowering time the following season leading to the alleviation of the alternate bearing habit (Collins & George, 1997). Fruit thinning by hand is, however, labor intensive and costly, while chemical thinning agents are also expensive, and may have variable effectiveness (George *et al.,* 1997). Early application (10 days after bloom) of Ethrel (2-chloroethylphosphonic acid) led to excessive fruit drop in 'Fuyu' persimmon while later applications (18 days after full bloom) caused less fruit drop, but still significantly more than the control (Nakamura and Wakasugi, 1978). Miller (1984) found that when both seeded and parthenocarpic fruit set on a tree, 80 to 100% of abscised fruit were parthenocarpic. Although some seeded fruit dropped, cultivars with well formed seeds were less susceptible to drop fruit. The fact that 'Triumph' sets fruit parthenocarpically makes it more prone to fruit drop.

In addition to the role of crop load in alternate bearing, Monselise and Goldschmidt (1982) also mention that vegetative organs may in some instances be more powerful sinks than fruit. This may occur especially during early stages of fruit development. Kitajima *et al*. (1987, 1990) found that excessive shoot growth during stage I (Fig. 1) of fruit development in persimmon can stimulate fruit drop through shading or by competing for assimilates with developing fruit. Excessive vigor may be stimulated by low crop loads (not in the case of alternation, where reserves are already at a minimum), excessive N application during early fruit development and severe winter pruning (George *et al*., 1997). Stress conditions such as high temperature (Prasad *et al.* 2000) and water stress (Mowat and George, 1994) during the flowering period may also play a significant role in fruit drop, especially when heavy crops are set and the competition for assimilates among fruitlets is high (Guardiola, 1997).

Kang and Ko (1997) have identified the control of vegetative growth as important for the successful production of persimmon in Korea. In South Africa, excessive vigor has also been identified as a potential cause of low productivity and biennial bearing. (Hill, personal communication). The tendency towards high density plantings makes the control of excessive vigor even more important in the South African industry.

3 ROOTSTOCK INFLUENCES ON VIGOR

The importance of rootstocks in controlling vigor can not be over emphasized as has been shown in various other fruit kinds such as peach and apple (Giorgi *et al*., 2005*).* According to Reddy *et al.* (2002), rootstocks have several applications of which one is the management of vigor and thereby securing regular, high yields. Vigor management is important for high density plantings and using dwarfing rootstocks is a means to achieve this goal (Reddy *et al.*, 2002). Rootstock vigor influences the intensity and duration of extension growth (Hansen, 1989). Dwarfing rootstocks reduce shoot growth and may improve fruit quality as a result of this reduction in vigor (Hansen, 1989; Reddy *et al.,* 2002).

Three different species of *Diospyros* are used as seedling rootstocks in commercial persimmon production, i.e., in order of high to low vigor, *D. lotus, D. virginiana* and *D. kaki* (Kitigawa & Glucina, 1984). *D. kaki* is the main rootstock used in the production of non-astringent persimmon in Japan (Kitigawa & Glucina, 1984). *D. lotus* is widely used in China, Italy, and northern Japan as it produces uniform seedlings and is more cold-hardy than *D. kaki.* It is, however, more susceptible to crown gall *(Agrobacterium tumifaciens*) than *D. kaki* (Kitigawa & Glucina, 1984) and excessive fruit shedding can be a problem (Schroeder, 1950). *D. lotus* also shows signs of incompatibility with pollination constant non-astringent cultivars such as Fuyu (Kitigawa & Glucina, 1984). *D. virginiana* is well adapted to damp soils and is very cold-hardy (Kitigawa & Glucina, 1984), but is prone to form suckers (Sharpe, 1966). Sharpe (1966) found no difference in growth and fruit production between *D. kaki* and *D. virginiana* when grafted to 23 different scion cultivars. However, trees propagated on *D. virginiana* are not always uniform in size and vigor (Kitigawa & Glucina, 1984). For this reason, *D. kaki* is preferred in New Zealand for use with non-astringent cultivars. The main rootstock used for 'Triumph' in Israel is *D. virginiana*, possibly due to its better adaptation to high pH soils (Rabe, 2003). *D. kaki* is also used, but not to the same extent as *D. virginiana*. Due to the Israeli influence, about 90% of 'Triumph' trees in South Africa are grafted on *D. virginiana*, with the balance shared equally between *D. kaki* and *D. lotus* (Hill, personal communication).

Unlike other fruit crops where growers have a choice between a wide range of clonal rootstocks, no dwarfing clonal rootstocks were available for persimmon up to the mid 1980's (Kitigawa & Glucina, 1984). Recently, some progress has been made towards the development of dwarfing rootstocks and interstocks for persimmon. Yakushiji *et al.* (2008) grafted 'Fuyu' on three rootstocks, viz. "No. 3", "S22" and *D. rhombifolia. D. kaki* was used as control rootstock. Both "No. 3" and "S22" shows promise as they reduce tree size compared to the control, while tree vigor with *D. rhombifolia* was considered to be too weak to sustain acceptable yields. Koshita *et al.* (2007) identified two possible dwarfing interstocks, viz. Ac-1 and Y, for use with 'Fuyu'. These interstocks were grafted on "Aogaki" (*D. kaki*) rootstock and induced comparable yields than seedling rootstock while reducing vegetative growth. Whether these interstocks would be suitable for use with other persimmon cultivars still needs to be established. The breeding of dwarfing rootstocks should be high on the priority list of the persimmon industry. George *et al.* (2003) also expresses the need for further evaluation of a wider range of species for compatibility and dwarfing effects, both as rootstock and interstock. In the meantime, however, the industry is forced to look at various other methods of vigor control such as girdling, strapping and the use of plant growth retardants (PGR's). Pruning and training methods can also be used for vigor control.

4 EFFECT OF PRUNING ON FRUIT TREE VIGOR

4.1 Interference of pruning with endogenous growth control

Increasing severity of summer and dormant pruning reduces tree size. The dwarfing potential of both summer and dormant pruning is most likely due to the removal of reserves (Marini, 2003) and sites of hormone production (Stiles, 1984). The tree tends to re-establish a functional equilibrium at a smaller size. It has been proposed that pruning interferes with endogenous growth control by removing sites of auxin production (Saure, 1992). Heavy pruning is locally invigorating, especially when heading cuts are used on very vigorous trees. Shoot thinning is generally less invigorating because it preserves some of the growth control capacity.

The timing of pruning also has a localized effect on growth response. Since the intensity of summer pruning is usually less than that of dormant pruning, its invigorating effect is also less because it interferes less with endogenous growth control (Saure, 1992). The later in the season summer pruning is done, the weaker is the regrowth reaction (Ferree *et al*., 1984). However, studies by Marini and Barden (1982) on physiological aspects of summer pruning in apple have shown no difference in vegetative growth control compared to dormant pruning. Ferree *et al*. (1984) concludes that summer pruning in apple has no real advantage in terms of controlling growth, but that its advantage lies in the efficient use of labor, increasing light penetration to the fruiting canopy and improving quality aspects such as fruit colour.

4.2 Pruning for balance in persimmon

The most important point to remember when pruning persimmon trees is that only the 2-3 buds at the distal end of the current season’s growth may be reproductive. Cutting shoots back heavily will therefore decrease yields (Kitagawa & Glucina, 1984). Severe pruning also reduces the crop by forcing excessive vegetative growth, resulting in increased fruit drop while moderate pruning to promote annual renewal of fruiting branches seems to be the most desirable.

Kitigawa and Glucina (1984) do recognize that, occasionally, it is necessary to prune back some shoots severely to create more fruiting positions for the following season. Heavy pruning to approx. 5 - 10 cm from a main lateral is necessary to maintain bearing shoots close to the main tree structure. As persimmon is essentially a tip bearer, bearing positions gradually shift further away from the centre of the tree and long, bare, unproductive shoots are formed. These shoots tend to bend excessively under fruit load and produce a drooping tree which is prone to wind damage. To overcome this, vigorous shoots with well developed buds should be left unpruned to bear fruit for season 1, while some less vigorous shoots should be cut back severely to 2-3 buds. From these buds vigorous growth will develop which will provide the fruiting shoots for season 2.

Branches tend to die back fairly easily if leaves receive insufficient sunlight. It is therefore important to develop a fairly open system of pruning to allow sunlight to penetrate into the canopy. In this regard it is also necessary to consider the possible training systems used in persimmon production to optimize light interception and at the same time create a tree shape that is easily managed in terms of cultural practices.

5 THE USE OF TRAINING SYSTEMS TO MANAGE TREE SIZE AND SHAPE

5.1 Considerations in choosing a training system

To decide on a suitable training system for any tree, the first question that should be asked is: “What is the growth habit of the tree”? Champagnat (1978) used the term “acrotony” to indicate the dominant growth of the distal laterals after bud dormancy in woody plants. This growth habit implies that the most distal or apical buds are dominant and are most commonly the buds that burst and form extension shoots as is the case in apple and pear (Cook *et al.*, 1998). The persimmon also displays a typical acrotonic growth habit.

The second question to be asked is: “What do we want to achieve with a particular training system”? The obvious answer should be to enhance marketable fruit production while partially reducing vegetative growth. According to Martin (1989), the purpose of a training system should be to direct and restrict vegetative growth to maximize flower bud formation and fruit formation. This goal is achieved by allowing channels for light penetration and bending branches to both restrict the length of new vegetative growth and increase the number of flower buds formed on the same limb. Martin (1989) also mentions that the cost to erect and maintain a specific training system should be kept in mind and compared to the benefits of the specific system in terms of yield and quality of fruit.

5.2 Training systems in persimmon cultivation

The persimmon tree, if left to grow freely, assumes a more or less globose shape (Kitigawa & Glucina, 1984). In Japan, persimmon trees are mostly trained into a modified central leader with well spaced lateral branches. The open centre or vase system is also used. In Italy persimmon trees are grown on the palmette system (Kitigawa & Glucina, 1984). Various training systems are being used and evaluated in New Zealand such as the two-leader Y-shaped tree or Tatura trellis system (Chalmers & van den Ende, 1975), the Lincoln Canopy (Dunn,1974), the Ebro-espalier system (Anon, 1981) and the continuous pergola (Kitigawa & Glucina, 1984). In South Africa, initial plantings were established either as free-standing trees or on a three- to four-wire system. The wires are mostly used for support and the trees trained as central leaders, but with no real formal structure in mind. Renewal pruning is done in the winter by cutting back older branches. In order to improve light interception, vigorous upright shoots are removed in summer.

6 THE USE OF GIRDLING AND STRAPPING FOR VIGOR CONTROL AND IMPROVED FRUIT SET

Girdling is an effective technique to reduce vegetative growth, promote flowering, improve fruit set, increase fruit size and advance maturity in a wide variety of crops (Goren *et al.*, 2004) such as apples (Hoying and Robinson, 1992), citrus (Agusti *et al.* 1992), macadamia (Trueman & Turnbull, 1994), mango (José, 1997), litchi (Li &

Xiao, 2001), nectarines (Agenbach, 1990), peaches (Dann *et al.,* 1984; Onguso *et al.*, 2004) and persimmon (Fumuro, 1996, 1997,1998; Hasegawa *et al*., 2003).

Girdling, or “ringing” as referred to by Autio and Greene (1992), is a process whereby a strip of bark is removed without penetrating the xylem, thus removing only the phloem outside the cambium with a pruning saw, a ringing knife or a chain saw blade. Scoring, on the other hand is the process of making a single cut with a knife around the trunk (Autio & Greene, 1992). Noel (1970) indicates that two fundamentally different types of girdles may be produced, depending on whether or not there is removal of tissues internal to the vascular cambium. He refers to girdling as the removal of a strip of bark, either narrow or wide, of all tissue external to the secondary xylem. If the xylem is penetrated, Noel (1970) refers to the action as “notch-girdling”. For the purposes of this review the term “girdling” will be used for the removal of a strip of bark, but not deeper than the cambium and the term “scoring” will refer to a single knife cut. “Strapping” or “partial girdling” refers to the action of tying wire around the trunk (Hasegawa *et al.,* 2003) or roots (Goodwin & Lumis,1992), resulting in gradual strangulation and interruption of phloem transport.

It is more than likely that the girdling action may result in some damage to the xylem vessels, as mentioned by Goodwin & Lumis (1992), in which case the upward movement of water and solutes may be impeded. This possibility, and the effect this may have on production and tree health, is however not discussed in this paper.

6.1 Timing and severity of application in persimmon

What needs to be taken into consideration when applying the girdling technique to control growth and improve fruit set is firstly the timing and secondly the severity of the application. Fumuro (1998) found that a 1 cm wide girdle on the trunks of ‘Nishimurawase’ persimmon trees 23 and 34 days before full bloom (DBFB) inhibited shoot and trunk growth and decreased leaf number per tree. Shoot growth inhibition lasted into the next season, but the treatment had little or no effect on yield and fruit quality in either of the two seasons in which the treatments were applied. Strapping of peach laterals also reduced vigor and increased fruit set (Hasegawa *et al*., 1998). Hasegawa *et al*. (2003) found that strapping ‘Matsumotowase Fuyu’ persimmon before full bloom has a more pronounced effect on fruit set compared to strapping at full bloom while Fumuro (1998) and Hasegawa *et al.* (2003) found that the earlier trees are girdled or strapped, the greater the growth inhibition.

The results achieved with girdling also depend on its severity. A severe girdle of 5 to 10 mm results in a definite reduction in shoot growth, while a partial girdling technique such as strapping does not seem to affect vegetative growth as much (Hasegawa *et al,* 2003). Hodgson (1938) has shown that removing a strip of bark about 5 mm in width at anthesis and up to one month after flowering decreased fruit drop and increased flowering in the next season in young, excessively vigorous 'Hachiya' persimmon trees.

6.2 Mechanism of action of girdling

Girdling breaks the flow of nutrients, photosynthates and growth regulators between the tree canopy and roots (Autio & Greene, 1992). The mode of action of girdling on fruit set and vegetative growth is not clearly understood, but seems to be related to interrupting either carbohydrates and/or endogenous hormone transport to the roots (Noel, 1970) or to the redistribution of carbohydrates above the girdle (Dann *et al.,* 1984). An increase in fruit set due to girdling will thus limit shoot growth because of the higher demand of fruit for carbohydrates as opposed to shoot growth (Dann *et al.,* 1984).

6.2.1 The possible role of carbohydrates

Girdling blocks the translocation of sucrose from leaves to the root zone through the phloem bundles. This block causes a decrease in starch content in the root system (Schneider, 1954) and an accumulation of sucrose in the leaves (Plaut & Reinholt, 1967). Noel (1970) states that carbohydrates or other nutrients accumulating above the girdle, or being prevented by the girdle from reaching the roots, accounts for the effects of girdling upon growth. Dann *et al.* (1984), in girdling done on peaches, concluded that the redistribution of assimilate supply between organs appears to be the predominant effect of girdling, with the growth of fruit being favored over the growth of vegetative organs. In their trial, starch did not accumulate above the girdle. Hansen (1989) stated that, due to the lack of assimilates in the root system, caused by girdling, water and nutrient uptake is inhibited, thereby affecting the growth of above ground organs.

It is not only the functions of the root system that seems to be inhibited by the lack of carbohydrate flow, but also root growth. Huang (2002) found in litchi that the downstream translocation of carbohydrates was almost completely blocked by girdling, causing the inhibition of root growth. He states that it is common knowledge that expansion of the root system is favored over the expansion of above ground tissues in young trees. Trunk girdling may alter this tendency. He concludes that trunk girdling may lead to better fruit retention by depressing early root growth and the ensuing tree flushing during the physiological fruit drop period. It may also lead to intensified relative sink strength of existing growing fruit. Yamane and Shibayama (2006) found that the root elongation of ‘Aki Queen” grapevine stopped for two weeks after girdling treatment, regardless of crop load. Root elongation after the girdle healed was vigorous when the crop load was low and less vigorous with a high crop load, indicating that the fruit had become the main sinks after the girdling treatments, which corresponds with the work of Huang (2002).

Whether the girdling action has an effect on redistributing assimilate flow above the girdle, depleting the roots of necessary carbohydrates for optimal function or stopping root growth for a period, the fact remains that carbohydrates do play a significant role in the action of girdling. It is also possible that the action of hormones may be influenced by the act of girdling (Dann *et al.*, 1984; Skene, 1975). It is therefore necessary to consider the possibility that other substances such as hormones may play a role in the effect of girdling on growth and fruit set.

6.2.2 The possible role of hormones

According to Dann *et al.* (1984), girdling may alter the balance between endogenous hormones which favor reproductive development over vegetative growth by accumulating such hormones above the girdle as an initial effect. In their trials, in which they girdled some limbs on a tree while leaving other limbs intact, the effect of girdling eventually also spread to ungirdled limbs, implicating that the roots play a definite role. Cytokinins (CK) and gibberellins (GA) are both synthesized or activated in the roots (Skene, 1975). These hormones are transported in the xylem stream and according to Dann *et al.* (1984), a suitable hypothesis must still explain why interrupting the phloem should affect activity of root hormones above the girdle.

According to Chalmers and van den Ende (1975), a strong linear relationship exists between the growth rate of the roots and shoots in peach trees. This relationship supports the hypotheses that root and shoot growth are correlated by feedback signals (Dann *et al*., 1984). If the coordinating signal moved in the phloem from shoots to roots, the roots would not receive the signal if the tree was girdled. Root growth and the synthesis of CK and other root hormones would be adjusted accordingly, with the ultimate effect being seen in inhibited vegetative growth and increased fruit set. Dann *et al.* (1984) found their results to be consistent with the hypothesis that girdling alters the balance between endogenous growth regulators favoring either vegetative or reproductive development. They suggested that the initial effects of girdling are attributable to accumulation of growth regulators above the girdle and that the reduction of the flow of growth regulators to the roots eventually results in lowered levels of root-produced hormones which subsequently causes effects throughout the tree. The question now is which growth regulators (or hormones) are responsible for these effects?

Auxin and GA's are both synthesized in young leaves and growing tips, and are then transported towards the roots via the phloem (Salisbury & Ross, 1992). Tanimoto (2005) singles out auxin and gibberellins as the most important hormones playing a role in root growth.

6.2.2.1 Auxins

Good evidence exists that auxin from stems strongly influences root initiation (Wareing & Phillips, 1981). Auxin is transported towards the roots from aboveground organs (Salisbury & Ross, 1992, Wareing & Phillips, 1981). Plant physiologists have investigated the possibility that auxin may affect root formation, thereby balancing root and shoot systems (Salisbury & Ross, 1992). Evans (1984) points out that Indoleacetic acid (IAA) is the most likely promotor of root elongation, but that its effect is dependent on other hormones and inhibitors while Went and Thimann (1937) and Fu & Harberd (2003) identified auxin as the root-forming hormone. Tanimoto (2005) states that auxin plays a central role in the growth regulation of roots and that IAA is possibly the most intensively studied hormone in this regard. He finds that the classical view of concentration dependency of IAA on plant growth is key to understanding the regulatory function of auxin in root growth. Removal of young leaves and buds, which are sources of auxin, inhibits the formation of lateral roots. Substitution of auxin for these organs often restores the plant's root-forming capacity (Salisbury & Ross, 1992; Naqvi, 1994).

Reed *et al.* (1998) showed in *Arabidopsis* that the application of naphthylphthalamic acid (NPA) at the root-shoot junction decreased the number and density of lateral roots and reduced the transport of IAA and free IAA levels in the root. They were also able to first stop lateral root growth by excision of the shoot and then reverse the inhibition with the application of exogenous IAA to the root-shoot junction. According to Tanimoto (2005), the higher the endogenous level of IAA (and GA) in shoots, the greater the shoot growth, but in contrast such high concentrations of auxin in the root tissues decreases root growth. According to Went and Thimann (1937), the effect of auxin on root cell elongation is the same as on stem and coleoptile cell elongation except that root cells are much more sensitive to auxin. Wrightman *et al.* (1980) found that there is an important difference in exogenous auxin effects on root elongation, in which an inhibition is normally observed, and in root initiation and early development, in which promotion is observed. Wareing and Phillips (1981) also confirms that the levels of endogenous IAA in roots are much lower than that of stems and that roots do appear to be very sensitive to changes in auxin concentrations.

Cutting and Lyne (1993) showed that the long-term inhibition of root growth in peach trees by girdling leads to a decrease in CK levels in the above ground parts, resulting in a decrease in shoot growth. Kamboj *et al.* (1997) and Kamboj *et al.* (1999) showed in apple that more dwarfing rootstocks restrict the movement of auxin to the root tips, which in turn leads to lower levels of CK in the shoots.

These studies make it clear that root growth is promoted at optimal levels of auxin supply, but when auxin is in short supply (e.g. when a plant stem is girdled and polar auxin transport is restricted), root growth is inhibited. On the other hand, at supra-optimal levels of auxin supply, root growth is also inhibited, which indicates that root growth is very sensitive to auxin concentrations. It is thus quite possible that by girdling a tree and restricting the downward movement of auxin, root growth and consequently whole plant growth will be inhibited.

6.2.2.2 Gibberellins

There are many conflicting reports with regard to the role GA’s might play in root growth and development. According to Burström and Svensson (1972), GA has hardly any effect on the growth of roots or root segments. They do mention that excised root segments, which may have been deprived of their source of GA, show some response to the addition of exogenous GA. Tanimoto (2005) also states that, compared to auxin, GA functions in roots are less remarkable over a wide range of concentrations, but that it does still play an indispensable role in the normal development of roots. Wareing and Phillips (1981) state that application of GA to intact plants generally has little effect on root elongation, but excised roots growing in aseptic culture sometimes grow more in length when supplied with GA. The importance of GA in root growth has also been demonstrated by Rademacher (2000) by using inhibitors of GA biosynthesis to decrease the endogenous GA in roots.

From the above it seems that, although not as concentration-dependent as auxin, GA is also important for root growth to take place. It is therefore possible that root growth can be inhibited by removal of the above ground sources of GA, such as would be the case when girdling a tree.

Even with all the work that has been done and with the knowledge that girdling as a technique to control vigor and set fruit is effective; the exact mechanism of action is still not known. It does seem that the effect girdling has on shoot vigor may not be a direct one, but rather that the growth control in shoots takes place due to a shift in sink strength from vigorous shoots to fruitlets due to a change in translocation of carbohydrates and hormones alike.

7. THE USE OF PLANT GROWTH RETARDANTS TO CONTROL VIGOR IN FRUIT TREES

Plant growth retardants (PGR's) are a diverse group of synthetic compounds that reduce stem elongation (Gianfagna, 1987; Rademacher, 1995). These compounds inhibit cell elongation in the sub-apical meristem, but have little effect on the production of leaves or on root growth and the physiological effects can normally be reversed by application of gibberellic acid (GA) (Gianfagna, 1987). All PGR's have one thing in common and that is that they inhibit the formation of growth-active GA's (Rademacher, 1995). In the following discussion, the focus will be on two specific compounds, namely paclobutrazol (PBZ) and prohexadione-Ca (P-Ca) with specific reference to work done on persimmon.

7.1 The use of PBZ in fruit trees

PBZ is used to reduce vegetative shoot growth in various pome and stone fruits, citrus, nuts and grapes (Rademacher, 1995). The general aim of PGR application in these plants is to alter partitioning of assimilates in favor of reproductive growth at the expense of vegetative shoot growth. This is particularly relevant in fruit kinds such as cherries and plums where no dwarfing rootstocks or compact scion cultivars are available to enable production in high density plantings (Rademacher, 1995). The same would apply to persimmon.

George *et al*. (1995) found that foliar sprays of PBZ at 2 g L^{-1} a.i. applied to the four terminal nodes of persimmon shoots before and after anthesis increased fruit weight but did not increase fruit set. Non-pollinated fruit exhibited more than double the growth response of pollinated fruit to PBZ indicating that control of shoot vigor may be more important in orchards where the crop sets parthenocarpically. George *et al*. (2003) mention that soil applications of PBZ reduced shoot extension growth and tree size in persimmon by at least 20% and advanced fruit maturity by about two weeks without a loss in fruit quality or storage life. However, in another study, spring root application of PBZ at 2 g L^{-1} a.i. to 'Triumph' persimmon accelerated ripening and also increased the rate of postharvest senescence (Ben-Arie *et al.,* 1997). These effects were partially curbed by pre-harvest application of GA_3.

Because PBZ persists in the soil and can still have an effect for years after application (Rademacher, 1995), and also because of its effect on fruit ripening, it is wise to consider the use of newer chemistry that does not have these side effects. P-Ca is a compound that could possibly be used to great effect on persimmon.

7.2 The use of P-Ca in fruit trees

P-Ca has been registered for growth control in various crops, e.g., rice, apples, peanuts, small grains and pear (Evans *et al*., 1999; Medjdoub *et al*., 2005). P-Ca is effective in controlling vegetative growth in pear (Meintjes *et al*., 2005) and apple (Byers & Yoder, 1999; Greene, 1999; Medjdoub *et al*., 2005),) but not 'Redhaven' peach (Byers & Yoder, 1999). Thus not all species respond to P-Ca. Cultivars may also differ in responsiveness to P-Ca (Meintjes *et al*., 2005).

Medjdoub *et al*. (2005) found that the extent of growth control in red apple cultivars was highly dependent on timing, number of spray applications and the rate applied. They also found that greater growth inhibition was observed in lateral shoots than in terminal shoots. Best results in apple were obtained when P-Ca was applied between full bloom and up to 12 days after full bloom when shoot length was about 3 - 10 cm (Byers and Yoder, 1999; Medjdoub *et al*., 2005). P-Ca was less effective when applied later in the growing season when shoots were longer than 15 cm. Rademacher (2000) states that this may be due to high concentrations of GA_1 already accumulated in shoot tissues by this time. This could also be the reason for the reduced efficacy of P-Ca in terminal shoots as compared to lateral shoots. Regrowth often occurs after an initial reduction in shoot growth in response to the first P-Ca application thus necessitating a second application (Medjdoub *et al*., 2005). Medjdoub *et al*. (2005) found that greater shoot regrowth occurred at relative high application concentrations. As P-Ca blocks the conversion of GA_{20} to GA_1 and of GA_1 to GA_8, it might be that when P-Ca is applied, an accumulation of GA_{20} takes place (Rademacher, 2000). As P-Ca is quickly metabolized the delayed conversion of GA_{20} to GA_1 may account for the observed regrowth (Medjdoub *et al*., 2005).

Byers and Yoder (1999) found very little direct effect of P-Ca on fruit firmness, soluble solids, starch content, shape or fruit cracking with any of the rates of P-Ca application used in their experiments on apple. Medjdoub *et al*. (2005) confirmed these results. Colour was improved in the experiments of Medjdoub *et al*. (2005), but this was attributed to improved light penetration. Application of P-Ca at the time of rapid cell division (FB and shortly thereafter) increased fruit set, but could decrease fruit size in apple (Greene, 1999) and pear (Meintjes *et al*., 2005). This decrease in fruit size could simply be due to the increase in fruit set (Meintjes *et al*., 2005). No results of P-Ca application on persimmon have been published to date.

8. THE USE OF IRRIGATION MANAGEMENT TO CONTROL VIGOR

That withholding water restricts vegetative growth has been known for thousands of years (Martin, 1989). Chalmers *et al.* (1981) showed in peach that withholding water during the pit hardening stage of fruit growth could decrease vegetative growth without decreasing fruit growth. Chalmers *et al.* (1984) were also able to restrict vegetative growth without negatively affecting fruit growth in pears by applying deficit irrigation. Vegetative growth has been successfully controlled with the use of water management techniques such as regulated deficit irrigation (RDI) or partial root zone drying (PRD) in plums (Intrigliolo & Castel, 2005) and grapevines (Dry *et al*., 1996). RDI is a system of managing soil water supply to impose periods of predetermined plant or soil water deficit that can result in some economic benefit (Behboudian & Mills, 1997). It involves providing less water to the plant than the prevailing evapotranspiration (ET) demand at selected times during the growing season. PRD is a technique in which only half of the root system is watered on one side of the plant, while drying out the other half of the root system at intervals of 7 - 14 days (Dry & Loveys, 1999). PRD originated from observations that an increase in abscisic acid (ABA) content derived from the drying roots reduces stomatal conductance, photosynthesis and vegetative growth (Dry & Loveys, 1999).

A functional equilibrium exists between root and shoot growth (Richards & Rowe, 1977). This means that a specific root to shoot ratio is maintained in a particular environment. Since roots are less active and grow less in a dry environment (Proebsting *et al*., 1977), deficit irrigation can reduce the effective root volume, thereby restricting shoot growth and increasing fruiting (Richards, 1985). Water deficit in the root zone, once established and maintained until the onset of rapid fruit growth, will primarily affect the development of shoots (Chalmers, 1989). Since fruit have a lower assimilate demand and are less sensitive to water stress than the shoots during early cell expansion, water deficit can significantly reduce shoot growth with little or no reduction in fruit growth (Behboudian & Mills, 1997). Fruit are thought to be less affected by water deficit than shoots because fruit are stronger sinks and accumulate large quantities of soluble solids over the season (Chalmers, 1989). Therefore, the use of RDI is also feasible in species where shoot and fruit growth overlaps (Behboudian & Mills, 1997). In other species, phenological separation of shoot and fruit growth allows the timely application of RDI to restrict shoot growth without an adverse effect on fruit growth (Behboudian & Mills, 1997).

When returning to full irrigation at the start of rapid fruit expansion, previously deficit-irrigated fruit may briefly grow at a faster rate than well-watered fruit (Mitchell & Chalmers, 1982). In peach, this compensation in growth has been attributed to active osmotic adjustment during RDI (Chalmers, 1989). Photosynthesis and translocation of assimilates are not suppressed at water potentials that inhibit cell expansion, which is particularly sensitive to water stress (Behboudian & Mills, 1997). There is, however, little evidence of osmotic adjustment in deficit-irrigated fruit in the literature.

According to Martin (1989), the precise management of water application for growth control is dependent on the following: 1) A light, sandy soil which drains rapidly; 2) a fail-safe irrigation system; 3) sufficient capacity of the irrigation system to refill the soil profile rapidly during peak periods; 4) closer water management than most people would be willing to provide; and 5) vegetative growth must occur at a different time to fruit growth. The light soil allows rapid response to either water restriction or addition. Without rapid response in either direction, the synchronization of irrigation with plant growth stages becomes too complex and unpredictable. No room for error is possible without incurring plant damage and crop loss. A malfunction in water delivery in such a system could result in severe tree damage. There are, however, managers who are able, and orchard sites, where water restriction could be used as an additional means to control vegetative growth (Chalmers *et al.*, 1981).

No literature is available with regards to the control of vigor in persimmon by regulating water supply. Hence, it remains to be seen whether persimmon will react in the same way to RDI as other species. In South Africa, persimmon buds sprout in

September and full bloom occurs during the end of October until the first week of November. RDI may prove a useful tool to inhibit shoot growth in this period before flowering. Also, if it would be possible to use RDI to inhibit shoot growth during the early stages of fruit growth, which overlaps with the first shoot flush (see Figure 1), and if the fruit can then compensate for growth lost in the early stages, RDI may be a feasible management tool to help control vigor in persimmon. Taking into consideration that excessive vigor during stage 1 (Fig. 1) is responsible for excessive fruit drop in persimmon (Kitajima *et al.,* 1987, 1990), it is possible that RDI during the early fruit growth phase may also improve fruit set.

9. SUMMARY

Various techniques are used to control vegetative growth and to improve fruit set in different fruit tree species. Dwarfing rootstocks, often developed through selection and cloning, are used extensively in major fruit kinds such as apple and pear (Giorgi *et al*., 2005; Hansen, 1989; Reddy *et al.,* 2002). Combined with the correct training system and pruning techniques, vigor control is fairly easy. Due to the lack of dwarfing rootstocks in the persimmon industry, other means to control vigor are required.

Girdling has been used as a technique to control vigor in various fruit crops including persimmon (Fumuro, 1998, 1997 & 1996, Hasegawa *et al*., 2003). Girdling, scoring and strapping are being investigated as means to control vigor in persimmon under South African conditions.

Plant growth retardants (PGR's) are a diverse group of synthetic compounds that reduce stem elongation (Gianfagna, 1987; Rademacher, 1995). PBZ is used in different pome and stone fruits, citrus, nuts and grapes to reduce vegetative shoot growth (Rademacher, 1995). PBZ also controls vigor in persimmon, but may negatively affect fruit shelf life and may, due to its persistence in the soil, suppress tree growth over a number of years (Ben-Arie *et al*., 1997). Due to these potential negative effects of PBZ, the use of P-Ca is being investigated. P-Ca is effective in controlling vegetative growth on pear (Meintjes *et al*., 2005) and apple (Byers & Yoder, 1999; Greene, 1999; Medjdoub *et al*., 2005), but not 'Redhaven' peach

(Byers & Yoder, 1999). Thus not all species respond to P-Ca. Also, not all pear cultivars responded to P-Ca (Meintjes *et al*., 2005). It remains to be seen whether P-Ca is effective in controlling vegetative growth in persimmon.

RDI and PRD are irrigation techniques used to control vegetative vigor and to improve fruit set and/or quality in peaches (Chalmers, 1989), plums (Intrigliolo & Castel, 2005) and grapevines (Dry *et al*., 1996). Whether these techniques can be applied to persimmon to control vigor and improve fruit set needs to be investigated. No literature is available on the subject of irrigation management in persimmon.

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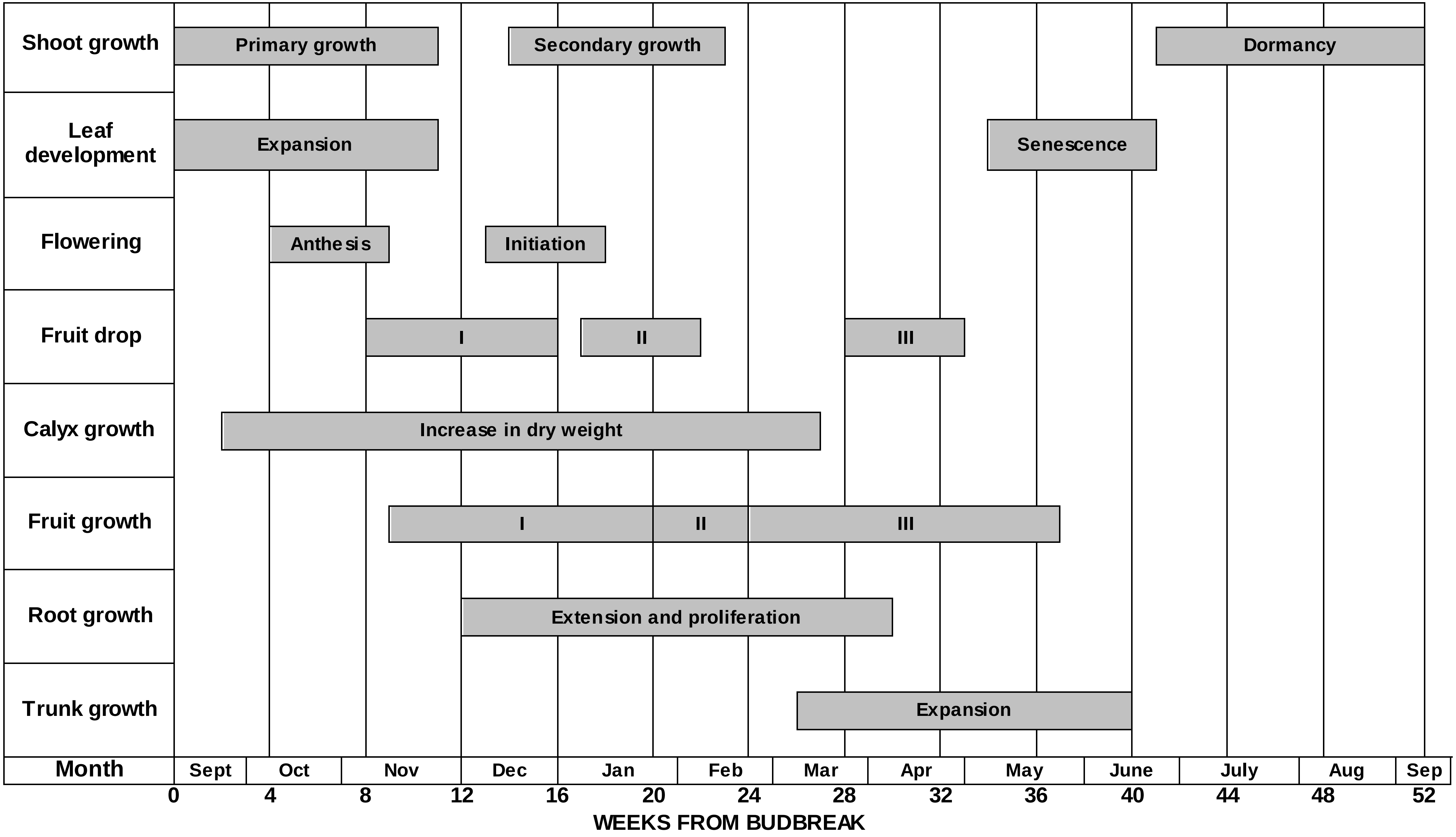

Figure 1: The phenology of the persimmon in the Southern Hemisphere (adapted from Mowat and George,1994).

PAPER 1: EFFECT OF GIRDLING AND PLANT GROWTH REGULATORS ON YIELD OF YOUNG, VIGOROUS ‘TRIUMPH’ PERSIMMON ORCHARDS.

ABSTRACT

Young persimmon orchards in South Africa are often excessively vigorous and slow to come into production. In this paper, we evaluate the use of girdling techniques differing in severity (viz., strapping, scoring, girdling with a hand saw and removal of 5 mm bark) and plant growth retardants, prohexadione-calcium (P-Ca) and paclobutrazol (PBZ), to curtail the vigor, induce flower formation and to increase fruit set and yield in young persimmon orchards. None of the treatments was effective in decreasing vegetative growth and inducing flower formation. Scoring and girdling significantly increased fruit set and yield in the year of application except when few flowers were present on the trees. An increase in fruit numbers and not fruit mass contributed to increases in yield. P-Ca and PBZ did not affect yield, whereas bark removal had a negative effect on yield in the following season, suggesting that this treatment is too severe. Phytotoxic reactions towards P-Ca and PBZ foliar applications were observed. Treatments did not have any major or consistent effect on fruit quality and harvest maturity.

INTRODUCTION

Since 1998, about 700 ha of the pollination variant, astringent, parthenocarpic persimmon cultivar Triumph has been established in the Mediterranean-type climate Western Cape region (32-34º S, 17-20º E, 200-800 m above sea level) of South Africa (Rabe, 2003). South African producers are struggling to obtain early and regular high yields. Many orchards are overly vigorous and show poor flower initiation as well as poor fruit set (Steyn *et al*., 2008). This has a severe effect on the profitability of these orchards.

Excessive vigor has often been cited as antagonistic towards flower bud initiation in temperate fruit trees (Faust, 1989) including apple (Forshey & Elfing, 1989), peach and pear (Chalmers *et al.,* 1984) as well as persimmon (Mowat & George, 1994).

Fruit drop after flowering due to competition for assimilates is an important problem in persimmon (Kitigawa & Glucina, 1984; George *et al.*, 1997). Since the industry lacks clonal dwarfing rootstocks, other means to counter the effects of excessive growth on flower initiation and fruit set have to be found.

Various techniques are available to fruit growers to curtail excessive vegetative growth, to induce flowering and to attain high fruit set. These include various girdling techniques and the application of plant growth retardants (PGR's). Girdling and scoring have been shown to be effective techniques to reduce vegetative growth, promote flowering, improve fruit set, increase fruit size and advance maturity in a wide variety of crops (Goren *et al.*, 2004) including persimmon (Fumuro, 1996, 1997, 1998). Girdling involves the removal of a strip of phloem from the circumference of the trunk or branch and is considered to be a dangerous technique that could result in the death of a tree if the xylem is severed or if the girdle is too wide (Fernandez-Escobar *et al.,* 1987; Goren et al., 2004 Hamada *et al*., 2009). Scoring, i.e., cutting through the phloem with a knife or similar instrument with a narrow blade without removal of any material, is a less aggressive treatment that has increased fruit mass (Juan *et al*., 2009) and fruit set in 'Triumph' persimmon (Steyn *et al*., 2008). Strapping, also referred to as wire-girdling or strangulation, is the use of wire tied around the circumference of the tree and is the least aggressive form of girdling that has been used extensively in persimmon to increase fruit size and total soluble solids (TSS) as well as promote fruit maturation and yield (Hasegawa *et al.*, 1998, 2003; Hamada *et al.,* 2009).

PGR's are a diverse group of synthetic compounds that reduce stem elongation (Evans *et al*., 1999; Rademacher, 1995; Gianfagna, 1987). Prohexadione-calcium (P-Ca), has been evaluated for growth control and subsequent improvement of fruit set, fruit quality and yield in various fruit crops, e.g., apple (Cline *et al.,* 2008; Medjdoub *et al*., 2005; Costa *et al.,* 2004a, Byers & Yoder, 1999), pear (Meintjes *et al., 2005;* Costa *et al.,* 2004b; Theron *et al.,* 2002), peach (Byers & Yoder, 1999) and sweet cherry (Guak *et al*., 2005). Matsumura *et al.* (1992) found that P-Ca inhibited early sprouting in persimmon when applied at bud break to prevent chilling injury. No references could be found as to the application of P-Ca at later stages of shoot growth. Paclobutrazol (PBZ) is used to reduce vegetative shoot growth and alter assimilate partitioning in favor of reproductive growth in various fruit kinds including citrus (Monselise, 1986), nuts and grapes (Rademacher, 1995), apple (Quinlan & Richardson, 1986), pear (Asín *et al.,* 2007), peach (Erez, 1984), mango (Oosthuyse & Jacobs, 1996) and persimmon (Murai, 1992; George *et al.* 1995; Ben-Arie *et al.*, 1997; George *et al*., 2003). PBZ reduces shoot growth (Murai, 1992; George *et al*., 2003) and increase fruit weight (George *et al*., 1995) in persimmon, but fruit set is not affected (George *et al*., 1995). PBZ also advances fruit maturity in persimmon (George *et al*., 2003) and this may have a negative impact on storage life (Ben-Arie *et al.*, 1997).

This paper reports on the efficacy of girdling techniques such as strapping (wire-girdling), scoring, girdling with a Felco saw removing ~2 mm bark and severe girdling entailing removal of 5 mm bark, as well as the use of the PGR's P-Ca and PBZ, to increase fruit set and yield in 'Triumph' persimmon planted on vigorous *D. lotus* and moderately vigorous *D. virginiana* seedling rootstocks. The effect of treatments on vegetative growth and fruit quality was also assessed.

MATERIALS AND METHODS

Planting material and site selection

Trials were conducted on five-year-old 'Triumph' persimmon trees planted at a spacing of 5 m x 2.5 m in Greyton (lat. 34°02' S, long. 19°32' E) during the 2004-05 and 2005-06 seasons and in Vyeboom (lat. 34°05' S, long. 19°02' E) during the 2005-06 season. Both these areas in the Western Cape Province of South Africa have a Mediterranean-type climate. Trees in Greyton and Vyeboom were grafted on vigorous *D. lotus* and the moderately vigorous *D. virginiana* seedling rootstocks, respectively.

Experimental design and treatments

Greyton

During the 2004-05 season, the Greyton trial consisted of seven treatments, viz. a control, trunk strapping, scoring once with a citrus girdling tool, girdling once or twice with a Felco handsaw, and application of P-Ca (Regalis®, 10 % a.i.; BASF plc, Ludwigshafen, Germany) at 125 or 250 mg L^{-1}. Treatments were randomized in seven blocks with two trees per treatment plot. A guard tree separated adjacent plots in the case of chemical treatments.

Scoring, trunk strapping and the first girdle were applied approximately 225 mm above the bud union 3 weeks before full bloom (FB) on 12 October 2004. A second saw girdle was applied approximately 30 mm above the first girdle at FB (2 November 2004) for the treatment that was girdled twice. In the strapping treatment, binding wire (2 mm diameter) was wound around the trunk twice and tightly secured with pliers. The wires were removed on 24 May 2005, coinciding with leaf drop. P-Ca was applied four weeks after bud break on 12 November 2004 when average shoot length was 30 - 40 cm and again 30 days later on 12 December 2004. Applications were done with motorized handguns attached to a vehicle mounted spray pump. Approximately 5 liters of spray mixture was applied per tree. Agral 90® (90 % Nonylphenoxy-poliethyoxy ethanol; Syngenta, Basel, Switzerland) was used as wetting agent at a rate of 10 ml 100 L^{-1} water in all spray treatments.

During the 2005-06 season, the two-tree treatment plots in Greyton were randomly split into single tree plots with one tree left untreated for the second season. The same seven treatments of 2004-05 were repeated on the second tree with the exception that a second score and girdle were added to the treatments that were scored or girdled only once in 2004-05 and a third girdle added to the treatment that consisted of girdling twice in 2004-05. The additional score and girdle were applied three weeks after FB (21 November 2005). P-Ca spray treatments were applied at 30 - 40 cm shoot length (15 November 2005), 21 days later on 6 December 2005 and again 14 days later on 20 December 2005.

Vyeboom

Treatments were applied during the 2005-06 season and consisted of a control, trunk strapping with 2 mm wire, three 2 mm girdles applied with a Felco handsaw, 5 mm bark removal, PBZ (Cultar®, 25 % a.i.; Syngenta, Basel, Switzerland) soil drench at 4 or 8 ml dissolved in 2 L water per tree, PBZ foliar application at 1000 mg L^{-1}, and P-Ca application at 125 or 250 mg L^{-1} applied three times as foliar spray. These nine treatments were randomized in 12 single tree plots with guard trees left adjacent to all chemical treatments. Trunk strapping, 5 mm bark removal and the first girdle with the Felco saw were applied 3 weeks before FB on 12 October 2005 approximately 150 mm above the bud union. The second Felco saw girdle was applied at FB (1 November 2005) and the third girdle three weeks later on 22 November 2005. Girdles were spaced at least 30 mm apart. PBZ soil drenches were applied on a 1 m^2 area around the tree 3 weeks before FB. The foliar sprays of PBZ and P-Ca were applied on the same dates as the spray treatments in Greyton.

Data collection

At the Greyton trial site, initial trunk diameters were recorded approximately 150 mm above the bud union before bud break and application of treatments on 15 September 2004. Trunk diameter was again measured after leaf drop on 25 May 2006. At Vyeboom, trunk diameter was measured 75 mm above the bud union on 22 September 2005 and again on 31 May 2006.

To determine fruit set, one branch per tree was selected and the flowers counted at FB (end of October 2005 and 2006). The fruit set percentage was determined at the end of the fruit drop period (end of December) by revisiting the selected branches and counting the remaining fruit. Trees were strip picked at the onset of commercial harvest (during April 2005, 2006), fruit were weighed and a sample of 20 fruit per tree used to determine average fruit size and mass, fruit colour, firmness and TSS. Fruit color was assessed using a color chart for astringent persimmon with values 1-8, where 1= red/orange and 8 = green (Plant Protection and Inspection Services (PPIS), Bet-Dagan, Israel). Firmness was determined on pared, opposite cheeks of the fruit using a bench mounted GÜSS fruit texture analyzer (GS, GÜSS Manufacturing (Pty.) Ltd., Strand, South Africa) with a 11.1 mm tip. Fruit flesh were pooled per plot, juiced and TSS recorded with a hand held refractometer (Atago Model PR32, ATAGO Co. Ltd., Tokyo, Japan). The same procedure was followed at both sites.

The diameter of branches used to determine fruit set was measured 30 - 40 mm from the crotch angle after leaf drop on the same dates as measurement of trunk diameter. All the one-year-old shoots on the branch were counted and their length measured.

Statistical analysis

Statistical analysis of the data was performed with the General Linear Models (GLM) procedure of the Statistical Analysis System (SAS, Version 9.1, SAS Institute Inc., 2002-03, Cary, NC).

RESULTS

Phytotoxicity of PGR foliar applications

Foliar symptoms of phytotoxicity were observed after foliar application of PBZ at Vyeboom and P-Ca at both Vyeboom and Greyton (Figure 1). Symptoms consisted of chlorosis, reddening and malformation of new growth and scorching of leaf margins of older leaves. Affected shoots appeared to be thinner than unaffected shoots. Symptoms were more pronounced at Vyeboom and in 2005-06 in Greyton.

Flowering and fruit set

None of the treatments increased fruit set percentage compared to the control in 2004-05 at Greyton (Table 1) and at Vyeboom in 2005-06 and 2006-07 (when trees were left untreated) (Table 2). Trees treated in 2004-05 at Greyton did not differ from the control in flower number or fruit set in 2005-06. However, strapping and girdling for a second season in 2005-06 at Greyton increased fruit set significantly compared to the control, P-Ca application and treatment in 2004-05 only (Table 1). Flower number was not assessed in 2006-07 at Greyton.

Yield

At Greyton, none of the treatments had an effect on yield in the first season of application (2004-05) (Figure 2). In 2005-06, significant interaction was found between treatments and whether or not they were repeated (Figure 2). Trees that were treated in 2004-05 only did not differ significantly in yield from the control in 2005-06. Scoring in 2005-06 increased yield compared to all treatments while girdling three times in 2005-06 increased yield compared to all treatments except for girdling twice in 2005-06. The latter treatment increased yield compared to P-Ca and the control. Strapping and P-Ca application in 2005-06 did not affect yield. Scoring in both seasons increased cumulative yield compared to all treatments except for girdling twice in 2004-05 plus three times in 2005-06. This latter treatment increased cumulative yield compared to all other treatments except for scoring in 2004-05 and girdling once in 2004-05 plus twice in 2005-06. None of the other treatments increased cumulative yield compared to the control while application of 125 mg L^{-1} P-Ca in both 2004-05 and 2005-06 decreased cumulative yield compared to the control.

At Vyeboom, girdling three times with a Felco saw increased yield in 2005-06 compared to all treatments except for bark removal and PBZ drench (Figure 3). Girdling three times and bark removal increased yield compared to the control. P-Ca significantly decreased yield compared to all other treatments (Figure 3). Bark removal in 2005-06 decreased yield in 2006-07 compared to all treatments except for girdling and PBZ drench at 4 ml per tree. P-Ca application at 125 mg L^{-1} in 2005-06 increased yield in 2006-07 compared to all treatments except for P-Ca at 250 mg L^{-1}. This latter treatment increased yield compared to bark removal, girdling and PBZ drench at 4 ml per tree. None of the treatments significantly increased cumulative yield compared to the control.

Fruit mass and fruit number

In 2004-05, treatments did not significantly affect fruit number or fruit mass at Greyton (data not presented, see addendum A). Scoring twice in 2005-06 increased fruit number compared to all treatments while girdling three times in 2005-06 increased fruit number compared to all other treatments except for girdling twice (Table 3). Girdling twice also increased fruit number compared to the control, strapping and P-Ca. Girdling in 2005-06 decreased fruit mass compared to all treatments except for scoring while scoring decreased fruit mass compared to the control, strapping, P-Ca and 2004-05 treatments, except for girdling once. Strapping in 2005-06 decreased fruit mass compared to the control and P-Ca at 250 mg L^{-1}.

At Vyeboom, P-Ca application in 2005-06 decreased fruit number, but increased fruit mass compared to all other treatments (Table 4). Bark removal, girdling and PBZ drench at 8 ml per tree also increased the fruit number per tree, but had no effect on fruit mass. Bark removal increased fruit number compared to strapping and PBZ foliar application while girdling and PBZ drench at 8 ml per tree increased fruit number compared to the PBZ foliar application. P-Ca application in 2005-2006 increased fruit numbers in 2006-07 compared to all treatments. None of the other treatments differed from the control in 2006-07. Treatment in 2005-06 had no effect on fruit mass in 2006-07.

TSS, firmness and color

At Greyton, treatments had no effect on fruit color (data not presented, see addendum A). Significant interaction was found between treatments and whether or not they were repeated. However, results were inconsistent and made no apparent logical sense (data not presented, see addendum A). At Vyeboom, the most severe treatments, viz. bark removal and girdling three times with a hand saw, significantly decreased TSS (Table 5). According to colour chart, PBZ drench and foliar application, in particular, seemed to advance fruit maturity. Although not statistically significant, foliar application of PBZ also seemed to decrease fruit firmness.

Vegetative growth

Treatments did not significantly affect trunk diameter or one-year-old shoot growth at Vyeboom (data not presented, see addendum A). Trunk diameter also did not differ at Greyton, but P-Ca at 125 mg L^{-1} increased total one-year-old shoot growth in 2005-06 compared to the control (Table 6). P-Ca at both concentrations also increased one-year-old shoot growth compared to trees that were girdling once in 2004-06 and twice in 2005-06.

DISCUSSION

Strapping, scoring, girdling and bark removal have been found to be effective in promoting flowering, fruiting and yield in persimmon (George *et al.,* 1997; Hasegawa *et. al*., 2003; Hamada *et al.* 2009; Steyn *et al*., 2008) as well as in other fruit kinds (Goren *et al.,* 2004). In the extremely vigorous and unproductive ‘Triumph’ orchard on *D. lotus* at Greyton*,* none of the treatments was effective in increasing fruit set and yield in the first season of application (2004-05). Trees on *D. lotus* rootstock are known to be very vigorous and prone to excessive fruit shedding (Hodgson, 1939; Schroeder, 1950). According to Hodgson (1939), ‘Hachiya’ persimmon trees grafted to *D. lotus* produce enough flowers, but fruit abscission is severe, especially in young orchards, possibly due to excessive vigor. However, the trees on *D. lotus* at Greyton produced very few flowers in 2004-05 (personal observation) and this may be a reason for the apparent ineffectiveness of treatments to increase set and yield during this season. The low flower numbers are most likely due to severe pruning during the preceding dormant period. In the subsequent season when trees flowered more profusely, scoring and girdling twice or three times significantly improved fruit set whereas strapping was not effective. The less vigorous and higher yielding 'Triumph' orchard on *D. virginiana* rootstock at Vyeboom also showed an increase in yield in response to girdling and bark removal while strapping again was ineffective. The effect of scoring and girdling is consistent with our previous research on 'Triumph' on *D. virginiana* rootstock (Steyn *et al*., 2008) and with Naito *et al.* (1981) who found that girdling improves flower number, fruit set and number of fruit per tree as well as yield in 'Saijo' persimmon. The efficacy of scoring compared to other treatments to increase fruit set and yield in the vigorous *D*. *lotus* orchard suggests that vigorous 'Triumph' orchards can be induced to produce high yields without the need for severe treatments to curtail growth. None of our treatments, including severe girdling or PBZ application, increased return bloom. P-Ca application in Greyton in 2004-05 increased one-year-old shoot growth compared to the control in 2005-06, most likely due to the negative effect of P-Ca on yield in this season.

In contrast to our results, Hasegawa *et al.* (2003) found that strapping increased fruit set, fruit number and yield in non-astringent persimmon cv. Matsumotowase Fuyu when applying 2.6 mm insulated wire for 75 days from 2 weeks before FB or from FB. The same result was found in 'Taishu' persimmon upon strapping for 60 days from before FB with 2 mm wire (Hasegawa *et al*., 2009). Strapping before FB was more effective than at FB. It is possible that strapping in Japan also has a limited effect on fruit set, but decreases subsequent fruit drop, which can be severe in persimmon (Mowat and George, 1994). In South Africa, the fruit set period seems to be of primary importance in determining final crop. Strapping may have proved more effective if left on the tree for more than one season.

Bark removal in 2005-06 decreased yield in the subsequent season suggesting that this severe treatment had a negative effect on tree health and reproductive development. Bark removal also decreased the TSS of fruit in the season of application. Lahav *et al.* (1971) reported that some avocado trees were seriously weakened and even killed and that yield was decreased after application of a 10 - 20 mm girdle on the main trunk. Contrary to these results, Fumuro (1998) found that a 5 mm as well as 10 mm wide trunk girdle 23 and 34 days before FB had little or no effect on yield in ‘Nishimurawase’ persimmon in either of the two seasons in which the treatments were applied.

Trees showed symptoms of phytotoxicity in response to P-Ca treatment, particularly at Vyeboom where the number of fruit per tree as well as yield were significantly decreased in the season of application. At Vyeboom, P-Ca did not affect yield in 2004-2005, but yield was considerably reduced in 2005-06 irrespective of whether or not application was repeated. P-Ca is used to decrease vegetative growth in apple (Cline *et al.,* 2008; Costa *et al*., 2004a; Byers and Yoder, 1999; Greene, 1999) and pear (Asin & Dalmau, 2005; Maas, 2005; Meintjes *et al.,* 2005; Asín *et al.*, 2007) without any adverse effects on yield. Meintjes *et al.* (2005) used these same rates of application and found significant increases in fruit set in ‘Rosemarie’ pear. Byers and Yoder (1999) used rates of up to 500 mg L^{-1} on ‘Starcrimson’ apple without any negative phytotoxic effects while Le Roux (2006) used P-Ca at rates of up to 400 mg L^{-1} on citrus without any negative effects. P-Ca did not have any apparent effect on shoot growth in ‘Triumph’ persimmon, except for indirectly stimulating shoot growth by decreasing the return crop at Greyton. Some fruit species, such as peach do not react to P-Ca (Byers & Yoder, 1999). At Vyeboom, P-Ca treated trees set a big crop in the following season, when applications were not repeated. This can possibly be ascribed to the low yield in the previous season, inducing a typical alternate bearing cycle. Accumulation of reserves during the ‘off’ year promotes heavy flowering in the following year (Mowat & George, 1994), leading to increased fruit set and fruit numbers per tree.

PBZ foliar application at 1000 mg L^{-1} also induced phytotoxicity at Vyeboom. Previously, George *et al*. (1995) and Murai (1992) reported no ill effects of foliar PBZ application at up to 2000 mg L^{-1} on persimmon. In fact, Murai (1992) found that foliar application of PBZ at 500, 1000 and 1500 mg L^{-1} increased fruit set in ‘Saijo’ persimmon in Japan. However, George *et al.* (1995) found that 2000 mg L^{-1} PBZ applied to the terminal 4 nodes of persimmon shoots before and after anthesis in Australia had no effect on fruit set, but increased fruit size. Erez (1984) found that

PBZ increased fruit size in peach while Oosthuyse and Jacobs (1996) found that fruit weight, but not fruit number or yield, was increased in ‘Sensation’ mango. For ‘Tommy Atkins’ mango, Oosthuyse and Jacobs (1996) reported a decrease in all these parameters in relation to the concentration of soil-applied PBZ. They concluded that these contrasting results between mango cultivars appear to relate to a difference in responsiveness to PBZ. Since PBZ did not affect fruit set, yield and fruit size in our trial, it may well be that persimmon cultivars also respond differentially to PBZ. The apparent ineffectiveness and possible phytotoxic effects P-Ca and PBZ cast doubt on the use of these chemicals to enhance reproductive development and to improve fruit set and yield in ‘Triumph’ persimmon in South Africa.

Fruit size and number of fruit per tree are the two components that influence the final yield of an orchard. Fruit size has become increasingly important in determining the profitability of an orchard (Atkins, 1990). Crop load (number of fruit per tree) influences the fruit size and the higher the crop load, the greater the number of fruit that falls into smaller fruit grade sizes (Rowe and Johnson, 1992). It is thus important to quantify the effect of the different treatments on fruit size. At Vyeboom in 2005-06, girdling, bark removal and PBZ drench at 8 ml per tree increased fruit numbers without affecting fruit size negatively, while at Greyton an increase in fruit number with scoring and girdling resulted in a decrease in mean fruit mass. A decrease in fruit number in 2006-07 after bark removal in 2005-06 was not accompanied by an increase in mean fruit size, again indicating that the health of trees was impaired by this severe treatment. The reduction in the TSS of fruit in 2005-06 suggests that bark removal had a negative effect on photosynthesis and the reserve status of the trees. Naito *et al*. (1981) found that girdling increased fruit per tree as well as fruit size in ‘Saijo’ persimmon. In contrast, Steyn *et al*. (2008) reported a decrease in fruit size of ‘Triumph’ persimmon in response to an increase in fruit numbers due to scoring and girdling.

Treatment effects on TSS at Greyton were inconsistent while at Vyeboom none of the treatments increased TSS compared to the control. In contrast, Hasegawa *et al*. (2009) found that wire-girdling (strapping) increased TSS in ‘Taishu’ persimmon while Arakawa *et al*. (1997) found that bark removal increased TSS in four apple cultivars. As our girdling treatments were applied early in the season, it is possible that it did not have a significant effect on carbohydrate partitioning because carbohydrates are not translocated from the above ground parts to the roots early in the season (Theron and Steyn, 2008). However, wire-girdling ‘Taishu’ persimmon for one month from before FB increased TSS at harvest (Hasegawa *et al.*, 2009). The lack of an effect of P-Ca and PBZ on TSS is in agreement with results for P-Ca in apple (Costa *et al.* 2004a) and pear (Costa *et al.* 2004b) and for PBZ in persimmon (Murai, 1992).

An early soil application of PBZ has been used to advance ripening in ‘Triumph’ persimmon in Israel (Ben-Arie *et al*., 1997) while girdling (Hasegawa *et al.*, 2009) and scoring (Juan *et al.*, 2009) increased the color of persimmon at harvest. Our results suggest that PBZ, especially when applied at 1000 mg L^{-1} as foliar spray, also advance ‘Triumph’ color development in South Africa. Girdling treatments and P-Ca did not affect fruit maturity.

Shoot growth and trunk growth have been used as measures of tree growth and size in various crops such as apple (Asín *et al.,* 2007, Greene, 1999), pear (Maas, 2005), citrus (Monselise, 1986) as well as persimmon (Kim *et al.*, 2003; Tetsumura *et al.* 1999; Yakushiji *et al.*, 2008). Fumuro (1998) found that girdles of 5 mm width, 10 cm above ground level applied 23 days and 34 DBFB inhibited both shoot and trunk growth of ‘Nishimurawase’ persimmon. The earlier trees were girdled, the greater the growth inhibition. Fumuro (1998) concluded that trunk girdling during early shoot elongation has a dwarfing effect on persimmon and ascribed this to a reduction in dry matter production due to smaller leaves and by inhibition of root functions. Matsumura *et al.* (1992) found that P-Ca applied at budbreak delayed sprouting of ‘Fuyu’ persimmon, but does not report on the effect on total shoot growth. Murai (1992) found that PBZ foliar application inhibited shoot growth in ‘Saijo’ persimmon and according to George *et al.* (2003). PBZ has been found to decrease non-astringent persimmon tree growth by about 20%. In contrast, our PBZ treatments did not affect shoot growth or trunk growth. It is not certain why none of the treatments at Greyton and Vyeboom decreased trunk and one-year-old shoot growth either directly or through increasing crop load.

CONCLUSION

Scoring and girdling were effective in improving fruit set and yield in two vigorous young orchards and can be recommended as tools to improve yield in 'Triumph' persimmon. Strapping, P-Ca and PBZ did not affect yield whereas 5 mm bark removal was too severe a treatment and negatively affected fruit quality in the season of application and yield in the subsequent season. None of the treatments decrease vegetative growth. The ineffectiveness of PBZ and P-Ca to induce early production as well as the phytotoxic damage to vegetative growth and resultant decrease in yield in response to P-Ca, may limit their use on 'Triumph' persimmon in South Africa. However, PBZ, especially as foliar spray, seemed to advance color development. Further research is required to assess the effect of scoring, girdling and PGR treatments on flower formation in vigorous 'Triumph' persimmon. Further work is also needed to verify the effect of PBZ on fruit maturity and the lack of an effect of PBZ and P-Ca on return bloom and vegetative growth.

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Table 1: The effect of girdling, strapping and prohexadione-Ca (P-Ca) on flowering and fruit set in 'Triumph' persimmon on *D. lotus* rootstock in the Greyton area of the Western Cape province, South Africa during the 2004-05 and 2005-06 seasons. Means were separated by LSD at the 5% level.

Treatment	Repeat[w]	Fruit Set % 2004-05	Number of Flowers[x] 2005-06	Fruit Set %[y] 2005-06
Control	1	1.6[ns]	1.0[ns]	1.6 cd
Control	2	1.6	1.3	0.0 d
Strapping	1	2.2	0.7	7.3 cd
Strapping	2	2.2	0.5	23.7 ab
Scoring	1	5.6	1.7	5.6 cd
Scoring	2	5.6	1.2	15.4 bc
Girdling A[Z]	1	2.4	2.5	2.4 cd
Girdling A[Z]	2	2.4	1.5	37.7 a
Girdling B[Z]	1	2.1	1.4	2.1 cd
Girdling B[Z]	2	2.1	1.5	22.4 b
P-Ca 125 mg L^{-1}	1	5.1	0.6	5.1 cd
P-Ca 125 mg L^{-1}	2	5.1	0.8	0.7 d
P-Ca 250 mg L^{-1}	1	0.0	0.3	0.0 d
P-Ca 250 mg L^{-1}	2	0.0	0.4	0.0 d
		Pr>F		
Treatment		0.1068	0.1525	0.0175
Repeat		.	0.7641	0.0210
Treatment x Repeat		.	0.7107	0.0008

[ns] Non significant

[w] Treatment applied in 2004-2005 only (1) or in both 2004-2005 and 2005-2006 (2)

[x] Number of flowers per 30 cm shoot length counted at full bloom.

[y] Means followed by the same letter do not differ significantly at Pr>F = 0.05

[Z] Girdled once in 2004-2005 and twice in 2005-2006 (A) or twice in 2004-2005 and three times in 2005-2006 (B).

Table 2: The effect of girdling, strapping, paclobutrazol (PBZ) and prohexadione-Ca (P-Ca) on flowering and fruit set in 'Triumph' persimmon on *D. virginiana* rootstock in the Vyeboom area of the Western Cape province, South Africa during the 2005-06 and 2006-07 seasons. Treatments were applied in 2005-06 only. Means were separated by LSD at the 5% level.

Treatment	Fruit Set % 2006	Fruit Set % 2007
Control	35.3^{ns}	39.1^{ns}
Strapping	27.8	35.4
Girdling 3	23.7	46.4
Bark removal	45.6	40.5
PBZ drench 4 ml	33.8	37.7
PBZ drench 8 ml	17.3	40.7
PBZ 1000 mg L^{-1}	40.8	45.2
P-Ca 125 mg L^{-1}	29.8	38.0
P-Ca 250 mg L^{-1}	22.5	26.4
	Pr>F	
Treatment	0.2258	0.9092

^{ns} Non significant

Table 3: The effect of strapping, scoring, girdling and prohexadione-Ca (P-Ca) on number of fruit per tree and fruit mass in 'Triumph' persimmon on *D. virginiana* rootstock in the Greyton area of the Western Cape province, South Africa during the 2005-06 season. Means were separated by LSD at the 5% level.

Treatment	Repeat[y]	Number of fruit per tree 2005-06[z]	Mean fruit mass (g) 2005-06
Control	1	86 ab	205 fg
Control	2	38 a	204 efg
Strapping	1	98 ab	184 cdef
Strapping	2	111 ab	171 cd
Scoring	1	108 ab	178 cde
Scoring	2	359 e	139 ab
Girdling A[x]	1	150 bc	165 bc
Girdling A[x]	2	208 cd	138 a
Girdling B[x]	1	72 ab	190 cdef
Girdling B[x]	2	249 d	138 a
P-Ca 125 mg L^{-1}	1	60 ab	183 cdef
P-Ca 125 mg L^{-1}	2	22 a	194 defg
P-Ca 250 mg L^{-1}	1	37 a	203 efg
P-Ca 250 mg L^{-1}	2	22 a	217 g
	Pr>F		
Treatment		<0.0001	0.0670
Repeat		0.0028	0.0041
Treatment x Repeat		0.0002	0.0073

[x] Girdled once in 2004-05 and twice in 2005-06 (A) or twice in 2004-05 and three times in 2005-06 (B).

[y] Treatment applied in 2004-05 only (1) or in both 2004-05 and 2005-06 (2)

[z] Means followed by the same letter do not differ significantly at the 5% level

Table 4: The effect of girdling, strapping, paclobutrazol (PBZ) and prohexadione-Ca (P-Ca) on number of fruit per tree and fruit mass in 'Triumph' persimmon on *D. virginiana* rootstock in the Vyeboom area of the Western Cape province, South Africa during the 2005-06 and 2006-07 seasons. Treatments were applied in 2005-06 only. Means were separated by LSD at the 5% level.

Treatment	Number of fruit per tree 2005-06	Mean fruit mass (g) 2005-06	Number of fruit per tree 2006-07	Mean fruit mass (g) 2006-07
Control	216 dc	172 b	317 bc	176^{ns}
Strapping	226 bcd	187 b	350 b	157
Girdling	313 ab	177 b	296 bc	148
Bark removal	335 a	172 b	190 c	144
PBZ drench 4 ml	252 abcd	173 b	257 bc	164
PBZ drench 8 ml	271 ab	182 b	314 bc	167
PBZ 1000 mg L^{-1}	182 d	173 b	318 bc	150
P-Ca 125 mg L^{-1}	63 e	225 a	494 a	139
P-Ca 250 mg L^{-1}	46 e	220 a	491 a	129
		Pr>F		
Treatment	<.0001	<.0001	0.0026	0.4395

[z] Means followed by the same letter do not differ significantly at the 5 % level.

ns = non significant

Table 5: The effect of girdling, strapping, paclobutrazol (PBZ) and prohexadione-Ca (P-Ca) on fruit quality and maturity in 'Triumph' persimmon on *D. virginiana* rootstock in the Vyeboom area of the Western Cape province, South Africa in the 2005-06 season. Means were separated by LSD at the 5% level.

Treatments	Total soluble solids (ºBRIX)	Colour chart[y]	Firmness (kg)
Control	18.7 a[z]	4.3 abc	6.1[ns]
Strapping	18.6 ab	4.5 ab	7.8
Girdling	17.6 cd	4.4 abc	8.0
Bark removal	17.2 d	4.4 abc	6.9
PBZ drench 4 ml	17.9 abcd	4.1 cd	6.1
PBZ drench 8 ml	18.7 a	4.2 cd	6.0
PBZ 1000 mg L^{-1}	17.7 bcd	3.9 d	5.4
P-Ca 125 mg L^{-1}	17.7 bcd	4.2 bc	6.6
P-Ca 250 mg L^{-1}	18.0 abc	4.6 a	8.1
		Pr>F	
Treatment	0.0072	0.0005	0.0753

ns = non significant

[y] 1-8 where 1 = red/orange, 8 = green (PPIS, Grabouw)

[z] Means with the same letter do not differ significantly at p<0.05.

Table 6: The effect of strapping, scoring, girdling and prohexadione-Ca (P-Ca) on vegetative growth in 'Triumph' persimmon on *D. lotus* rootstock in the Greyton area of the Western Cape province, South Africa during the 2004-05 and 2005-06 seasons. Means were separated by LSD at the 5 % level.

Treatments combinations	Total shoot growth (m) 2004-05	Trunk diameter (mm) 2005-06	Total shoot growth (m) 2005-06
Treatment			
Control	0.94^{ns}	88.0^{ns}	0.95 bc^{z}
Strapping	1.46	87.3	1.19 abc
Scoring	1.04	83.5	1.18 abc
Girdling A^{x}	0.72	81.4	0.87 c
Girdling B^{x}	1.19	85.0	1.06 bc
P-Ca 125 mg L^{-1}	1.22	87.4	1.41 a
P-Ca 250 mg L^{-1}	1.02	86.8	1.30 ab
Repeat^{y}			
No	-	86.2^{ns}	1.15^{ns}
Yes	-	85.0	1.13
		Pr>F	
Treatment	0.2676	0.4498	0.0389
Repeat	-	0.5212	0.3787
Treatment x Repeat	-	0.1729	0.5855

ns = non significant

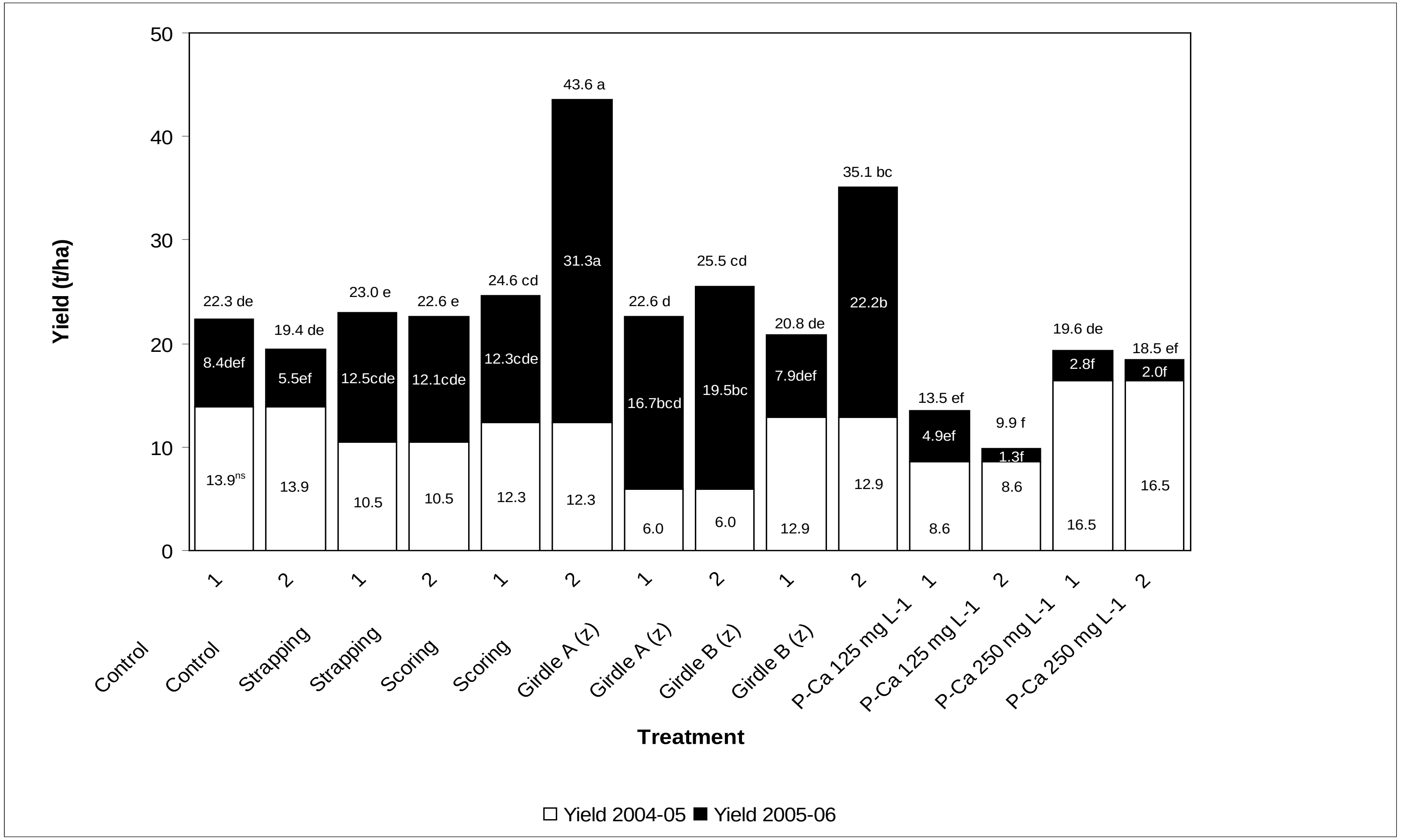
[x] Girdled once in 2004-05 and twice in 2005-06 (A) or twice in 2004-05 and three times in 2005-06 (B).

[y] Treatment applied in 2004-05 only (No) or in both 2004-05 and 2005-06 (Yes)

[z] Means with the same letter do not differ significantly at $p<0.05$.

(a) (b)

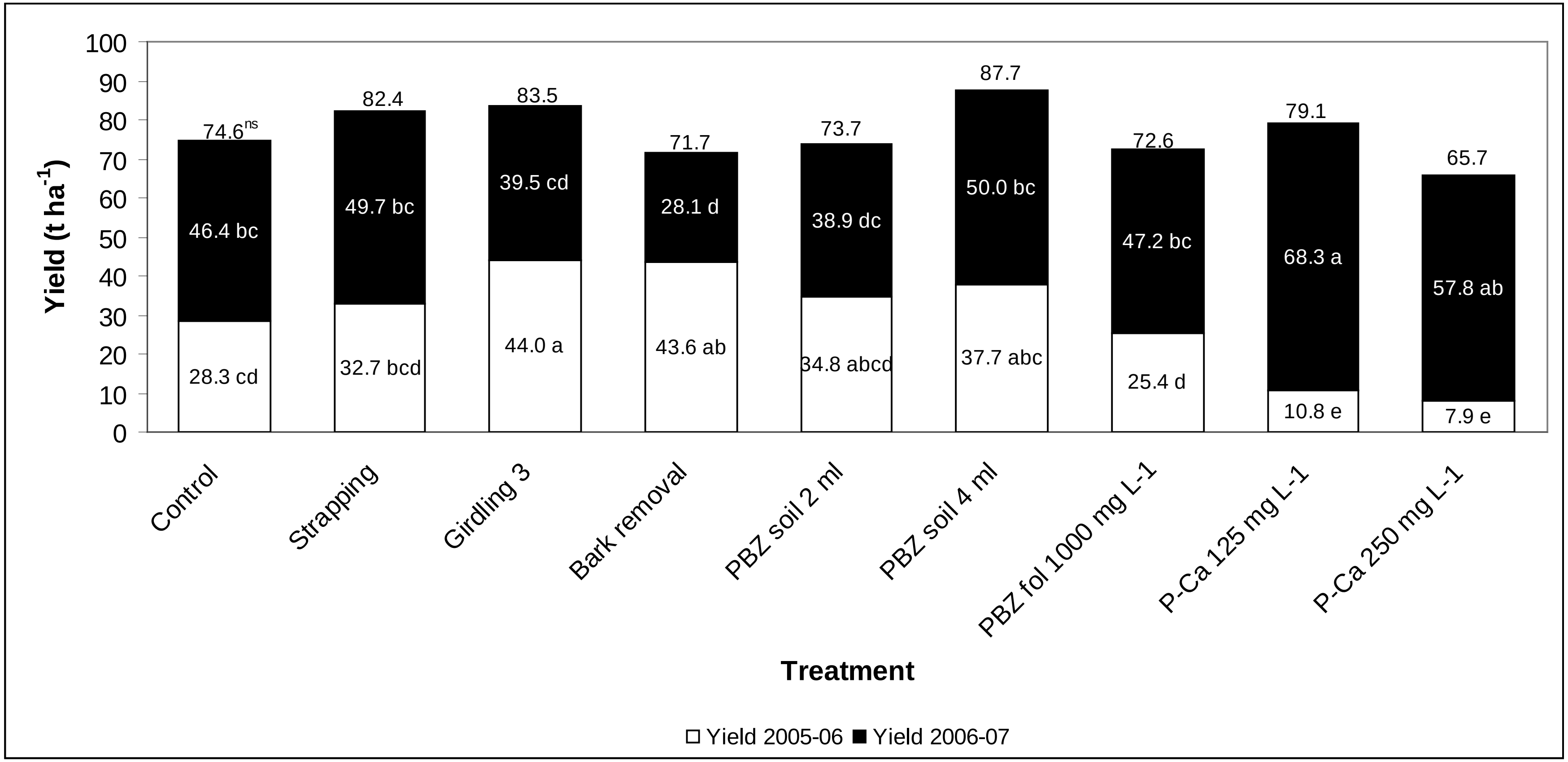
Figure 1. Phytotoxicity symptoms in response to two applications of prohexadione-Ca (P-Ca) at 250 mg L^{-1} (a) and one application of paclobutrazol PBZ at 1000 mg L^{-1} (b) in ‘Triumph’ persimmon in the Vyeboom area of the Western Cape Province, South Africa.



^{z} Girdled once in 2004-05 and twice in 2005-06 (A) or twice in 2004-05 and three times in 2005-06 (B).

Pr>F	**Yield 2005 (t ha^{-1})**	**Yield 2006 (t ha^{-1})**	**Cumulative yield 2005-06 (t ha^{-1})**
Treatment	0.7642	<0.0001	0.2108
Repeat	.	0.0203	0.0203
Treatment x Repeat	.	0.0028	0.0027

Figure 2. The effect of strapping, scoring, girdling and prohexadione-Ca (P-Ca) on yield in 'Triumph' persimmon on *D. lotus* rootstock in the Greyton area of the Western Cape province of South Africa over two seasons (2004-05 & 2005-06). Means are separated by LSD at the 5% level. Means followed by the same letter are not significantly different.



Pr>F	**Yield 2005-06 (t ha^{-1})**	**Yield 2006-07 (t ha^{-1})**	**Cumulative yield (t ha^{-1})**
Treatment	<0.0001	0.0015	0.3879

Figure 3. Effect of strapping, scoring, girdling x3, 5 mm bark removal, paclobutrazol (PBZ) and prohexadione-Ca (P-Ca) on yield in 'Triumph' persimmon on *D. virginiana* rootstock in the Vyeboom area of the Western Cape province of South Africa over two seasons (2005-06 & 2006-07). Treatments were applied in 2005-06 only. Means are separated by LSD at the 5% level. Means followed by the same letter are not significantly different.

PAPER 2: EFFECT OF IRRIGATION AND NUTRIENT LEVEL ON VEGETATIVE GROWTH AND FRUITING IN 'TRIUMPH' PERSIMMON.

ABSTRACT

A water and fertilizer application trial was conducted on 'Triumph' persimmon (*Diospyros kaki* Thunb.) grafted to *D. virginiana* seedling rootstock to assess the effect on vegetative growth, fruit set, fruit quality and yield. Water was applied at three levels, viz. ½X, X and 2X where X represents the water application rate in the rest of the orchard, either with or without fertilizer and based on the water holding capacity of the soil. Water application rate had no effect on leaf nitrogen levels, whereas higher fertilizer application rates increased leaf nitrogen. None of the treatments affected flower initiation or fruit set. Higher irrigation levels increased vegetative growth whereas increased fertilizer application had a lesser effect. Average fruit mass and yield per tree increased linearly with an increase in water application rate. It would seem that high irrigation levels may be beneficial in young persimmon orchards to increase both vegetative growth and early yield. However, the effect of increased irrigation on fruit storability needs to be assessed. Increasing irrigation level led to a decrease in fruit firmness and advanced fruit color while an increase in fertilizer level had the opposite effect. The management of irrigation and fertilizer application rate to advance or delay harvest maturity requires further research. It is expected that the effects of reduced water and fertilizer rates will become more evident as the orchard becomes older.

INTRODUCTION

The persimmon industry in South Africa is still in its infancy, with about 700 ha established mostly in the Mediterranean-type climate Western Cape region (32-34° S, 17-20° E, 200-800 m above sea level) (Rabe, 2003). Most orchards are less than five years old and producers are unfamiliar with the persimmon tree and still unsure about how to manage new orchards in order to maximize profits.

When establishing new orchards, the challenge is to find the right balance between vegetative growth and reproductive growth to first fill allotted tree space and then attain maximum yield within the shortest possible time. It is of the utmost importance to bring fruit trees into production within the first 3-4 years to ensure positive cash flow (Lang, 2001). To achieve this, the trees' allotted space needs to be filled as quickly as possible. Arguably the two most important external factors that influence the growth of plants and which can be controlled by the grower are the supply of nutrients, especially nitrogen (N), and water. Shackel *et al.* (1999) found that a combination of increased N and irrigation increased vigor in 'Bartlett' pear. Combining high N and water application rates increases vegetative growth of young trees, allowing them to fill their allotted space more quickly and to sooner achieve full production.

Unfortunately these same factors that increase growth to fill space may negatively affect flower initiation and fruit set (Kirda *et al*., 1999; Saenz *et al*., 1997). The principal yield components in fruit trees are fruit number (i.e., fruit set) per tree and fruit mass at maturity (Saenz *et al.,* 1997). Reproductive bud initiation and differentiation of persimmon takes place over a two month period from approximately end December to end February in the Southern hemisphere (Mowat & George, 1994). Excessive shoot growth may compete with and adversely affect bud initiation in peach, pear (Chalmers *et al.,* 1984) and Saskatoon berries (St-Pierre, 2008). Excessive N may increase fruit abscission in persimmon (Suzuki et al., 1989), but low levels may be equally detrimental to fruit set (George *et al*., 1997). For example, Ooshiro *et al.* (1999) found that flower number as well as yield were lower in 'Maekawa Jiro' persimmon trees not fertilized with N than in trees that did receive N applications. Water stress in combination with high temperatures can have a negative impact on flower formation (George *et al*., 1997). However, Chalmers *et al.* (1984) found that the vegetative growth of peach and pear trees was decreased by 80% and 70%, respectively, when their daily water allocation was reduced to 12.5% and 25% of the evaporation from a class A pan during the early stages of fruit growth without negatively affecting fruit size and number. Yield per hectare was increased by up to 30% with moderately severe drought.

N fertilization and irrigation levels also affect fruit quality. N fertilization has a positive influence on fruit mass in peach by prolonging the fruit development period (Saenz *et al*., 1997). Choi *et al.* (2009) found that high N application rates delays fruit ripening in peach and inhibit color formation in 'Fuyu' persimmon. Cui *et al.* (2008) found that firmness, total soluble sugars (TSS), sugar/acid ratio and vitamin C content of jujube fruit were enhanced as a result of deficit irrigation while fruit mass and volume were not negatively affected. Zegbe-Domínguez *et al.* (2003) found that TSS was higher and red color was promoted in tomato under partial root zone drying and deficit irrigation, thereby advancing harvest maturity by one week. The manipulation of fruit ripening by means of fertilization and irrigation may be advantageous to the South African persimmon industry with its restricted harvesting and marketing windows.

It is clear that the correct application of fertilizer (N) and irrigation is critical in controlling fruit set and vigor. The objective of this trial was to establish the optimum application rates of water and fertilizer for 'Triumph' persimmon under South African conditions that would ensure balanced vegetative growth to fill tree row volume while at the same time increasing early yield. We were also interested in the effect of N fertilizer and irrigation level on fruit quality and harvest maturity.

MATERIALS AND METHODS

Experimental design and treatments:

Irrigation and fertilizer treatments (Table 1) were randomized in four blocks with six trees per replicate in a two-year-old 'Triumph' persimmon (*Diospyros kaki* Thunb.) orchard in Greyton, Western Cape, South Africa (lat. 34°02' S; long. 19°32' E) starting February 2005. The area has a Mediterranean-type climate with low rainfall in summer (348 mm per annum), which makes the use of irrigation a necessity during the growing season. Trees on *D. virginiana* seedling rootstock were planted in a sandy loam soil with a water holding capacity of 148 mm m^{-1} at a spacing of 5 m x 2.25 m (888 trees ha^{2} and trained to a central leader system. Irrigation scheduling and fertilizer application rates for the orchard are summarized in Table 2. The industry standard fertigation program was used as control. The irrigation scheduling of the control treatment corresponds with the water holding capacity of the soil.

Treatments were chosen in order to obtain contrasts for irrigation level (½X vs. 1X vs. 2X, where 1X is the commercial irrigation level applied in the orchard) and level of fertilizer application (0X vs. ½X vs. 1X where 1X is the commercial fertilizer application rate followed in the orchard). The control treatment (Treatment 2) constituted a single dripper line (Ram 17, Netafim SA, Cape Town, South Africa) with drippers with a delivery rate of 2.3 $L{\cdot}h^{-1}$ spaced 0.75 m apart. To obtain ½X application of water and fertilizer, a single dripper line with a dripper spacing of 0.75 m and a delivery rate of 1.2 $L{\cdot}h^{-1}$ was used . Two dripper lines with a dripper spacing of 0.75 m and a delivery rate of 2.3 $L{\cdot}h^{-1}$ were tied together with the drippers of the two lines next to each other to achieve a 2X application of water and fertilizer. Treatments 1-3 were linked to a fertigation system (Two Tank system with Aquarius 5000 Series controller, Professional Irrigation Systems, Somerset West, South Africa) at a point after the injection of fertilizer had taken place. Treatments 4 to 6 that did not receive any fertilizer branched off from the irrigation system upstream of fertilizer injection. To obtain the X water and ½X fertilizer combination (Treatment 7), two dripper lines with drippers with delivery rates of 1.2 $L{\cdot}h^{-1}$ spaced 0.75 m apart were tied together. One dripper line was connected to the water supply line without fertilizer and the other to the fertilizer line. Seasonal water and fertilizer application rates for the control treatment, from which the application rates of the other treatments can be calculated, are summarized in Table 2. Fertilizer application ceased end February, but irrigation continued until the end of May.

Data collection:

Data were collected for the middle four trees in the 6-tree plots during the 2005-06 and 2006-07 seasons. Trunk diameter was measured 150 mm above the bud union with a digital electronic caliper at the onset of the trial on 2 February 2005, after leaf drop on 5 June 2005, before bud break on 15 September 2005 and again after leaf drop on 6 June 2006. Vegetative growth was assessed on 6 June 2006 by determining the total number of current season shoots as well as total shoot length of new shoots on one randomly selected scaffold branch per tree. The number of new shoots, average shoot length and total growth were expressed per cm^2 of scaffold branch diameter measured 2.5 cm from the main trunk.

Twenty leaves were sampled per treatment plot (5 per tree from the middle of 40 - 50 cm shoots) on 15 March 2006 and macro and micro nutrients analyzed and compared to norms established for persimmons in South Africa (Kotzé, 2001). The same sampling teqnique was followed on 30 March 2006 and used to determine chlorophyll concentration (CCM-200 chlorophyll content meter, Opti-Sciences, Hudson, USA), leaf area (LI-3000 portable leaf area meter, Lambda Instruments Corporation, Zürich, Switzerland), specific leaf weight (after drying the leaves at 70°C for 3 days) and mineral concentrations (Bemlab, Somerset West, South Africa).

Fruit set was determined on the same branch used to assess vegetative growth by counting flowers at full bloom (3 November 2005) and fruit at the end of the fruit drop period (16 January 2006). Fruit were harvested on 11 May 2006, weighed and a sample of 20 fruit per tree randomly selected and stored at 2ºC for 7 days before recording average fruit diameter and mass, fruit color, firmness and %TSS. Fruit color was assessed using a color chart for astringent persimmon with values 1 to 8, where 1 = red/orange and 8 = green (Plant Protection and Inspection Services (PPIS), Bet-Dagan, Israel) as well as a chromameter (Model CR-400, Minolta Co. Ltd., Tokyo, Japan). Firmness was determined on peeled, pared, opposite cheeks of the fruit using a bench-mounted GÜSS fruit texture analyzer (GS, GÜSS Manufacturing (Pty.) Ltd., Strand, South Africa) with an 11.1 mm tip. Fruit flesh was pooled per plot, juiced and TSS recorded with a hand held refractometer (Atago Model PR32, ATAGO Co. Ltd., Tokyo, Japan).

Fruit set and vegetative growth in the 2006-07 season were assessed in the same manner as described for 2005-06. Flowers and fruit were counted at full bloom (6 November 2006) and after the fruit drop period (16 January 2007), respectively. Vegetative growth was assessed on 7 August 2007. Fruit were harvested according to color at the Hortec color chart value of 4 to 5 on 8 May 2007. Remaining fruit were harvested on 17 May 2007. Fruit were weighed per tree to establish the harvest distribution.

Statistical analysis:

Statistical analysis of the data was performed with the General Linear Models (GLM) procedure of the Statistical Analysis System (SAS) (Enterprise Guide 3.0, SAS

Institute Inc., 2004, Cary, NC, USA). The effect of fertilizer (treatments 1 - 3) vs. no fertilizer (treatments 4 - 6), the linear and quadratic response to water application rates (½X, 1X and 2X) and interaction between fertilizer application and irrigation level were assessed in a first analysis. Linear and quadratic response to fertilizer application rates of ½X, 1X and 2X were assessed at 1X water application rate in a second analysis.

RESULTS AND DISCUSSION

Vegetative growth:

Tree growth, measured as the increase in trunk diameter 15 cm above the graft union, increased linearly with increasing irrigation level and fertilizer application rate during the two seasons, but irrigation had no effect on tree growth in the absence of fertilizer (Table 3). Trunk growth has been used in various fruit kinds such as peach (Mitchell & Chalmers*.,* 1982), pear (Maas, 2005), and also persimmon (Kim *et al.,* 2003, Tetsumura *et al.* 1999; Yakushiji *et al.*, 2008) as a measure of tree growth and size. Trees were uniform in size at the onset of the trial with no significant difference in trunk diameter between treatments (data not presented).

Since shoot growth had already ceased at the onset of the experiment on 2 February 2005, no vegetative growth data were collected for the 2004-05 season. None of the treatments affected shoot extension growth in 2005-06 (data not presented), possibly due to too much variation within treatment plots. In 2006-07, average shoot length increased linearly with fertigation level (Table 3). In the absence of fertilizer application, 2X irrigation increased average shoot length compared to ½X and 1X irrigation. Although treatments did not differ significantly, shoot growth per cm branch diameter seemed to increase linearly with an increase in fertigation level. Irrigation on its own did not appear to affect shoot growth per cm branch diameter (Table 3).

At the onset of water stress, extension growth and leaf expansion are affected first (Kirnak *et al.*, 2001), thus shoot growth, leaf area and leaf dry mass (DM) should be good indicators of the effect of water application on vegetative growth. Chlorophyll concentration and DM production were used by Kirnak *et al.* (2001) to assess the effect of water stress on eggplant growth. Although treatment differences were not significant, fertilizer application increased the leaf chlorophyll concentration in 2005-06 (p = 0.0341) (Table 4). This can be ascribed to the increase in foliar nitrogen levels brought about by fertilizer application (Table 5). Evans (1983) found a strong positive correlation between the chlorophyll concentration and nitrogen percentage in wheat flag leaves. Irrigation level had no effect on chlorophyll concentration. This is in contrast to the decrease in chlorophyll content under conditions of water stress reported in eggplant (*Solanum melongena* L.) (Kirnak *et al.*, 2001) and peach (Steinberg *et al.*, 1990). The difference between the ½X and 2X water applications in this trial was probably inadequate to effect significant changes in the chlorophyll concentration of the leaves. The question may be asked if the ½X application induced sufficient stress to alter chlorophyll content in the leaves.

Leaf area increased linearly with increasing irrigation level, but fertilizer application had no significant effect (Table 4). This corresponds with work done by Cheng and Fuchigami (2002) on young apple trees where the current supply of N only slightly increased total leaf area. Leaf DM percentage was significantly decreased by fertigation and also decreased linearly with increasing irrigation level (Table 4). Alva *et al.* (2003) also found that citrus leaf DM decreased with an increase in rate of fertilization and attributed this to the dilution effect of bigger leaves with bigger cells.

Nutrient accumulation in the leaves

The only significant differences between treatments in nutrient levels were found for N and P (Table 5). All micronutrient levels (data not shown) were within the optimal ranges established for persimmon (Kotzé, 2001). Fertigation increased leaf N levels compared to irrigation without fertilizer application. Leaf N increased linearly with increasing fertigation level, resulting in significantly higher leaf N at 2X compared to ½X fertigation. Irrigation level did not affect leaf N level in the absence of fertilizer application. Leaf N levels also increased linearly with increasing fertilizer application at the 1X water application level, even though treatments did not differ significantly. Leaf P levels seemed to increase linearly with irrigation level although the only significant difference was between the ½X and 2X fertigation levels. According to Briedenhann, R. (Personal communication, 2006) and van Zyl, H.G.M. (Personal communication, 2007), high nutrient levels in the leaves were expected since the fertilizer rates in the first two years after planting of the orchard were fairly high to stimulate vegetative growth. The soils were also ameliorated to the desired levels before planting. This would have led to high levels of all nutrients except N in the soil, which could have negated the effect of fertilizer application rate differences in the first year of trials. Greater segregation in leaf mineral content between treatments is expected as the orchard matures.

Yield and fruit quality

None of the treatments had any effect on flowering or fruit set in either of the two seasons (Table 6). However, it is possible that these treatment regimes may influence flowering and fruit set in the long run. George *et al.* (2003) found that both low (<40 kg ha^{-1}) and high (>100 kg ha^{-1}) annual rates of N decreased the total number of fruit per tree in non-astringent persimmon due to adverse effects on fruit set and increased fruit drop.

Average fruit mass and yield per tree increased linearly with an increase in water application rate in both 2005-06 and 2006-07 (Table 7). Since the estimated number of fruit per tree did not differ significantly in either season (Table 7), fruit mass was the major factor contributing to the yield increase observed in response to increased irrigation. Fertigation increased fruit mass in both 2005-06 and 2006-07 (Table 7). Fruit mass decreased linearly with increasing fertilizer level at the X water level in 2005-06 (Table 7). The decrease in fruit mass may be due to increased competition for assimilates with shoot growth at higher levels of N. Cumulative yield over the 2005-06 and 2006-07 seasons increased linearly with increased irrigation. There was, however, no significant difference between the 1X and 2X application rates, suggesting that the water application rate of 1X is very close to optimal.

Increasing irrigation accelerated fruit ripening, except when combined with fertilizer in which case fruit ripening was significantly delayed irrespective of irrigation level (Fig. 1). In addition, ripening was delayed by increasing fertilizer levels at 1X water. Wargo *et al.* (2000) showed on ‘Jonagold’ apple that higher rates of nitrogen application delayed fruit ripening and thus harvest maturity by 7-10 days. Urusaki and Imagawa (2002) found that increasing irrigation delayed coloring and harvesting in persimmon while reduced irrigation increased fruit softening. The exclusion of fertilizer led to lower fruit firmness at the time of harvest (Table 7), indicating that these fruit could have been harvested even earlier. Fruit that received 1X and 2X water and fertilizer were firmer than fruit of other treatments. Inglese *et al.* (1996) found that the harvesting of olives was delayed when applying more water while Torrecillas *et al.* (2000) found that withholding water from apricot led to earlier harvest maturity. No mention was made as to the rates of fertilizer application that might have delayed fruit coloring in some of the other research. The percentage of the crop harvested at the first harvest decreased linearly with increasing fertilizer application rates at a water application rate of 1X. Based on color chart values and firmness, treatments apparently had the same effect on fruit maturity in the 2005-06 season when fruit were picked on one harvest date (Table 7).

Fruit were greener, judging from color chart values, and firmness increased linearly with fertilizer application level at 1X water application level (Table 8). Fruit were also greener at harvest with an increase in fertigation level and fruit that received fertilizer were greener than fruit that did not. High nitrogen application rates lead to delayed red and orange color development in apple fruit (Fallahi, 1997) and citrus (Dasberg *et. al.,* 1983), respectively. Choi *et al.* (2009) on ‘Fuyu’ and Aoki *et al.* (1977) on ‘Wase Jiro’ persimmon showed that fruit coloration was negatively affected by nitrogen fertilization. Higher water application rates delayed color formation in ‘Triumph’ persimmon as reflected by color chart and hue angle values (Table 7.) This is in contrast to work done by Kaniszewski *et al.* (1987) who found that fruit color in tomato was not affected by irrigation level, although fruit that received more water were firmer.

The possibility of delaying harvest with fertilizer and water application, especially in late production areas, may widen the market window for ‘Triumph’. It may also decrease the reliance on the pre-harvest application of GA_3 that is currently used to delay fruit ripening. These GA_3 applications negatively affect flowering in the subsequent season (Ungerer, 2007). However, GA_3 has the positive effect of increasing the storability and extending the shelf life of ‘Triumph’ fruit (Ungerer, 2007). High rates of N are known to have a negative effect on fruit storability in various crops (Crisosto *et al*., 1997; Lysrak & Pacholuk, 1994). The effect of high N rates on storability and shelfe life needs to be assessed.

TSS increased linearly with increasing fertilizer application at 1X water application level (Table 7). Although TSS was only significantly lower at 2X fertigation level, TSS seemed to decrease linearly with increasing water application rate. Due to dilution, treatments that produced larger fruit also produced lower TSS levels in these fruits. Sánchez Blanco *et al.* (1989) found this to be true for 'Verna' lemon trees irrigated at six different watering regimes.

CONCLUSION

In this trial, an increase in water application rate led to an increase in tree size as reflected by the increase in trunk diameter achieved. Hence, these trees can fill their allotted space sooner and will be able to come into full production earlier. None of the treatments affected flowering and fruit set. However, yield increased linearly with an increase in water application rate due to an increase in fruit size. However, the effect of high irrigation levels on yield needs to be weighed against the possible detrimental effect on fruit quality and storability. An increase in fertilizer application rate affected fruit size negatively at 1X water application level.

The considerable delay in fruit ripening that was observed with an increase in water and fertilizer application rate in particular may widen the harvesting and, therefore, the marketing period of South African 'Triumph' persimmon. It may also allow producers to discard the use of pre-harvest gibberellin application to delay ripening. However, as mentioned before, the potential negative effect of N on fruit quality needs to be assessed.

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Table 1: Summary of water and fertilizer treatment combinations and water delivery rates in a fertigation trial conducted on three year old 'Triumph' persimmon trees on *D. virginiana* seedling rootstock in the Greyton area of the Western Cape Province, South Africa.

Treatment	Water	Fertilizer	Dripper delivery ($L\ h^{-1}$)	Water delivery ($m^3\ ha^{-1}\ h^{-1}$)	Water per tree ($L\ h^{-1}$)
1	0.5 X	0.5 X	1.2	3.2	3.6
2[z]	X	X	2.3	6.1	6.9
3	2 X	2 X	4.6	12.3	13.8
4	0.5 X	-	1.2	3.2	3.6
5	X	-	2.3	6.1	6.9
6	2 X	-	4.6	12.3	13.8
7	1X	0.5X	2.3	6.1	6.9

[z] Treatment 2 is the standard irrigation and fertigation practice used as control.

Table 2: Seasonal water delivery rates and fertilizer applications for the control treatment in a fertigation trial conducted on three year old ‘Triumph’ persimmon trees on *D. virginiana* seedling rootstock in the Greyton area of the Western Cape Province, South Africa.

Period	Irrigation schedule			Fertilizer per period (kg ha^{-1})						Fertilizer per tree (g)					
	h day^{-1}	m^3 ha^{-1} day^{-1}	L tree^{-1} day^{-1}	N	P	K	Ca	Mg	S	N	P	K	Ca	Mg	S
Beg-Mid Oct	1.0	3.2	3.6	-	-	-	-	-	-	-	-	-	-	-	-
Mid Oct-End Nov	2.0	6.4	7.2	-	-	-	-	-	-	-	-	-	-	-	-
End Nov-Mid Dec	2.5	8.0	9.0	31	10	16	11	4	12	35	11	18	12	5	14
Mid-End Dec	2.5	8.0	9.0	29	13	21	14	5	16	33	15	24	16	6	18
End Dec-End Jan	3.0	9.6	10.8	14	4	29	14	3	10	16	5	33	16	3	11
End Jan-End Feb	3.0	9.6	10.8	4	3	14	3	0	5	5	3	16	3	0	6
End Feb-End Mar	2.0	6.4	7.2	1	2	8	0	0	3	1	2	9	0	0	3
Season total				78	33	87	43	12	45	90	36	100	47	14	52

Table 3: The effect of combinations of water and fertilizer level on trunk and shoot growth of 'Triumph' persimmon on *D. virginiana* seedling rootstock in the Greyton area of the Western Cape Province, South Africa over two seasons (2005-07). Means were separated by LSD with Pr>F at 5 % level.

Treatment	Water	Fertilizer	Cumulative trunk growth^{z} (mm) 2005-07	Average shoot lenght^{y} (cm) 2006-07	Total shoot growth per cm branch diameter (cm) 2006-07
1	0.5X	0.5X	19.0 d^{x}	20.8 c	3.09^{ns}
2	1X	1X	25.2 bc	22.5 bc	4.87
3	2X	2X	30.3 a	25.8 b	5.13
4	0.5X	-	22.0 dc	21.0 c	4.68
5	1X	-	24.1 bc	22.2 bc	4.63
6	2X	-	26.9 abc	29.8 a	3.82
7	1X	0.5X	28.2 ab	25.2 b	4.54
			Contrasts (Pr>F)		
Treatment			0.0432	0.0327	0.1386
First analysis:					
Fertilizer			0.8897	0.4080	0.9733
Water linear			0.0077	0.1152	0.3847
Water quadratic			0.2681	0.0869	0.0869
Fertilizer*water linear			0.0460	0.0186	0.0186
Fertilizer*water quadratic			0.6528	0.6701	0.3544
Second analysis:					
Fertilizer linear at X water			0.9764	0.6479	0.9836
Fertilizer quadratic at X water			0.3303	0.0585	0.4352

ns = non significant

[x] Means followed by the same letter do not differ significantly at $p<0.05$.

[y] Number of shoots, average shoot length and average one-year-old shoot growth measured 2.5 cm from the trunk for the one scaffold branch measured per treatment plot to assess vegetative growth.

[z] Cumulative trunk growth over two seasons (2005-06 & 2006-07)

Table 4: The effect of various combinations of water and fertilizer on leaf chlorophyll content, leaf area and leaf dry mass of 'Triumph' persimmon on D. virginiana seedling rootstock in the Greyton area of the Western Cape province, South Africa in the 2005-06 season. Means were separated by LSD with Pr>F at 5 % level.

Treatment	Water	Fertilizer	Chlorophyll ($\mu g\ g^{-1}$)	Leaf area (cm^2)	Leaf dry mass (%)
1	0.5X	0.5X	480^{ns}	57.8 c^{z}	53.0 a
2	1X	1X	499	63.3 bc	49.5 abc
3	2X	2X	499	73.6 a	46.0 dc
4	0.5X	-	451	57.3 c	50.3 ab
5	1X	-	442	69.0 ab	47.0 bcd
6	2X	-	456	74.5 a	43.5 d
7	1X	0.5X	492	70.5 ab	46.8 bcd
			Contrasts (Pr>F)		
Treatment			0.4059	0.0039	0.0006
First analysis:					
Fertilizer			0.0341	0.4530	0.0159
Water linear			0.6177	<0.0001	<0.0001
Water quadratic			0.9604	0.2919	0.3160
Fertilizer*water linear			0.8489	0.9864	0.9278
Fertilizer*water quadratic			0.5851	0.3282	0.9376
Second analysis:					
Fertilizer linear at X water			0.0989	0.2287	0.1544
Fertilizer quadratic at X water			0.4673	0.2886	0.3166

ns = non significant

[z] Means followed by the same letter do not differ significantly at p<0.05.

Table 5: The effect of combinations of water and fertilizer level on the leaf nutrient status of 'Triumph' persimmon on *D. virginiana* seedling rootstock in the Greyton area of the Western Cape Province, South Africa in the 2005-06 season. Means were separated by LSD with Pr>F at 5 % level.

Treatment	Water	Fertilizer	N (%)	P (%)	K (%)
1	0.5X	0.5X	1.97 bc[y]	0.130 c	2.02^{ns}
2	1X	1X	2.06 ab	0.140 abc	2.24
3	2X	2X	2.15 a	0.143 ab	2.15
4	0.5X	-	1.98 bc	0.135 bc	2.11
5	1X	-	1.86 c	0.133 bc	2.11
6	2X	-	1.84 c	0.143 ab	2.05
7	1X	0.5X	1.94 bc	0.148 a	2.10
			Contrasts (Pr>F)		
Treatment			0.0034	0.0491	0.4751
First analysis:					
Fertilizer			0.0005	0.7930	0.4590
Water linear			0.5538	0.0168	0.8376
Water quadratic			0.5972	0.9038	0.1354
Fertilizer*water linear			0.0057	0.7246	0.2800
Fertilizer*water quadratic			0.2842	0.1264	0.2409
Second analysis:					
Fertilizer linear at X water			0.0106	0.1833	0.2316
Fertilizer quadratic at X water			0.7393	0.0276	0.4039
			March leaf norms for persimmon[z]		
Minimum			1.57	0.10	2.40
Maximum			2.00	0.19	3.70

ns = non significant

[y] Means followed by the same letter do not differ significantly at $p<0.05$.

[z] Source: Kotzé (2001)

Table 6: The effect of combinations of water and fertilizer level on fruit set of ‘Triumph’ persimmon on *D. virginiana* seedling rootstock in the Greyton area of the Western Cape Province, South Africa, over two seasons (2005-06 and 2006-07). Means were separated by LSD with Pr>F at 5 % level.

Treatment	Water	Fertilizer	Flowers[z] 2005-06	Fruit set % 2005-06	Flowers 2006-07	Fruit set % 2006-07
1	0.5X	0.5X	5.5^{ns}	23.8^{ns}	6.7^{ns}	50.3^{ns}
2	1X	1X	3.3	35.5	8.6	65.1
3	2X	2X	3.5	28.5	8.2	59.7
4	0.5X	-	3.5	21.5	8.0	55.1
5	1X	-	2.8	34.3	8.3	56.9
6	2X	-	3.8	26.8	5.4	47.0
7	1X	0.5X	2.0	35.5	7.9	51.3
Contrasts (Pr>F)						
Treatment			0.0558	0.7023	0.7209	0.1303
First analysis:						
Fertilizer			0.1870	0.7712	0.6119	0.4688
Water linear			0.3599	0.7045	0.5761	0.9629
Water quadratic			0.0557	0.1156	0.3422	0.2557
Fertilizer*water linear			0.1294	0.9822	0.1702	0.4032
Fertilizer*water quadratic			0.5337	0.9488	0.9343	0.5784
Second analysis:						
Fertilizer linear at X water			0.6040	0.9044	0.6142	0.4473
Fertilizer quadratic at X water			0.2385	0.9447	0.7209	0.3019

ns = non significant

[z] Number of flowers per 30 cm shoot length

Table 7: The effect of combinations of water and fertilizer level on yield of 'Triumph' persimmon on *D. virginiana* seedling rootstock in the Greyton area of the Western Cape Province, South Africa, over two seasons (2005-06 and 2006-07). Means were separated by LSD with Pr>F at 5 % level.

Treatment	Water	Fertilizer	Yield (t ha^{-1}) 2005-06	Fruit mass (g) 2005-06	Estimated number of fruit / tree 2005-06	Yield (t ha^{-1}) 2006-07	Fruit mass (g) 2006-07	Estimated number of fruit / tree 2006-07	Cumulative yield (t ha^{-1})^{z}
1	0.5X	0.5X	10.2^{ns}	148 d^{y}	79^{ns}	18.4^{ns}	145 c	147^{ns}	27.6 c
2	1X	1X	12.0	178 c	76	29.6	174 abc	204	40.4 abc
3	2X	2X	17.9	192 bc	105	34.0	210 a	185	50.1 a
4	0.5X	-	14.0	187 bc	86	21.1	149 bc	161	33.8 bc
5	1X	-	15.0	202 ab	88	26.3	169 bc	175	39.8 abc
6	2X	-	19.5	220 a	99	31.1	184 ab	198	48.6 a
7	1X	0.5X	16.6	207 ab	90	27.1	185 ab	167	42.0 ab
Contrasts (Pr>F)									
Treatment			0.0700	<0.0010	0.7526	0.1303	0.0213	0.8769	0.0437
First analysis:									
Fertilizer			0.1245	<0.0001	0.7142	0.7250	0.3896	0.9780	0.7309
Water linear			0.0043	<0.0001	0.1314	0.0065	0.0008	0.3293	0.0011
Water quadratic			0.6812	0.1388	0.5840	0.2785	0.4704	0.4247	0.4568
Fertilizer*water linear			0.5884	0.5306	0.5935	0.5501	0.2218	0.8991	0.4716
Fertilizer*water quadratic			0.9825	0.3647	0.7170	0.5573	0.9630	0.4726	0.6232
Second analysis:									
Fertilizer linear at X water			0.3317	0.0277	0.5600	0.5612	0.7854	0.5402	0.9325
Fertilizer quadratic at X water			0.2438	0.0649	0.6309	0.8582	0.3808	0.5745	0.7421

ns = non significant

[y] Means followed by the same letter do not differ significantly at p<0.05.

[z] Cumulative yield over two seasons (2005-07).

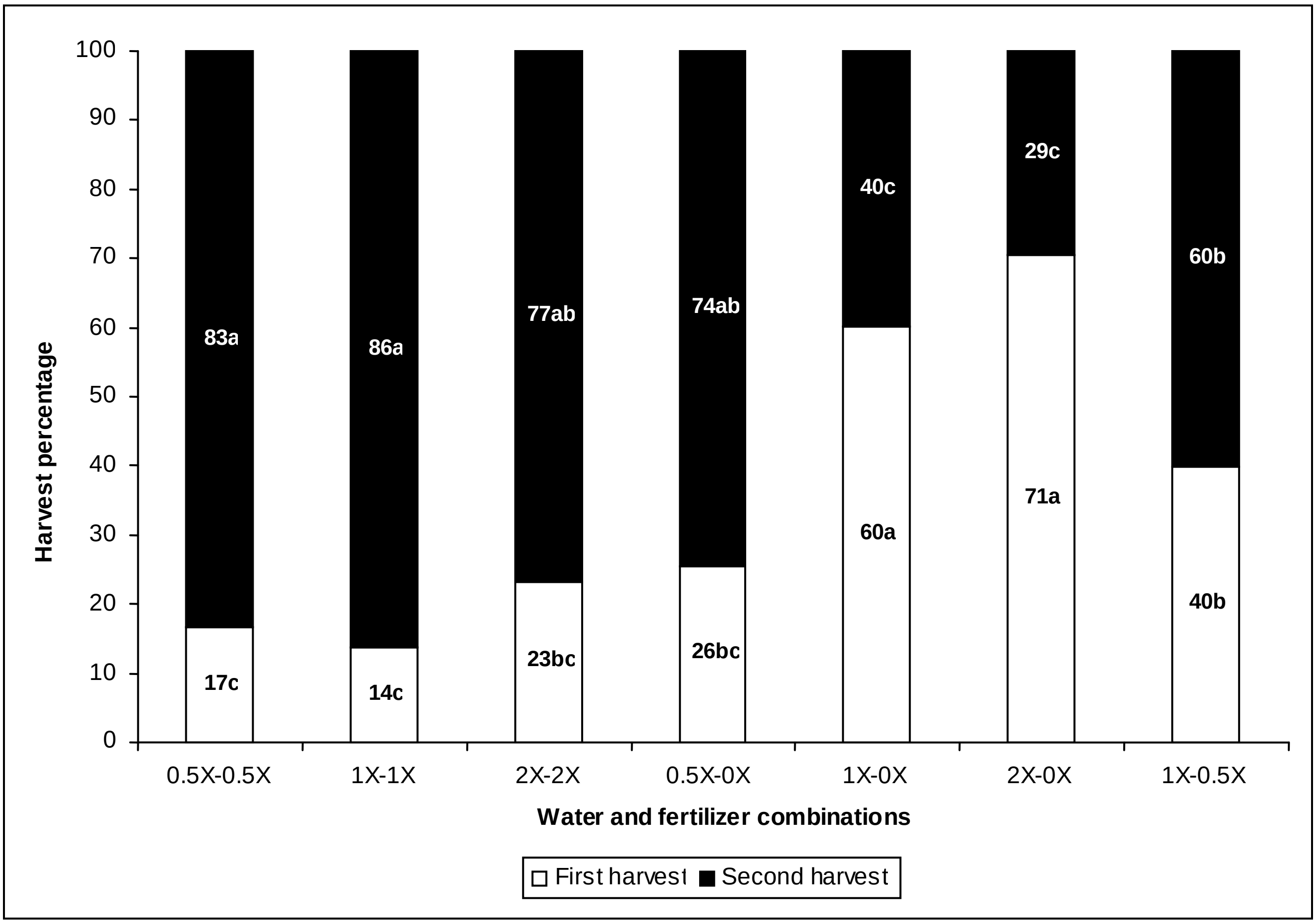
Table 8: The effect of combinations of irrigation and fertilizer level on fruit size, colour, firmness and TSS of ‘Triumph’ persimmon on *D. virginiana* seedling rootstock in the Greyton area of the Western Cape Province, South Africa in the 2005-06 season. Means were separated by LSD with Pr>F at 5 % level.

Treatment	Water	Fertilizer	Fruit diameter (mm)	Colour chart[y]	Hue (°)	Firmness (kg)	TSS[z] (°Brix)
1	0.5X	0.5X	64.3 d[x]	4.4 bc	75.2 bc	10.2 abc	21.9 a
2	1X	1X	69.0 c	5.1 a	77.7 ab	11.1 ab	21.9 a
3	2X	2X	71.3 bc	5.4 a	80.0 a	11.7 a	20.1 c
4	0.5X	-	71.3 bc	4.3 bc	71.9 d	8.8 dc	21.4 ab
5	1X	-	72.9 ab	4.1 c	72.5 dc	8.0 d	20.7 bc
6	2X	-	74.6 a	4.5 bc	75.1 bc	9.1 cd	20.4 bc
7	1X	0.5X	73.8 ab	4.6 b	74.7 c	9.7 bc	20.8 bc
Contrasts (Pr>F)							
Treatment			<0.0001	0.0002	0.0001	0.0026	0.0090
First analysis:							
Fertilizer			<0.0001	<0.0001	<0.0001	<0.0001	0.1204
Water linear			0.0001	0.0007	0.0004	0.1008	0.0006
Water quadratic			0.1334	0.6188	0.7631	0.6347	0.7999
Fertilizer*water linear			0.1106	0.0626	0.4881	0.3579	0.1812
Fertilizer*water quadratic			0.3029	0.0381	0.4113	0.2162	0.1321
Second analysis:							
Fertilizer linear at X water			0.0158	0.0003	0.0010	0.0012	0.0263
Fertilizer quadratic at X water			0.0349	1.0000	0.6919	0.7904	0.2594

[x] Means with the same letter do not differ significantly at $p<0.05$.

[y] 1-8 where 1 = red/orange, 8 = green (PPIS, Grabouw)

[z] TSS = Total Soluble Solids



	1^{st} Harvest
Contrasts (Pr>F)	
Treatment	<0.0001
First analysis:	
Fertilizer	<0.0001
Water linear	0.0007
Water quadratic	0.1878
Fertilizer*Water linerar	0.0116
Fertilizer*Water quadratic	0.0318
Second analysis:	
Fertilizer linear at X water	<0.0001
Fertilizer quadratic at X water	0.7054

Fig 1: The effect of various combinations of water and fertilizer on harvest distribution of ‘Triumph’ persimmon on *D. virginiana* seedling rootstock in the Greyton area of the Western Cape province, South Africa in the 2006-07 season. Means were separated by LSD with Pr>F at 5 % level.

GENERAL DISCUSSION AND CONCLUSIONS

It is of the utmost importance to fill a fruit tree's allotted space in the orchard as soon as possible in order to ensure the early onset of full production. Many 'Triumph' orchards in South Africa are between 3 and 5 years old. These trees are therefore in transition between the first few years after planting when the emphasis is on vegetative growth and the full bearing phase that commences when trees reach their mature size.

Young fruit trees are usually supplied with high rates of N and water to encourage vegetative growth (Robinson, 2008). Water and fertilizer were applied at 3 different levels, i.e. ½X, 1X and 2X, with 1X being the commercial application rate. Some treatments received only water at ½X, 1X and 2X while fertilizer was also applied at 0X, ½X and 1X at 1X level of irrigation. An increase in water application rate led to an increase in tree size as reflected in an increase in trunk diameter. Hence, trees that received more water were faster in filling their allotted space. Yield also increased linearly with an increase in water application rate due to an increase in fruit size. However, the effect of high irrigation levels on yield needs to be weighed against the possible detrimental effect on fruit quality and storability. An increase in water and, in particular, fertilizer application rate significantly delayed fruit ripening. Hence, in full bearing orchards, it may be possible to extend the harvesting period and, therefore, the marketing period of 'Triumph' persimmon by regulating water and fertilizer availability. None of the treatments affected flower numbers or fruit set. This may change as trees grow bigger and shading within and between trees increases. We recommend that the trial be continued for a further number of years for assessment of treatment effects on mature trees and on fruit quality and storability of fruit.

Persimmon trees are generally prone to excessive fruit drop, often attributable to excessive vigor (Kitigawa & Glucina, 1994). Persimmons in South Africa are planted at fairly high density (800-1111 trees per ha) compared to other parts of the world (<740 trees per ha). Excessive vigor and reduced fruitfulness due to shading are becoming problematic as trees are reaching their mature size and exceeding their allotted volume (Ungerer, personal communication).

The effect of different severities of girdling, viz. strapping with 2 mm wire, scoring, girdling with a handsaw and removal of 5 mm bark as well as different rates of the plant growth regulators prohexadione-Ca (P-Ca) (foliar application at 125 & 250 mg L^{-1}) and paclobutrazol (PBZ) (soil drench at 1 ml or 2 ml per tree and 1000 mg L^{-1} foliar application) on vegetative growth, flower initiation, fruit set and yield were evaluated in orchards grafted on the very vigorous *D. lotus* and moderately vigorous *D. virginiana* seedling rootstocks. Scoring and girdling improved fruit set and yield and can be recommended as tools to improve yield in young, vigorous 'Triumph' orchards. Strapping, P-Ca and PBZ did not affect fruit set and yield whereas 5 mm bark removal had a negative effect on yield in the following season. Vegetative growth, flower initiation and fruit quality were not significantly affected by any of the treatments, with the exception of bark removal that decreased fruit TSS. PBZ application seemed to advance fruit maturity and is extensively used in Israel to advance fruit maturity in 'Triumph' (Ben-Arie *et al*., 1997).

P-Ca and PBZ foliar applications were phytotoxic to 'Triumph' trees. P-Ca rates were comparable to those used in pear (Meintjes *et al.*, 2005) and lower than rates used in citrus (Le Roux, 2006) In the case of P-Ca, the phytotoxicity negatively affected fruit set in the season of application in one orchard while in the second orchard, fruit set and yield were significantly reduced in the following season. As PBZ is used in Israel without any report of negative effects on tree health (Ben-Arie *et al*., 1997), and is also known to promote flower formation (Murai, 1992), further research is required before the use of P-Ca and PBZ in South Africa can be completely discarded due to a lack of positive results in this thesis.

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ADDENDUM A

Table 1: The effect of strapping, scoring, girdling and prohexadione-Ca (P-Ca) on number of fruit per tree and fruit mass in 'Triumph' persimmon on *D. lotus* rootstock in the Greyton area of the Western Cape province of South Africa during the 2004-05 season. Means were separated by LSD at the 5 % level.

Treatments	Number of fruit per tree 2004-05	Fruit mass (g) 2004-05
Control	70^{ns}	258^{ns}
Strapping	52	290
Scoring	61	255
Girdle A^y	30	273
Girdle B^z	75	242
P-Ca 125 mg L^{-1}	42	271
P-Ca 250 mg L^{-1}	91	245
Pr>F		
Treatment	0.2690	0.6571

[y] Girdled once in 2004-05.

[z] Girdled twice in 2004-05.

ns = non significant

Table 2: The effect of girdling, strapping and prohexadione-Ca (P-Ca) on fruit quality in 'Triumph' persimmon on *D. lotus* rootstock in the Greyton area of the Western Cape province, South Africa during the 2005-06 seasons. Means were separated by LSD at the 5% level.

Treatment	Repeat[w]	Colour chart[y]	TSS[z] (º Brix)	Firmness (kg)
Control	1	4.0[ns]	19.6 efg	4.9 cde
Control	2	3.9	20.1 g	4.2 abc
Strapping	1	4.1	18.7 ab	5.3 def
Strapping	2	4.3	19.3 cdef	6.1 f
Scoring	1	3.9	19.1 bcde	4.1 ab
Scoring	2	3.8	18.5 a	4.3 abc
Girdling A[Z]	1	4.0	18.8abc	5.0 cde
Girdling A[Z]	2	4.0	19.3 cdef	4.8 bcde
Girdling B[Z]	1	3.9	19 abcde	3.7 a
Girdling B[Z]	2	4.1	18.5 a	4.5 abcd
P-Ca 125 mg L^{-1}	1	4.1	19.0 abcd	5.6 ef
P-Ca 125 mg L^{-1}	2	4.1	18.9 abcd	4.4 abcd
P-Ca 250 mg L^{-1}	1	3.7	19.8 defg	3.9 a
P-Ca 250 mg L^{-1}	2	4.1	19.9 fg	5.0 cde
		Pr>F		
Treatment		0.1425	0.0368	0.1181
Repeat		0.2262	0.4932	0.4106
Treatment x Repeat		0.5571	0.0125	0.0033

ns = non significant

[x] Means with the same letter do not differ significantly at p<0.05.

[y] 1-8 where 1 = red/orange, 8 = green (PPIS, Bet-Dagan, Israel)

[z] TSS = Total Soluble Solids

Table 3: The effect of strapping, scoring, girdling x3, 5 mm bark removal, paclobutrazol (PBZ) and prohexadione-Ca (P-Ca) on vegetative growth in 'Triumph' persimmon on *D. virginiana* rootstock in the Vyeboom area of the Western Cape province of South Africa over two seasons (2005-06 & 2006-07). Treatments were applied in 2005-06 only. Means were separated by LSD at the 5 % level.

Treatments	Total shoot growth(m) 2005-06	Trunk diameter (mm) 2006-07	Total shoot growth (m) 2006-07
Control	0.55^{ns}	77.8^{ns}	0.72^{ns}
Strapping	0.57	79.9	0.72
Girdling	0.60	77.7	0.74
Bark removal	0.59	75.8	0.66
PBZ drench 2 ml	0.60	71.8	0.81
PBZ drench 4 ml	0.67	78.6	0.68
PBZ 1000 mg L^{-1}	0.60	71.0	0.71
P-Ca 125 mg L^{-1}	0.55	79.4	0.85
P-Ca 250 mg L^{-1}	0.50	73.6	0.89
Pr>F			
Treatment	0.7444	0.1795	0.4875

ns = non significant