ADVANCING HARVEST MATURITY AND IMPROVING STORABILITY OF 'TRIUMPH' PERSIMMONS

By

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Sharon Fruit of South Africa

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DECLARATION

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SUMMARY

‘Triumph’ persimmon production in South Africa is export driven and the profitability of the industry is largely dependent on consumer demand and supermarket shelf space in the European market. In order to realise high returns, it is important to advance harvest maturity to attain early fruit that arrives on the market prior to European summer fruits. In addition, market feedback suggests that fruit picked during the second half of the harvesting period stores poorly and rapidly softens during shelf life. It is important to establish whether this is the case.

The effect of paclobutrazol (PBZ) application rate on fruit maturity and keeping quality, return bloom and vegetative growth was investigated over two seasons. Advanced harvest maturity was attained at a compromise of reduced fruit storage quality and stunted growth with the severity of the compromise increasing with increasing PBZ application rate. To advance harvest maturity while maintaining acceptable keeping quality, PBZ application at 0.75 ml per plant is recommended although effects on harvest maturity will not persist into the subsequent season as found at higher application rates.

Prohexadione-calcium (P-Ca) as an alternative for PBZ in advancing harvest maturity was evaluated over two seasons. A positive response to three foliar applications of P-Ca at 200 $mg \cdot L^{-1}$ was noticed in the first season. In the second season, a single application of P-Ca at 300 $mg \cdot L^{-1}$ two weeks before harvest significantly advanced harvest maturity. Due to the rapid metabolism of P-Ca in the plant, it is unlikely that growth in the subsequent season will be affected. Based on these results, the persimmon industry will undertake commercial trials in the 2012 season to further assess the efficacy of P-Ca application in advancing harvest maturity.

The effect of various rest breaking agents (RBAs) on bud break, flowering, fruit maturity and quality as well as vegetative growth was assessed for one season. RBAs did not increase or advance bud break and flowering. Consequently, yield and

harvest maturity were unaffected by the treatments. The ineffectiveness of the RBAs could be due to the low application rates used or the fulfilment of the chilling requirement prior to treatment application.

An experiment was carried out to determine whether storability and shelf-life differ between "early" and "late" production areas in South Africa as well as between orchards within these areas. The data indicated that fruit colour is a good maturity parameter and indicator of fruit storability. However, "late" fruit were about 1 kg softer than "early" fruit at the same colour chart value. We therefore recommend that fruit from late regions are harvested at colour chart values of 5 and 6 (yellow-green) instead of 3 and 4. Fruit from "late" orchards as well as GA_3-treated fruit with a colour chart value of 3 and less should be culled due to the high propensity (>20%) of these fruit to become soft during storage and shelf life. A delay in 1-MCP treatment and interruption of the cold chain considerably increased fruit softening during storage and shelf-life. Further research is required to verify this result.

OPSOMMING

‘Triumph’ persimmon produksie in Suid-Afrika is uitvoergedrewe en die winsgewendheid van die bedryf is grootliks afhanklik van verbruikervraag en supermark spasie in die Europese mark. Ten einde hoë pryse te realiseer, is dit belangrik om ’n vroeë oes te verkry sodat vrugte voor die Europese somervrugte op die mark beland. Mark terugvoer dui verder daarop dat vrugte wat tydens die tweede helfte van die oesperiode gepluk word, swakker opberg en vinnig sag word gedurende op die rak. Dit is belangrik om vas te stel of hierdie waarneming juis is.

Die effek van paklobutrazol (PBZ) toedieningshoeveelheid op vrugrypwording en -houvermoë, opvolgblom en vegetatiewe groei is oor twee seisoene ondersoek. Oesrypheid is vervroeg, maar tot nadeel van vrughouvermoë en vegetatiewe groei. Die omvang van die negatiewe effekte van PBZ het toegeneem met ’n toename in toedieningshoeveelheid. Ten einde oesrypheid te vervroeg terwyl aanvaarbare houvermoë behou word, word toediening van PBZ teen 0.75 ml per plant aanbeveel alhoewel die effek op oesrypheid anders as die geval met hoër toedieningshoeveelhede nie in die opeenvolgende seisoen sal voortduur nie.

Proheksadioon-kalsium (P-Ca) as alternatief tot PBZ om oesrypheid te vervroeg is oor twee seisoene gee-valueer. ’n Positiewe effek op vrugrypwording is in die eerste seisoen verkry met drie blaartoedienings van P-Ca teen 200 $mg \cdot L^{-1}$. In die tweede seisoen is oesrypheid betekenisvol vervroeg deur ’n enkel toediening van 300 $mg \cdot L^{-1}$ P-Ca ’n maand voor oes. Vanweë hierdie resultate gaan die persimmonbedryf in die 2012 seisoen kommersiële proewe onderneem om die effektiwiteit van P-Ca om oes te vervroeg, verder te ondersoek.

Die effek van verskeie rusbrekende middels (RBAs) op bot, blom, vrugrypheid, vrugkwaliteit en vegetatiewe groei is vir een seisoen ondersoek. RBAs het bot en blom vervroeg of vermeerder nie en het daarom ook geen effek op produksie en oesrypheid gehad nie. Die oneffektiwiteit van die RBAs kan moontlik toegeskryf word

aan die lae toedieningsvlakke wat gebruik is of aan die kouebehoefte wat bevredig is voor toediening van RBAs.

ʼn Eksperiment is gedoen om vas te stel of die opberging- en houvermoë van vrugte verskil tussen “vroeë” en “laat” produksieareas in Suid-Afrika en ook tussen boorde in hierdie areas. Die data dui daarop dat vrugkleur ʼn goeie rypheidsparameter en indikator van opbergingsvermoë is. Vrugte van laat areas was egter omtrent 1 kg sagter as vrugte van vroeë areas van dieselfde kleur. Ons beveel gevolglik aan dat vrugte van laat areas by ʼn kleurkaartwaarde van 5 tot 6 (geelgroen) geoes word eerder as by 3 tot 4. Vrugte van laat boorde sowel as vrugte wat met GA_3 behandel is met ʼn kleurkaartwaarde van 3 en laer moet afgradeer word weens die hoë geneigdheid (>20%) van hierdie vrugte om sag te word tydens opberging en op die rak. Uitstel van 1-MCP behandeling en die onderbreking van die koueketting veroorsaak ʼn aansienlike toename in sagte vrugte tydens opberging en op die rak. Verdere navorsing word benodig om hierdie resultaat te verifieer.

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DEDICATION

Dedicated to my late brothers Onslow and Malory.

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GENERAL INTRODUCTION

The persimmon (*Diospyros kaki* Thunb.) is a deciduous fruit tree originating in China (Kitagawa and Glucina, 1984). Persimmons have been planted in the Mediterranean-type climate Western Cape region of South Africa since 1998 and the country has a great opportunity to be a major counter season supplier of persimmons to Northern Hemisphere markets (Rabe, 2003). Currently, the astringent cultivar Triumph is favoured. In South Africa, 'Triumph' is harvested from April to June. Highest prices are attained for early fruit. Thus there is need for advancing harvest maturity of the fruit.

Plant growth regulators (PGRs) can be used to advance fruit harvest maturity (Rademacher *et al*., 2004). The PGRs can either be ethylene-releasing compounds or gibberellin (GA) inhibitors. Ethylene releasing compounds directly stimulate ripening (Lieberman, 1979) while GA inhibitors indirectly advance harvest maturity through inhibiting vegetative growth thereby increasing resource availability for fruit development (Rademacher, 2000). Paclobutrazol (PBZ) and Prohexadione-Ca (P-Ca) are the GA inhibitors most commonly used for this purpose. A major difficulty in using PGRs to artificially advance harvest maturity is to determine the most effective application rates and time of application. PBZ is very persistent in the plant and may stunt growth in subsequent seasons. In contrast, P-Ca is rapidly metabolised in the plant. Although PBZ advances fruit maturity; it has major drawbacks in that the storability and shelf life of persimmons are reduced. The study therefore investigated the effect of reduced PBZ application rates and the effect of P-Ca as a substitute for PBZ in advancing harvest maturity in 'Triumph' persimmon.

Persimmon trees generally have a low chilling requirement of ca. 300 Richardson chilling units (Mowat and George, 1995). However, chilling may be insufficient in some years in some of the warmer production areas (Berg and Breede river valleys) in the Western Cape province of South Africa. Growth abnormalities such as delayed and uneven blossoming occur when winter chilling is insufficient causing delayed and uneven fruit maturity (Mowat and George, 1995). Rest breaking agents (RBA's) can be applied to normalise and advance bud break (Saure, 1985). In the latter case, this may advance harvest maturity (Saure, 1985). Hence, the second aim of the study was to investigate the effect of various RBA's in advancing harvest maturity in 'Triumph' persimmons grown in warm production areas of South Africa.

There is a perception that 'Triumph' persimmon fruit from "late" production areas in South Africa do not store as well as fruit from "earlier" areas. Fruit from "early" regions are harvested from the first week of April until mid-May while in the "late" regions the fruit are harvested from the end of May until mid-June (S. F. Ungerer, personal communication). Persimmons generally have a limited storage and shelf-life (Kitagawa and Glucina, 1984). 'Fuyu' persimmons can only be stored for 2 months under air storage at 0 to 2 ℃ and 90% relative humidity (RH) (Cia *et al*., 2006). Amongst the many factors that determine the storability of persimmons, fruit maturity at harvest is the most important (Öz and Ergun, 2010). A study was carried out to determine whether storability and shelf-life differ between early and late production areas as well as between orchards within these areas. The relationship between fruit colour, maturity and storability in orchards that received a preharvest gibberellic acid (GA_3) application was also investigated considering that GA_3 delays fruit ripening and extends the harvesting window by 2 to 3 weeks in 'Triumph' persimmon when sprayed 10 days prior to harvesting (Ben-Arie *et al*., 1986), which in turn improves the storability of persimmons.

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LITERATURE REVIEW: ADVANCING FRUIT MATURITY AND IMPROVING FRUIT STORABILITY

1. INTRODUCTION

The Japanese persimmon (*Diospyros kaki* Thunb.) is a deciduous fruit tree belonging to the family Ebenaceae (Kitagawa and Glucina, 1984). The genus Diospyros has approximately 200 species including *D. virginiana* and *D. lotus* used as rootstocks of persimmon (Garcia-Carbonell *et al*., 2002). The persimmon originated in China, but has long been grown in Japan where it is regarded as a national fruit (George *et al*., 1994). Commercial production of the fruit is also found in countries such as South Korea, Australia, Brazil, Israel, Italy, New Zealand, Spain and China (Table 1), where summers are warm and winters provide sufficient chilling to overcome a short dormancy requirement (Garcia-Carbonell *et al*., 2002).

Persimmons are classified into two groups, viz astringent and non-astringent, based on the presence or absence of astringency in the fruit at maturity (Neuwald *et al.*, 2009). Each group is further classified into two sub-types, viz pollination-constant (PC) or pollination-variant (PV), depending on the seed effect on the loss of astringency and flesh colour (Yakushiji and Nakatsuka, 2007). PC cultivars show no change in flesh colour after pollination while PV cultivars have light coloured flesh when seedless, and dark reddish brown when seeded (Kitagawa and Glucina, 1984).

Since 1998, South Africa (SA) has also been actively involved in persimmon production targeting Europe, Asia, the Middle East and Canada as its export markets (Rabe, 2003). The late-maturing, astringent PC cultivar Triumph is the major persimmon cultivar grown in the Mediterranean-type climate Western Cape region of SA. This review therefore aims to focus on factors that influence fruit development with emphasis on plant hormones and strategies used in advancing harvest maturity and improving storability of persimmons as well as other fruits.

Table 1: Persimmon production statistics (FAOSTAT, 2009)

Rank	Country	Annual production (MT)
1	China	2 533 899
2	Republic of Korea	430 521
3	Japan	266 600
4	Brazil	173 297
5	Azerbaijan	132 179
6	Italy	50 000
7	Israel	45 350
8	Uzbekistan	31 000
9	New Zealand	3 000
10	Iran	1 000
11	Australia	715
12	Nepal	509
13	Mexico	442
14	Slovenia	441

2. PERSIMMON FRUIT DEVELOPMENT

2.1. Fruit growth

The persimmon fruit is botanically a berry (Schroeder, 1950) consisting of a parenchymatous mesocarp surrounded by an epicarp, covered by a cuticle (Ida, 1932). Fruit mass and size curves follow a double sigmoid growth pattern (Kitagawa and Glucina, 1984) consisting of two active stages of growth, stage I and stage III, separated by a less active stage (stage II). Fruit development ranges from 120-190 days, depending on cultivar and environment; and the duration of stages I, II and III is 60-100 days, 20-40 days and 40-50 days, respectively. Growth stage I is thought to be associated with cell division or differentiation and growth stage III with cell expansion or maturation. The significance of growth stage II is not clear, but it does not appear to be related to seed development as the growth curves of seed-bearing and seedless cultivars are similar (George *et al*., 1997). High fruit temperatures (greater than 20 °C) can extend the duration of stage II (Mowat *et al*., 1995). Seed growth is completed by the end of stage I, after which physiological changes associated with seed coat colouring and endosperm hardening occurs (Otani, 1961). Calyx growth commences before flowering and is completed by the end of stage II. At full bloom the calyx may comprise more than 50% of the flower weight (Kitagawa and Glucina, 1984). It is not known if the calyx is a significant source of photosynthates for the developing fruit, though the calyx can assimilate carbon (Nakano *et al*., 1997). However, the calyx is an important gas exchange organ for the fruit, which lack stomata or lenticels and is covered by a layer of wax (Itoo, 1986). The calyx has a major influence on fruit growth and development. Removal of the lobes of the calyx or damage by agrochemicals and disease can enhance fruit drop and reduce fruit size and soluble solids. Calyx lobe removal at stage I and stage II inhibits fruit development by 50 to 75 percent (George *et al*., 1997). Calyx removal inhibits sucrose hydrolysis at unloading sites in the fruit (Yonimori *et al*., 1995).

Greatest dry matter accumulation occurs during stage III, which lasts between 100 to 150 days after anthesis (Nii, 1980). Fruit weight is also influenced by cell number and size (George *et al*., 1997). Reserves assimilated during autumn influence fruit cell number while cell size is determined by source availability during fruit growth (George *et al*., 1997). The soluble sugars, fructose and glucose accumulate after the hydrolysis of translocated sucrose (Mowat and George, 1996). Fructose invertase activity controls the rate of sugar unloading and this varies with fruit age (Zheng and Suguira, 1990) and it is disrupted by calyx removal (Hirano *et al.*, 1995). Mature ripe fruit have a sugar composition of ca. glucose (48%), fructose (49%) and sucrose (3%) (Mowat and George, 1996). Fruit colour increases with maturation as a result of chlorophyll degradation and carotenoid synthesis (Ebert and Gross, 1985).

Within the parenchyma of the fruit mesocarp are tannin cells where soluble tannin is contained (Itoo, 1986). In astringent cultivars, tannin cells enlarge from flowering until stage III while in pollination constant non-astringent (PCNA) cultivars they cease growth at the end of stage I (Yonimori and Matsushima, 1987). Tannin accumulation stops when cell growth ceases because of pore closure in the cell wall (Yonimori and

Matsushima, 1987). Loss of astringency in PCNA cultivars is a combination of two processes: Firstly a dilution of soluble tannins and, secondly, the coagulation of soluble tannins into an insoluble forms (Itoo, 1986). Astringent cultivars require treatment to remove astringency (Kitagawa and Glucina, 1984).

2.2. Fruit set and development

In fruit trees such as pears, cherries and plums, plant hormones such as gibberellins (GAs) and auxin (IAA) may stimulate fruit set. Species and cultivars within species differ in their hormone requirement for fruit set (Greene, 1989). GA treatments on fruit have variable effects on fruit growth and development (Krishnamoorthy, 1975). GA treatments are used to induce parthenocarpic fruit set in persimmons (Sugiyama and Yamaki, 1994). Application of GA to flowers creates more effective assimilate sinks in the fruit-forming tissues for fruit development (Krishnamoorthy, 1975). In contrast, exogenous GA may result in decreased fruit set in most grape cultivars (Dass and Randhawa, 1968). A spray made by combining GA_{4+7} and aminoethoxyvinylglycine (AVG) has been reported to increase fruit set in apples and pears (Bramlage *et al*., 1980). In general, application of GA later in the growing season affects growth and development of fruits with seeds (Looney and Pharis, 1986) by significantly decreasing fruit dry matter accumulation and delaying fruit ripening (Hamed *et al*., 1996). In addition, GA can also work together with cytokinins (CKs) to promote fruit development and cell division (Ozga and Reinecke, 2003). CK concentration is high at the peak of mitotic division in tomato fruit (Bohner and Bangerth, 1988).

2.3. Fruit maturity

Fruit maturity changes lead to alterations in endogenous hormone content and significant changes in fruit composition (Larrigaudiere *et al*., 1995). Abscisic acid (ABA) levels in the fruit have been shown to have a regulatory effect on ethylene production which is a key factor in fruit maturation (Guis *et al.*, 1997). Zhang and Yang (1987) found that a certain ABA threshold triggers the auto-catalysis of ethylene production. Vendrell (1970) indicated that endogenous gibberellins in conjunction with other hormones play an important role in fruit ripening. An increase in endogenous gibberellin and cytokinin levels was reported to be associated with delay in fruit ripening in citrus (Ladaniya, 2008). Goldschmidt (1988) showed that high gibberellin levels in fruit during maturation delay chloroplast to chromoplast transformation. The effect of hormones on ripening is evident from exogenous application of these hormones or their inhibitors as discussed in the following section.

3. STRATEGIES USED TO MANIPULATE FRUIT MATURITY AND IMPROVE FRUIT STORABILITY

3.1. Advancing fruit maturity

Plant growth regulators (PGRs) can be used to advance fruit harvest maturity (Rademacher *et al*., 2004). The PGRs can either be ethylene-releasing compounds or gibberellin (GA) inhibitors. Various other strategies are being used in different fruit trees to advance fruit maturity and these include the use of rest breaking agents, girdling or scoring, and deficit irrigation. All these strategies will be discussed in detail below.

3.1.1. Growth regulator use in advancing harvest maturity

Paclobutrazol (PBZ): PBZ is a triazole that inhibits GA synthesis (Lever, 1986). PBZ inhibits GA biosynthesis by blocking the oxidation of 3 intermediary precursors derived from mevalonic acid, viz ent-kaurenyl, ent-kaurenol, and ent-kaurenal (Bai and Chaney, 2001). PBZ achieves this by binding to the proto-heme iron of cytochrome P450 dependent monooxygenases, thus inhibiting their activity and blocking the synthesis of GA (Grossmann, 1992). As GA levels in plants decrease, the rate of cell division and expansion also decreases (Dalziel and Lawrence, 1984). PBZ thereby inhibits vegetative growth and its application before blooming increases fruit set in grapes (Carreño, *et al*., 2007). It does this by altering sink strength in a plant, which results in more assimilates being partitioned to reproductive growth, formation of flower buds, formation of fruit and fruit growth (Lever, 1986). In avocado, PBZ enhances fruit set by increasing the partitioning of dry matter to fruits (Wolstenholme *et al*., 1990). In persimmons, soil drench application of PBZ accelerates ripening by 2 to 3 weeks (Ben-Arie *et al*., 1997) and increases fruitfulness in the following season (Shalhout *et al*., 1987). However, the results of soil treatments show a lack of consistency and the tree vegetative growth is sometimes adversely affected.

Prohexadione-Ca (P-Ca): P-Ca is a growth retardant that inhibits the late stages of GA biosynthesis (Šabajeviene *et al.*, 2008), between GA_{2O} and GA_1 (Rademacher, 1995). P-Ca acts as a structural mimic of 2-oxoglutaric acid, which is a required as a co-substrate in GA biosynthesis (Rademacher *et al*., 2006). P-Ca inhibits excessive growth in fruit trees and increases fruit set (Rademacher *et al*., 2006), and unlike PBZ, does not increase flower bud formation in the next season in pear trees (Vercammen and Gomand, 2008). P-Ca has been shown to reduce vegetative growth and advance terminal bud set in apple trees (Byers *et al*., 2004). P-Ca also reduces ethylene formation in pome fruit trees where it mimics ascorbic acid, which is a co-substrate in ethylene formation (Dal Cin *et al*., 2005). P-Ca is short-lived; for example, in actively growing apple trees, it has a biological half-life of 10 to 14 days (Šabajeviene *et al.*, 2008). P-Ca has no negative effect on soil micro-organisms and animals (Evans *et al*., 1999) and decomposes in soil with a half-life of less than a week (Palonen and Mouhu, 2008). Apple trees treated with P-Ca are less susceptible to a number of diseases including fire blight (Miller, 1984). In persimmons, literature only indicates that P-Ca has been applied as a foliar spray to trees to retard sprouting and has thus efficiently reduced damage from spring frosts (Matsumura *et al*., 1992).

Ethephon: Ethephon (Ethrel) is an ethylene releasing compound that directly stimulates fruit ripening (Lieberman, 1979). Ethephon applied 22 days before harvest at a rate of 3.5 L ha^{-1} enhanced exocarp color in 'Bing' sweet cherry by 27% (Smith and Whiting, 2010). Ethephon application, however, can result in small fruit size, and can shorten storability and shelf life of fruit (Lieberman, 1979). Ethephon has been found to be effective in advancing maturity of 'Tydeman Early' apples when applied at a concentration of 200 $mg \cdot L^{-1}$ (Jones, 1979). Ethephon foliar spray in 'Cardinal' grape at 480 $mg \cdot L^{-1}$ increased TSS at harvest by 1.6 °Brix and also increased berry anthocyanins, thereby enhancing maturation (Nikolaou *et al*., 2003). Ethephon applied at a rate of 1000 $mg \cdot L^{-1}$ during period II of fruit development in blueberries enhanced colour (advanced fruit maturity) without affecting fruit size, but also reduced the length of the harvest period by approximately 1 week (Dekazos, 1976). In 'Tone Wase' persimmon, ethephon sprayed at 200 $mg \cdot L^{-1}$ about 120 days after full bloom advanced fruit maturity by 13 to 22 days (Kim *et al*., 2004). However, there is a prize to pay for the use of ethephon to advance fruit maturity. In persimmon and apple, ethephon reduces fruit storability and yield in the subsequent season (Kim *et al*., 2004; Jones, 1979).

3.1.2. Rest breaking

Lack of low temperatures to satisfy the chilling requirements for breaking endodormancy in deciduous fruit trees is one of the most serious problems in warm regions (Westwood, 1978). Chilling is required to cause the transition of both vegetative and floral buds of temperate or semi-deciduous subtropical fruit species from the dormant to active state (George *et al.*, 2002) and this process is known as rest breaking. If winter chilling is insufficient, then growth abnormalities such as delayed and uneven flowering, which delays fruit maturity, can occur. Length of fruit development may also be affected by time of bud break (George *et al*., 1997). Persimmons have a chilling requirement of ca. 300 chill units, based on the Richardson model (Mowat, 1995). Release from dormancy requires oxidative processes and several rest break agents can be used to induce oxidation to break dormancy and force spring bud break in deciduous fruit trees by increasing respiration (Shulman *et al*., 1986).

Rest-break chemicals such as hydrogen cyanamide (HCN) can be used to manipulate the timing and uniformity of bud break in deciduous fruit (Fuchigami and Nee, 1987). If applied at an early date, HCN at 3% advances harvest maturity in apples and full bloom is reached 30 to 51 days earlier in 'Anna' trees compared to untreated trees (Hasseeb and Elezaby, 1995). HCN when applied to table grapes 8 to 10 weeks before natural budburst, advanced fruit maturity by 14 to 8 days (George *et al*., 1988). However, in some cases HCN sprays cause poor bud opening and twig die back (Shulman *et al*., 1986). Thidiazuron (TDZ), a synthetic CK, is another RBA registered for use in apples. TDZ results in early reproductive bud break when sprayed 5 to 6 weeks before full bloom at 3 to 4%, which in turn advances harvest maturity (Costa *et al*., 2004). A combination of potassium nitrate (KNO_3) and thiourea has been reported to advance harvesting as well as increase fruit size in peach. KNO_3 alone has a mild rest-breaking ability (George *et al.*, 2002). In 'Fuyu' persimmon, a combination of KNO_3 at 50 $g \cdot L^{-1}$ and Wainken® (fatty acid esters) 40 $ml \cdot L^{-1}$ can advance bud break and flowering by 2-3 weeks (George *et al*., 2002). Thiourea also gives fruit with higher total soluble solids ratio and total acid content (Kuden *et al*., 1995).

3.1.3. Other strategies

Deficit Irrigation (DI): DI, if applied judiciously, minimizes water use. It decreases vegetative growth, improves fruit quality and advance fruit maturity (Behboudian and Mills, 1997). Late DI (applied from 118 days after full bloom (DAFB) to final harvest 201 DAFB) in 'Braeburn' apples gave the highest percentage of ripe fruit, increased TSS and fruit firmness and advanced fruit internal ethylene concentration (Mpelasokaa *et al*., 2001). Morinaga and Sykes (2001) found that water stress advanced rind colour development, which could result in early harvesting and also resulted in a higher juice TSS for 'Silverhill' Satsuma mandarin. Wan Zaliha and Singh (2010a) proved that 75% regulated deficit irrigation (RDI) applied from 135 DAFB continuously for 72 days till harvest significantly increased fruit colour, total anthocyanin concentration and fruit firmness of 'Cripps' Pink' apples. Withholding irrigation from 145 to 175 DAFB in 'Cripps' Pink' apple enhanced red skin colour, concentration of total anthocyanin, soluble solids concentration and firmness at harvest compared to commercial irrigation (Wan Zaliha and Singh, 2010b). Ripening rate is accelerated by 40% in avocado fruits that lose water at rate of 2.9% fresh weight per day, compared with those that lose only 0.5% per day (Adato and Gazit, 1974).

Girdling and Scoring: Girdling involves the removal of a cylinder of bark from the trunk without damaging the underlying tissue (Noel, 1970). Scoring, on the other hand is the process of making a single cut with a knife around the trunk. These techniques break the flow of photosynthates and growth regulators between the tree canopy and roots (Autio and Greene, 1994). According to Day and DeJong (1990), girdling improves fruit size and advances maturity of fresh market stone fruits. Fruit colour enhancement and advanced fruit maturity can be obtained by girdling 3 or 4 weeks prior to harvesting. Ethylene biosynthesis in fruit is enhanced by the girdling treatment and stimulates fruit softening in 'Bartlett' pear (Murayama *et al*., 2002). Wire-girdling lateral branches of 'Taishu' Japanese persimmon 2 weeks before full bloom (BFB) with removal of wires after 60 days increased fruit size, peel coloration and TSS concentration in fruit at harvest (Hasegawa *et al*., 2009). Scoring at about 70% of the final fruit size in 'Rojo Brillante' persimmon increased fruit size and accelerated colour development of the skin thereby advancing commercial harvest (Juan *et al*., 2009).

3.2. Delaying fruit maturity and improving fruit storability and shelf life

Persimmons generally do not store well and have a short shelf-life (Kitagawa and Glucina, 1984). Persimmons can only be stored for 2 months under air storage at 0 to 2 ℃ at 90% relative humidity (Cia *et al*., 2006). Amongst many other factors that determine the storability of persimmons, time of harvest is the most important (Öz and Ergun, 2010). Harvest time affects the respiration rate of persimmons (Kim *et al*., 2010). The ripening of persimmon fruit is ethylene-regulated. At commercial maturity, ethylene production is low in persimmons (Öz and Ergun, 2010). Associated with fruit ripening is a loss of firmness, changes in pigment content and an increase in TSS concentration. Fruit firmness, titrable acidity, soluble tannin and vitamin C content significantly decreases with maturity, while pH and soluble solid content increases (Ramin and Tabatabaie, 2003). A high degree of firmness at harvest therefore plays a decisive role in being able to preserve the quality of the fruit during storage and shelf-life (Salvador *et al*., 2007). Öz and Ergun (2010) indicated that early harvested 'Harbiye' persimmon fruit had higher firmness and lower ethylene production than late harvested fruit.

In both climacteric and non-climacteric fruits, ripening increases as the fruit advances in maturity. Ethylene is the natural central feature in the ripening process of fruits (Kays and Puall, 2004). Ripening in fruit is associated with loss of firmness. Inhibition of ethylene synthesis therefore reduces the rate of fruit softening (Guis *et al.*, 1997) in various crops. Ethylene concentration increases as the rate of respiration increases in most climacteric fruits. There are some chemicals, such as 1-methylcycopropene and gibberellic acid that can be used to inhibit ethylene action and thus prolong storability and shelf life of fruits.

3.2.1. Strategies used in improving fruit storability

1-Methylcyclopropene (1-MCP): 1-MCP is a new and unique tool that has been added to the list of options for extending the shelf life and quality of plant products. 1-MCP is a non-toxic gas that is structurally very similar to ethylene and that binds irreversibly to the ethylene receptor site (Serek *et al*., 1994), thus inhibiting ethylene synthesis and action. Inhibiting ethylene biosynthesis plays an important role in slowing the ripening process (Luo, 2004). Respiration can be suppressed by the use of 1-MCP in persimmons (Luo, 2004) and other fruits such as mango (Grima-Calvo *et al*., 2005) and apple (Argenta *et al*., 2005). At moderate temperature such as 15 ℃, 1-MCP can delay ripening and controls softening thus improving storability of persimmon fruits (Besada *et al*., 2008). Factors such as cultivar, stage of ripeness and storage atmosphere may limit the effectiveness of 1-MCP (Wright and Kader, 1997). 'Qiandaowuhe' persimmon when treated with 3 $\mu l \cdot L^{-1}$ 1-MCP for 6 hours had a postharvest life of 22 days at 20 ℃ storage temp erature (Luo, 2004). 1 $\mu l \cdot L^{-1}$ 1-MCP has been proved to maintain firmness and delay softening in 'Black Amber' plums harvested at commercial maturity stage and stored at 1 ±0.5 ℃ and 90%

relative humidity (RH) for 30 days (Özkaya *et al*., 2010). These results agree with Velardo *et al*. (2010) who found that 3.33% 1-MCP delayed fruit softening during shelf life of 'Larry Ann' and 'Songold' plums and the fruit were firmer than the untreated fruit. Positive results have also been found in apples after the use of 1-MCP. 'Golden Delicious' apple subjected to 625 $\mu l \cdot L^{-1}$ 1-MCP immediately after harvest and stored for 16 weeks at -0.5 ℃, followed by a shelf life of 7 days at 20 ℃ have been shown to have a flesh firmness that is well above the minimum flesh firmness requirement compared to untreated fruit (Crouch, 2010). 1-MCP also has the ability to reduce weight loss in 'Gloster' and 'Cooper 900' apples during cold storage (Özüpek and Köksal, 2010).

Gibberellic acid (GA_3) and other hormones: GA_3 retards colour development by delaying chlorophyll degradation and carotenoid synthesis as well as fruit growth rate (Martínez *et al*., 1996). GA_3 delays fruit ripening and extends the harvesting window by 2 to 3 weeks in persimmon when sprayed 10 days prior to harvesting (Ben-Arie *et al*., 1986). GA_3 has, therefore, been used to extend the storage life of Japanese persimmon by inhibiting the rate of fruit softening (Kitagawa *et al.*, 1966). However, GA_3 sprays delay bud break and decrease bud break percentage in the following season in persimmon (Gross *et al*., 1984). GA_3 applications at full bloom in persimmon significantly reduce return bloom in the subsequent seasons and this result in a decrease in yield due to a reduction in flower numbers (Steyn *et al*., 2008).

The CK-like regulator N-(2-Chloro-4-pyridyl)-N'-phenyl urea (CPPU) can be applied for delaying fruit maturity of blueberries (Serri and Hepp, 2006). Zilkah *et al*. (2008) reported that CPPU significantly increased the fruit firmness of 'Late Fuyu Mutant', which resulted in a delay in harvesting and also improved the postharvest storability. These dual effects might contribute significantly to delaying the time of marketing. AVG has also been used to delay fruit maturity. AVG is a naturally occurring amino acid that suppresses production of ethylene in plant tissues by competitively inhibiting ACC synthase, which is the rate limiting enzyme in the ethylene biosynthesis pathway (Boller *et al*., 1979). In apples, AVG applied at 125 ppm 3 to 4 weeks before commercial harvest has been shown to delay fruit ripening and reduce pre-harvest fruit drop of fruit (Andrew *et al*., 2006). A preharvest spray of ReTain (AVG active ingredient) at 200 mg·L^{-1} has been found to prevent development of red colour and reduced ethylene production rates in green table olives (Tsantili *et al*., 2010).

Controlled atmosphere (CA): In a CA, oxygen (O_2) is reduced and carbon-dioxide (CO_2) increased to prolong the storage life of fruit. Low O_2 and high CO_2 atmosphere slows activity of cell wall degrading enzymes (Kader and Saltviet, 2003). 1.5% O_2 and CO_2 at 1 ℃ has been used to store 'Triumph' persimmon fruit for 3 to 4 months in Israel (Testoni, 2002). CA has been shown to retard softening and to reduce astringency (Arnal *et al*., 2008) of persimmons during storage, but the level of CO_2 required to achieve this, however, results in internal browning due to the accumulation of acetaldehyde (Ben-Arie *et al.*, 1991). Off-flavours also develop under high CO_2 levels due to the accumulation of ethanol (Neuwald *et al*., 2009). Fruit packed in bags with 100% nitrogen (N) (modified atmosphere packaging) and stored at -1 ℃ have been shown to store for 18 wee ks and 1 week at 20 ℃ with good quality both in appearance and taste (Ben-Arie *et al.*, 1991). 'Rojo Brilliante' persimmon can be stored for 50 days at 15 ℃ under a 97% N plus air and for 5 days at 20 ℃ in air free of CO_2.

4. CONCLUSION

Various strategies have been successfully used to advance harvest maturity and to improve fruit storability. However, each method comes with its own drawbacks. The use of PGRs seems to be the most commonly used artificial method of advancing harvest maturity of fruits. However, the most effective application rates and time of application, as well as potential negative effects of the PGR in question, have to be determined for each fruit kind and cultivar. Fruit maturity at harvest has a direct effect on fruit storability and shelf-life. Hence, it is important to determine the optimum harvest maturity that will allow export to foreign markets, an adequate shelf life and ripening to a level that will achieve consumer acceptance.

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PAPER 1: EFFECT OF PACLOBUTRAZOL APPLICATION RATE ON HARVEST MATURITY AS WELL AS VEGETATIVE AND REPRODUCTIVE GROWTH IN 'TRIUMPH' PERSIMMON

Abstract

Advancing persimmon ripening in South Africa has proved to be a worthwhile strategy to attain early fruit that realise higher returns in the European market. This is currently achieved through use of the growth retardant paclobutrazol (PBZ) applied at a standard rate of 1.5 g per plant. However, even at this standard rate, PBZ results in excessive reduction in vegetative growth and decline in the fruit storage quality. The effect of lower PBZ application rates on fruit maturity and keeping quality, return bloom and vegetative growth was investigated over two seasons in 'Triumph' persimmon orchards at Simondium in the Western Cape Province of South Africa. The following treatments were evaluated: untreated control, 1.5 ml PBZ drench on 14 December 2009, 0.75 ml PBZ drench on 14 December 2009 and 17 February 2010, 0.75 ml PBZ drench on 14 December 2009 and 0.375 ml PBZ drench on 14 December 2009. In the second season (2010-2011), trees were left untreated as per current industry practise. In the first season (2009-10), all the PBZ treatments advanced harvest maturity regardless of application rate. PBZ seemed to decrease fruit firmness and increased the percentage soft fruit compared to the control after shelf-life in the season of application. The effect of the highest PBZ application rates (1.5 ml PBZ drench and 0.75 ml PBZ drench twice) on harvest maturity carried through to the subsequent season. Firmness at harvest and after shelf life in the 2010-2011 season decreased linearly while the percentage soft fruit increased linearly with increasing PBZ application rate. Lower PBZ application rates (0.375 ml and 0.75 ml PBZ drench) advanced harvest maturity in the season of application. At these rates, no effect on harvest maturity was observed in the subsequent season although 0.75 ml PBZ decreased fruit firmness after shelf life. PBZ at 0.375 ml did not decrease vegetative growth compared to the control. Considering all the data, it would appear that persimmon growers should use lower PBZ application rates than the current norm.

INTRODUCTION

Delivering 'Triumph' persimmon fruit to international markets when demand is high is one of the major challenges facing the persimmon industry in South Africa. In South Africa, 'Triumph' persimmons are usually harvested from the beginning of April until the end of June. Fruit that arrives in the European market during the first week of May fetches US$ 1,000 per ton while fruit that arrives in July is sold at a loss (S. F. Ungerer, personal communication). Therefore, there is a need to devise strategies to advance harvest maturity in order to benefit from early, high prices and to decrease the crop volume at the tail end of the season.

Application of plant growth retardants is one of the main strategies used to advance fruit harvest maturity (Nickell, 1994). Most growth retardants inhibit gibberellin (GA) synthesis thereby reducing vegetative growth. The inhibition of shoot growth decreases the sink demand of vegetative growth (Rademacher, 2000) thereby allowing a greater partitioning of assimilates to fruit growth. Since fruit ripening requires metabolic energy for the breakdown of chlorophyll, catabolism of organic acids, synthesis of carotenoids and inter-conversion of sugars (Surendranathan, 2005), an increase in carbohydrate availability advances harvest maturity (Lever, 1986). A heavy crop load delays harvest maturity due to a limited availability of carbohydrates in peaches (Johnson and Handley, 1989). In contrast, the abundant availability of assimilates, induced by girdling stimulates flower induction in olives (Proietti *et al*., 2006) and advances harvest maturity in persimmons (Steyn *et al*., 2008). GA inhibitors may also have a direct effect on fruit ripening considering that gibberellic acid (GA_3) application just prior to harvest delays fruit ripening of persimmons by up to 21 days and increases the storability of fruit by 2 weeks (Ben-Arie *et al*., 1986). Paclobutrazol (PBZ), one such GA inhibitor, is widely used to advance harvest maturity in various fruit crops including mango (Khader, 1990), peach (George and Nissen, 1992) and persimmon (Ben-Arie *et al*., 1997). PBZ applied to the soil is taken up through the root system and is transported primarily in the xylem through the stem to accumulate in the leaves and fruit (Lever, 1986).

Ben-Arie *et al*. (1997) found that a PBZ drench of 2 g per plant advanced harvest maturity in 'Triumph' persimmons in Israel by 2 to 3 weeks. PBZ has since been introduced to the South African persimmon industry at a standard application rate of 1.5 g PBZ (6 ml Avocet™, Fine Agrochemicals Limited, Worcester, UK) in 1.5 L drench per plant (S. F. Ungerer, personal communication). However, the use of PBZ at this standard application rate has some limitations. Persimmon orchards in SA are still young and less vigorous than 'Triumph' orchards in Israel. Soil drench application of PBZ in South Africa has been found to induce an excessive reduction in vegetative growth and a decline in fruit storage quality (S. F. Ungerer, personal communication). In mango, PBZ at 2 g per meter of canopy width has been found to increase fruit softening and weight loss during storage compared to the control treatment (Rebolledo-Martínez *et al*., 2008) while in 'Triumph' persimmon in Israel, a PBZ drench of 2 g per plant accelerated fruit softening and increased the incidence of decay during storage (Ben-Arie *et al*., 1997). Due to the reduction in vegetative growth in response to PBZ application, fruit become more exposed and therefore more prone to sunburn (Mowat and George, 1995). Although the reduced storability of fruit can be offset to some extent by treatment with 1-methylcyclopropene (MCP) and by marketing fruit soon after harvest (Besada *et al*., 2008), the use of MCP increases costs. PBZ also increases return bloom in the subsequent season, which may result in a large number of small fruit if a large percentage of flowers set (George and Nissen, 1992).

The aim of this study was to investigate the effect of reduced PBZ application rates on fruit maturity and fruit keeping quality. The effect of different PBZ application rates on vegetative growth and return bloom was also assessed.

MATERIALS AND METHODS

Plant material and trial design: The experiment was conducted in a 'Triumph' persimmon (*Diospyros kaki* L) orchard at Simondium (latitude: 33° 3' S, longitude: 19° 9' E) in the Western Cape Province (Mediterranean-type climate) of South Africa for two seasons (2009-2010 and 2010-2011). Trees were grafted to *D. virginiana* rootstock and planted in 2002 at a spacing of 5 m x 2 m. PBZ (Avocet™, 25% PBZ, Fine Agrochemicals Limited, Worcester, UK) was drenched at different application rates and timings. The following treatments were evaluated: 1) a control, 2) 1.5 ml PBZ drench on 14 December 2009, 3) 0.75 ml PBZ drench on 14 December 2009 and 17 February 2010, 4) 0.75 ml PBZ drench on 14 December 2009 and 5) 0.375 ml PBZ drench on 14 December 2009. PBZ diluted in 1.5 L of water was applied to the soil in the dripping area of the canopy along the dripper line. Treatments were randomised in eight blocks with single trees per plot. Treatments were only applied in the first season of the trial (2009-2010). In the second season (2010-2011), trees were left untreated as per current industry practise.

Data collection: In 2009-2010, the trunk diameter was measured in December 2009, 30 cm above ground using an electronic calliper and again after leaf drop during winter (June 2010) to determine the trunk growth. Fruit were harvested when commercial harvest maturity was reached. Fruit were weighed per tree on each harvest date (12 April 2010, 28 April 2010 and 7 May 2010) to determine harvest distribution and yield. Samples of 15 fruit per tree were randomly collected to determine fruit size, colour and maturity while an additional 30 fruits per tree were used to assess storability and shelf life. Six out of the eight fruit samples for the control treatment were collected on the second harvest date (28 April 2010) whereas all other samples were collected on the first harvest date (12 April 2010).

Flesh firmness, fruit colour and total soluble solids (TSS) concentration were measured at harvest, after storage and after shelf-life. Fruit samples were stored at -0.5 ℃ for 1 month to simulate shipping after astri ngency removal and 1-MCP fumigation (simultaneously at 20 ℃ for 24 hours) p lus 4 days shelf-life at room temperature (ca. 20^{o}C). Flesh firmness was determined on pared, opposite cheeks of the fruit using a GUSS fruit texture analyser (GS, GUSS Manufacturing (Pty.) Ltd., Strand, South Africa) with an 11 mm plunger. Each fruit was pressed slightly using fingers to determine the percentage of soft fruit per each sample. Fruit colour was determined by using the PPIS persimmon colour chart (Sweet Persimmon Growers Trust, South Africa; values 1-8, where 1 = red/ orange and 8 = green). Slices cut from each side of the fruit were pooled and juiced and TSS measured using a refractometer (PR32, Atago Co. Ltd., Tokyo Japan). Fruit diameter was measured using an electronic calliper and fruit weight was measured using an electronic balance for each sample. To determine fruit set, four 30 to 45 cm, one-year-old shoots per tree were randomly selected and tagged during early January in the subsequent season. Remaining peduncles and fruits were counted on 24 January 2011 to assess fruit set.

In 2010-2011, fruit were harvested at commercial harvest maturity and weighed per tree on each harvest date (1 April 2011, 8 April 2011 and 14 April 2011) to determine harvest distribution. Samples of 16 fruits were collected from each tree from the last two harvest dates (8 April and 14 April 2011). Half the fruit were used for immediate analysis. Remaining fruit were treated with 1-MCP at 20 ℃ for 24 hours and stored at -0.5 ℃ for 3 weeks plus 4 days shelf-life at ro om temperature (ca. 20 ℃) prior to analysis of fruit quality and maturity after shelf-life. All the parameters were analysed as described for the first season. Vegetative growth was assessed on 28 June 2011. Four branches that had been used for fruit set assessments were measured. The following measurements were taken to assess vegetative growth: branch diameter (1 cm from the intercalation between 2- and 1-year-old growth), number of new shoots on each branch and the length of each shoot. Trunk diameter was measured at the beginning of the second season in December 2010, 30 cm above ground using a calliper and again after leaf drop during winter in June 2011 to determine trunk growth.

Statistical analysis: Data of the experiment were analysed with the General Linear Models (GLM) procedure in the SAS (Statistical Analysis System) computer program (SAS Enterprise Guide 4.0; SAS Institute, 2006, Cary, NC). Means were separated by LSD (5%). Trunk diameter was used as covariate to amend for differences between trees where applicable.

RESULTS AND DISCUSSION

Either delaying or advancing ripening could be worthwhile in regulating the marketability of fruit, leading to subsequent higher returns (Khader, 1990). In our study, all the PBZ drench treatments, except for the lowest application rate of 0.375 ml per tree, significantly increased the proportion of the crop harvested on the first harvest date (12 April 2010) in the season of application (Table 1). The 0.375 ml PBZ drench was not significantly less effective than the higher application rates of PBZ. Significantly more fruit were harvested on the second harvest date (28 April 2010) for PBZ treatments while significantly fewer fruit remained on the tree until the third and final harvest date (7 May 2010). Most control fruit (71% of the total crop) were harvested on the third harvest date (7 May 2010) while ≥50% of the PBZ treatments were harvested on the first two harvest dates. The above findings are in agreement with Ben Arie *et al*. (1997) who found that 2 g PBZ per tree advanced fruit ripening by 2 to 3 weeks in 'Triumph' persimmons in Israel. Similarly Flohr *et al*. (1993) found that PBZ applied in May (northern hemisphere) advanced ripening in 'Triumph' persimmon by 2 to 4 weeks.

In persimmons, fruit ripening has been related to an increase in both orange colour and TSS (Besada *et al*., 2009). In our study, colour chart values did not differ significantly at harvest, but decreased similarly during storage and shelf-life in all treatments (Table 2). This suggests that fruit of the different treatments were picked at similar maturity.

Treatments only differed significantly in their effect on TSS at harvest in the first season (Table 2). Compared to the control treatment, all PBZ treatments, except for the 1.5 ml drench, decreased the fruit TSS at harvest. The 0.375 ml drench decreased TSS compared to the other PBZ treatments. A possible explanation for the higher TSS of control fruit is that samples from six out of the eight replications of the control treatment were collected on the second harvest date, at which date more soluble solids may have accumulated in the fruit. All other fruit samples were collected on the first harvest date. The average TSS of the six replications collected on the second date was approximately 2° higher than that of the two replications collected on the first date. No treatment differences in TSS were found after shelf life (Table 2). In mangoes, TSS increased with an increase in PBZ application rate from 250 to 3000 mg L^{-1} (Khader, 1990). In contrast, Carreno *et al*. (2007) found that TSS in grapes decreased with an increase in PBZ application rate from 1 to 3 ml per plant and they believed that this decrease was due to an increase in fruit diameter in response to PBZ. PBZ had no significant effect on fruit diameter in 'Triumph' in the year of application (Table 2).

PBZ had no effect on fruit firmness at harvest in the first season (Table 3). Although fruit were treated with 1-MCP before storage, firmness of PBZ fruit after shelf-life seemed to be lower compared to the control (p=0.0628), especially at the highest PBZ application rate. Although firmness at harvest was a significant covariant, it did not affect the significance level of firmness after shelf life (Table 3). Ben-Arie *et al*. (1997) found that PBZ greatly accelerated the rate of fruit softening during storage and particularly during shelf-life in 'Triumph' persimmon, especially at the higher rate of 2 g PBZ per tree. Although treatment differences were not statistically significant (p=0.0892), PBZ significantly (p=0.0181) increased the percentage soft fruit (42%) compared to the control (12%) (Table 3). Firmness at harvest was not a significant covariant for the percentage soft fruit after shelf-life indicating that the increase in soft fruit for the PBZ treatments did not relate to differences in harvest maturity, but to a decrease in the storability of fruit from treated trees. Thus, the keeping quality of fruit from PBZ treated trees had been compromised.

PBZ application in the 2009-2010 season increased the average number of flowers per shoot compared to the control in the 2010-2011 season except for the 0.375 ml treatment (Table 4). Flower numbers also increased linearly with an increase in PBZ application rate. An increase in return bloom is a common response to PBZ treatment and has been reported for various fruit crops, such as mango (Nafees *et al*., 2010), peach (Loreti *et al*., 1989) and apple (Costa *et al*., 2004). There were no significant treatment effects on fruit set (Table 4). In contrast, Kaset (1992) found that fruit set percentage increased linearly with increasing PBZ application rate in citrus. No significant differences in fruit size were found between treatments (Table 4). However, fruit diameter increased linearly with an increase in PBZ application rate. In agreement, Carreno *et al*. (2007) found that grape berry size increased linearly with an increase in PBZ application rate. On the contrary, fruit size is often smaller in the subsequent season following PBZ treatment due to an increase in fruit number (Khurshid *et al*., 1997b). Treatments did not differ significantly in the estimated number of fruit per tree and total yield, although yield seemed to increase linearly with an increase in PBZ application rate (p=0.0936). The effect of PBZ application rate on yield probably relates to the increase in fruit diameter in response to increasing PBZ application rate. Shoot number was not a significant covariant for estimated fruit number per tree. Hence, differences in shoot number do not explain why estimated fruit numbers per tree did not differ between treatments considering that PBZ increased flower numbers while not affecting fruit set.

The effect of PBZ application at 0.75 ml per tree in December and February in the 2009-2010 season on fruit maturity persisted into the 2010-2011 season. A greater proportion of the crop from this treatment was picked on the first harvest date (1 April 2011) compared to other treatments except for 1.5 ml PBZ applied in December 2009 (Table 5). The majority of the crop was harvested on the second (8 April 2011) and third (14 April 2011) dates. No treatment differences were found on the second date, but the two PBZ applications at 0.75 ml per tree and the 1.5 ml application decreased the proportion of the crop harvested on 14 April by 22 to 29% compared to the control and the 0.375 ml application. The proportion of the crop harvested on the second and third harvest dates increased and decreased respectively with an increase in PBZ application rate.

Fruit from trees treated with 1.5 ml PBZ drench in December 2009 were more orange than any other treatment both at harvest in 2011 and after shelf-life (Table 6) suggesting that these fruit were more mature at harvest. A significantly more orange peel colour was noted following shelf-life with increase in PBZ application rate despite the application of 1-MCP. Treatments did not differ significantly for TSS at harvest and after shelf life (Table 7). However, TSS after shelf life increased linearly with an increase in PBZ concentration.

A linear decrease in fruit firmness with an increase in PBZ application rate was noticed at harvest (Table 7). Fruit that received 1.5 ml PBZ drench in December and 0.75 ml PBZ drenched twice in December and February were significantly softer at harvest than fruit from other treatments. On average, fruit from PBZ treatments were softer after shelf life than control fruit and firmness decreased with an increase in PBZ application rate. All PBZ treatments, except for 0.375 ml per tree, decreased firmness after shelf-life compared to the control. PBZ at 1.5 ml per tree significantly increased the percentage soft fruit compared to all treatments except two applications at 0.75 ml (Table 7). The percentage soft fruit increased significantly with an increase in PBZ application rate. Ben-Arie *et al.* (1997) also found that 2 g PBZ per tree resulted in a considerable decrease in firmness and high decay percentages during storage and shelf-life of 'Triumph' persimmon compared to 1 g PBZ per tree. In contrast, in strawberries PBZ application rate had no significant effect on fruit firmness (Shakeri *et al*., 2009). Eshel *et al*. (2000) found that PBZ application at a rate of 0.5 g PBZ in 2 L of water per tree resulted in a significant loss of firmness in persimmons after storage compared to the control treatment.

The advancement of harvest maturity in the season subsequent to the season of PBZ application is in agreement with findings in peach where PBZ drench applications had a dose-related stimulating effect on fruit maturity in the subsequent season (Loreti *et al*., 1989). From previous studies, PBZ can either decrease or have no effect on storage quality of fruit in the subsequent season (Jacyna and Dodds, 1995; Khurshid *et al*., 1997a). In this study, PBZ was observed to decrease the storage quality indicated by a significant decrease in fruit firmness after shelf-life from PBZ treated trees. However, peel colour at harvest as a significant covariant for peel colour after shelf life and firmness at harvest as significant covariant for firmness and the percentage soft fruit after shelf life negate treatment differences for these variables (Table 6). This indicates that treatment differences in storability and in maturity parameters after shelf-life were due to differences in maturity at harvest.

In the season of application when fruit of comparable maturity were stored, the effect of PBZ on storability was less pronounced.

Shoot growth has been used as a measure of tree growth in various fruit crops, e.g. apple (Greene, 1999), apricot (Jacyna and Dodds, 1995) and persimmon (Kim *et al*., 2004). Jacyna and Dodds (1995) found that 2 g PBZ per tree effectively controlled vegetative growth in apricot trees for three years. In this experiment, the lowest PBZ application rates of 0.375 and 0.75 ml per tree increased trunk growth compared to the control (Table 8). This could possibly be due to more photosynthate being available for secondary growth in trees that received lower PBZ rates (Khurshid *et al*., 1997b) whereas the control channelled it into shoot growth. PBZ application at 1.5 ml or twice at 0.75 ml did not affect trunk growth, but significantly reduced the average shoot diameter compared to the control treatment while together with 0.75 ml PBZ decreased average shoot length and total vegetative growth compared to the control. In apples, PBZ at the highest application rate of 250 mg per tree was found to reduce total shoot length, shoot number per tree and trunk diameter for up to four years compared to the control (Khurshid *et al*., 1997b). Branch diameter, average shoot length and total vegetative growth decreased linearly with increasing PBZ application rate (Table 8). PBZ did not affect the number of new shoots that developed per tagged one-year-old shoot.

CONCLUSION

Advanced harvest maturity in 'Triumph' persimmons due to PBZ application was attained at a compromise of reduced fruit storage quality (decreased fruit firmness and an increase in the percentage soft fruit). The severity of the compromise depends on PBZ application rate. PBZ increased flower numbers and decreased vegetative growth in 'Triumph' persimmons at application rates of 0.75 ml and higher. The effect of advanced harvest maturity persisted into the subsequent season following high PBZ application rates (1.5 ml PBZ drench and 0.75 ml PBZ drench twice), but with dire effects on fruit storage quality. However, it seems that the detrimental effect on storability might have been less if fruit from PBZ treatments were harvested even sooner. Thus, to advance harvest maturity while maintaining acceptable keeping quality, PBZ application at 0.75 ml per tree (compared to the current industry standard application rate of 1.5 ml per tree) is recommended although effects will not persist into the subsequent season. Further research is needed to assess the extent to which the reduction in vegetative growth due to PBZ treatment increases the percentage fruit with sunburn and black spot (*Alternaria alternata*).

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Table 1: Effect of paclobutrazol (PBZ) application rate on harvest distribution of 'Triumph' persimmon on *D. virginiana* rootstock in the Simondium area of the Western Cape Province, South Africa in the 2009-10 season.

Treatments	Harvest 1 % (12 April 2010)	Harvest 2 % (28 April 2010)	Harvest 3 % (7 May 2010)
Control	6 b[x]	23 b	71 a
0.375 ml PBZ / plant in Dec	13 ab	37 a	50 b
0.75 ml PBZ / plant in Dec	15 a	37 a	48 b
0.75 ml PBZ / plant in Dec & Feb	19 a	45 a	36 b
1.5 ml PBZ / plant in Dec	18 a	39 a	43 b
Pr>F			
Treatment	0.0426	0.0120	0.0005
Control vs PBZ	0.0052	0.0012	<.0001
PBZ linear	0.9137	0.4033	0.5355
PBZ quadratic	0.1643	0.2572	0.0756

[NS] not significant

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

Table 2: Effect of paclobutrazol (PBZ) application rate on fruit maturity and quality in 'Triumph' persimmon on *D. virginiana* rootstock at harvest and after shelf-life in the 2009-10 season.

Treatments	Colour at harvest ^{z}	Colour chart after shelf-life	TSS at harvest	TSS after shelf-life	Fruit diameter (mm)
Control	5.4 ^{NS}	4.9 ^{NS}	20.3 a ^{x}	20.6 ^{NS}	71.4 ^{NS}
0.375 ml PBZ / plant in Dec	5.3	5.0	17.9 c	20.2	75.0
0.75 ml PBZ / plant in Dec	5.3	5.0	18.9 b	20.3	72.9
0.75 ml PBZ / plant in Dec & Feb	4.9	4.3	19.1 b	20.2	74.1
1.5 ml PBZ / plant in Dec	4.8	4.4	19.4 ab	20.6	71.2
Pr>F					
Treatment	0.3212	0.2804	0.0011	0.1730	0.1912
Control vs PBZ	0.8128	0.2418	0.0060	0.1702	0.1948
PBZ linear	0.0943	0.5847	0.0114	0.0399	0.0686
PBZ quadratic	0.3260	0.1131	0.1246	0.7160	0.2999

^{NS} not significant

^{x} means followed by the same letter do not differ significantly at $p<0.05$.

^{z} Colour chart where 1 = red/ orange and 8 = green.

Table 3: Effect of paclobutrazol (PBZ) application rate on fruit quality in 'Triumph' persimmon on *D. virginiana* rootstock at harvest and after shelf-life in the 2009-10 season.

Treatments	Firmness (kg) at harvest	Firmness (kg) after shelf-life	% soft fruit after shelf-life
Control	10.7 ^{NS}	7.6 ^{NS}	11.6 ^{NS}
0.375 ml PBZ / plant in Dec	10.9	7.0	29.5
0.75 ml PBZ / plant in Dec	10.6	6.5	25.1
0.75 ml PBZ / plant in Dec & Feb	10.8	5.6	33.8
1.5 ml PBZ / plant in Dec	10.6	4.6	41.6
Pr>F			
Treatment	0.9416	0.0864	0.0892
Control vs PBZ	0.9487	0.0628	0.0181
PBZ linear	0.6027	0.2108	0.3707
PBZ quadratic	0.6729	0.0971	0.4637
Cov (Firmness at harvest)	x	0.0299	x
Treatment	x	0.0846	x
Control vs PBZ	x	0.0557	x
PBZ linear	x	0.2624	x
PBZ quadratic	x	0.1136	x

^{NS} not significant

Table 4: Effect of paclobutrazol (PBZ) application rate in the 2009-10 season on return bloom, percentage fruit set, estimated fruit number per tree and yield of 'Triumph' persimmon on D. *virginiana* rootstock in the 2010-11 season.

Treatments	Flower number per one-year-old shoot	Fruit set %	Estimated fruit number per tree	Fruit weight (g)	Fruit diameter (mm)	Yield (ton ha^{-1})
Control	6.6 d[x]	51.5 [NS]	138.1 [NS]	187.9 [NS]	74.2 [NS]	23.7 [NS]
0.375 ml PBZ / plant in Dec	8.4 cd	47.9	99.7	192.5	74.9	17.5
0.75 ml PBZ / plant in Dec	8.6 bc	46.0	133.4	190.9	75.7	24.7
0.75 ml PBZ / plant in Dec & Feb	10.3 ab	51.5	159.2	204.4	76.8	32.1
1.5 ml PBZ / plant in Dec	11.3 a	50.1	134.9	205.3	78.4	27.6
Pr>F						
Cov (Shoot number)	x	x	0.5903	x	x	x
Treatment	0.0003	0.8804	0.5581	0.3371	0.1149	0.1306
Control vs PBZ	0.0003	0.6053	0.7974	0.2144	0.0906	0.6837
PBZ linear	0.0022	0.6577	0.3470	0.1944	0.0441	0.0936
PBZ quadratic	0.3866	0.6373	0.4540	0.5628	0.8155	0.4270

[NS] not significant

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

Table 5: Effect of paclobutrazol (PBZ) application rate in the 2009-10 season on harvest distribution of 'Triumph' persimmon on *D. virginiana* rootstock in the Simondium area of the Western Cape Province, South Africa in the 2010-11 season.

Treatments	Harvest 1 % (1 April 2011)	Harvest 2 % (8 April 2011)	Harvest 3 % (14 April 2011)
Control	4.3 b[x]	28.0 [NS]	67.7 a
0.375 ml PBZ / plant in Dec	5.7 b	27.6	66.7 a
0.75 ml PBZ / plant in Dec	6.7 b	36.3	57.0 ab
0.75 ml PBZ / plant in Dec & Feb	18.9 a	43.0	38.1 b
1.5 ml PBZ / plant in Dec	10.2 ab	45.3	44.5 b
Pr>F			
Treatment	0.0249	0.1232	0.0201
Control vs PBZ	0.1046	0.1320	0.0503
PBZ linear	0.3189	0.0438	0.0368
PBZ quadratic	0.8971	0.6997	0.7938

[NS] not significant

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

Table 6: Effect of paclobutrazol (PBZ) application rate in the 2009-10 season on fruit maturity and quality in 'Triumph' persimmon on *D. virginiana* rootstock at harvest and after shelf-life in the 2010-11 season.

Treatments	Colour at harvest [z]	Colour after shelf-life	TSS at harvest	TSS after shelf-life
Control	6.0 a[x]	5.8 a	19.6 [NS]	19.7 [NS]
0.375 ml PBZ / plant in Dec	5.5 ab	5.2 ab	19.8	20.0
0.75 ml PBZ / plant in Dec	5.4 b	4.9 ab	20.2	20.3
0.75 ml PBZ / plant in Dec & Feb	5.0 b	4.5 bc	20.9	21.0
1.5 ml PBZ / plant in Dec	4.1 c	4.1 c	20.7	21.1
Pr>F				
Treatment	<.0001	0.0435	0.2647	0.1189
Control vs PBZ	0.0005	0.0250	0.4105	0.2554
PBZ linear	0.0003	0.0336	0.0796	0.0349
PBZ quadratic	0.2452	0.9597	0.6092	0.9246
Cov (Colour at harvest)	x	0.0018	x	x
Treatment	x	0.6839	x	x
Control vs PBZ	x	0.2640	x	x
PBZ linear	x	0.6462	x	x
PBZ quadratic	x	0.7755	x	x

[NS] not significant

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

[z] Colour chart where 1 = red/ orange and 8 = green.

Table 7: Effect of paclobutrazol (PBZ) application rate in the 2009-10 season on fruit quality and maturity in 'Triumph' persimmon on *D. virginiana* rootstock at harvest and after shelf-life in the 2010-11 season.

Treatments	Firmness (kg) at harvest	Firmness (kg) after shelf-life	% soft fruit after shelf-life
Control	11.8 a[x]	9.7 a	0.1 b
0.375 ml PBZ / plant in Dec	10.7 a	7.7 ab	9.5 b
0.75 ml PBZ / plant in Dec	10.5 a	6.3 bc	18.5 b
0.75 ml PBZ / plant in Dec & Feb	8.6 b	4.9 cd	26.6 ab
1.5 ml PBZ / plant in Dec	8.2 b	3.1 d	32.8 a
Pr>F			
Treatment	<.0001	0.0010	0.0154
Control vs PBZ	0.0001	0.0017	0.0118
PBZ linear	0.0007	0.0016	0.0159
PBZ quadratic	0.2900	0.9615	0.8812
Cov (Firmness at harvest)	x	<.0001	0.0011
Treatment	x	0.2307	0.2549
Control vs PBZ	x	0.1062	0.0701
PBZ linear	x	0.0551	0.0652
PBZ quadratic	x	0.7613	0.8474

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

Table 8: Effect of paclobutrazol (PBZ) application rate in the 2009-10 season on vegetative growth of 'Triumph' persimmon on *D. virginiana* rootstock in the 2010-11 season.

Treatments	Increase in trunk diameter (mm)	Branch diameter (mm)	Number of new shoots	Average length of new shoots (cm)	Total vegetative growth (cm)
Control	2.6 c[x]	9.4 a	7.4 [NS]	26.3 a	198 a
0.375 ml PBZ / plant in Dec	4.4 ab	9.2 a	7.1	25.2 a	184 ab
0.75 ml PBZ / plant in Dec	5.3 a	8.4 ab	6.9	19.8 b	138 bc
0.75 ml PBZ / plant in Dec & Feb	2.3 c	7.6 b	7.0	17.8 b	123 c
1.5 ml PBZ / plant in Dec	3.5 bc	7.6 b	6.5	19.9 b	131 c
Pr>F					
Treatment	0.0119	0.0218	0.5109	0.0013	0.0079
Control vs PBZ	0.0636	0.0280	0.1877	0.0026	0.0061
PBZ linear	0.1553	0.0198	0.2580	0.0424	0.0485
PBZ quadratic	0.1824	0.6533	0.9860	0.0602	0.1749

[NS] not significant

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

PAPER 2: PROHEXADIONE-CALCIUM AS AN ALTERNATIVE TO PACLOBUTRAZOL FOR ADVANCING HARVEST MATURITY IN 'TRIUMPH' PERSIMMON

Abstract

Export market opportunities exist in the European market for out-of-season persimmon fruit. Persimmons that reach the market before the arrival of European summer fruits sell for a much higher price than later fruit. The need to produce early fruit has led the South African persimmon industry to adopt the use of paclobutrazol (PBZ) to advance harvest maturity. PBZ, however, has detrimental effects on fruit storability while stunted growth in response to PBZ may increase sunburn and black spot infection. Hence, the potential use of prohexadione-calcium (P-Ca) as replacement for PBZ in advancing harvest maturity in 'Triumph' persimmon was evaluated for two seasons. In the first season (2009-10), the following treatments were evaluated: untreated control, 1.5 ml PBZ drench per plant on 19 January, 100 mg·L^{-1} P-Ca foliar application on 19 January, 200 mg·L^{-1} P-Ca foliar application on 19 January, 100 mg·L^{-1} P-Ca foliar application on 11 February, 200 mg·L^{-1} P-Ca foliar application on 11 February, 100 mg·L^{-1} P-Ca foliar application on 3 March, 200 mg·L^{-1} P-Ca foliar application on 3 March, 100 mg·L^{-1} P-Ca foliar application on 19 January, 11 February, 3 March, 200 mg·L^{-1} P-Ca foliar application on 19 January, 11 February, 3 March, and 1.5 g P-Ca drench per plant on 19 January. A positive response to the multiple applications of P-Ca at 200 mg·L^{-1} was observed. In the second season (2010-11), treatments consisted of an untreated control, 3 ml PBZ drench per plant on 1 December, 300 mg·L^{-1} P-Ca foliar application on 14 March, 600 mg·L^{-1} P-Ca foliar application on 14 March, 200 mg·L^{-1} P-Ca foliar application on 23 February, 2 March and 14 March and 300 mg·L^{-1} P-Ca foliar application on 2 March and 14 March. P-Ca at 300 mg·L^{-1} was found to be effective in advancing harvest maturity in 'Triumph' persimmons with a lesser negative effect on fruit keeping quality (firmness and fruit softness) compared to PBZ. However, to optimize the effectiveness of P-Ca in persimmons, the effect of P-Ca on the vegetative growth and return bloom in the season after

application, the incidence of black spot, and the optimum rate and timing of P-Ca application need to be assessed.

INTRODUCTION

'Triumph' persimmons in South Africa are harvested from the beginning of April until the beginning of June. Since early fruit arriving in the European market during the first week of May sells for around US$ 1,000 per tonne while late fruit that arrive in August is sold at a loss (S. F. Ungerer, personal communication), it is of utmost importance to advance harvest maturity.

Plant growth regulators (PGRs) can be used to advance fruit harvest maturity (Rademacher *et al*., 2004). The PGRs can either be ethylene-releasing compounds or gibberellin (GA) inhibitors. Ethylene releasing compounds directly stimulate ripening (Lieberman, 1979) while GA inhibitors indirectly advance harvest maturity through inhibiting vegetative growth and promoting reproductive growth (Rademacher, 2000). GA inhibitors may also have a direct effect on fruit ripening considering that gibberellic acid (GA_3) application just prior to harvest delays fruit ripening by up to 21 days and increases the storability of fruit by 2 weeks (Ben-Arie *et al*., 1986).

Ethephon, an ethylene releasing compound, advances harvest maturity in various fruits including persimmon (Kim *et al*., 2004; Ungerer, 2007). However, in persimmon and apple, ethephon reduces fruit storability and yield in the subsequent season (Kim *et al*., 2004; Jones, 1979). A GA inhibitor, paclobutrazol, has been used in various crops to advance harvest maturity as a possible alternative to ethephon. Ben-Arie *et al*. (1997) found that a paclobutrazol drench at 2 g per plant advanced harvest maturity in persimmons by 2 to 3 weeks. However, as with ethephon, paclobutrazol also has drawbacks. Foremost, paclobutrazol is not registered for use on persimmon in South Africa. Another drawback is a decrease in the keeping quality of the fruit associated with the acceleration of fruit ripening (Ben-Arie *et al*., 1997; Flohr *et al*., 1993; Paper 1). Although the reduced storability of fruit can be offset to some extent by treatment with 1-methylcyclopropene (MCP) and by marketing fruit soon after harvest (Besada *et al*., 2008), the use of MCP increases production costs. Another major shortcoming of paclobutrazol is that it is persistent in the plant (Lever, 1986). This persistency may reduce vegetative growth and result in high fruit set of resultant small fruit in the subsequent season (George and Nissen, 1992). Due to reduction in vegetative growth, fruit become more exposed to sunlight and therefore more prone to develop sunburn (Mowat and George, 1995), hence resulting in poor quality fruit which will not meet the high standards of the international market.

Prohexadione-Ca (P-Ca), another GA inhibitor, advances harvest maturity in avocadoes (Salazar-García *et al*., 2007) and mangoes (Mouco *et al*., 2010) with no negative effects on tree growth compared to the PBZ control treatment. P-Ca inhibits the late stages of GA biosynthesis between GA_{2O} and GA_1 (Rademacher, 1995) through structurally mimicking 2-oxoglutaric acid, which is a required co-substrate in GA biosynthesis (Rademacher *et al*., 2006). Through the use of P-Ca, excessive growth in fruit trees is inhibited and fruit set is increased (Rademacher *et al*., 2006). Matsumura and Niikawa (1992) found that application of P-Ca to persimmon trees delayed sprouting which in turn decreased the risk and damage caused by spring frosts. P-Ca decomposes relatively quickly in soil with a half-life of less than 2 weeks (Palonen and Mouhu, 2008) and does not negatively affect soil micro-organisms (Evans *et al*., 1999), as compared to PBZ (Silva *et al*., 2003). In actively growing apple trees, the biological half-life of P-Ca is only 10 to 14 days (Evans *et al*., 1999).

P-Ca may also inhibit ethylene synthesis through its inhibitory effect on amino-cyclopropane-carboxylic acid (ACC) oxidase by structurally mimicking ascorbic acid, which is a co-substrate for this enzyme (Rademacher, 2000). Ethylene synthesis decreased in pome fruit as a result of P-Ca application at 250 $mg \cdot L^{-1}$ (Costa *et al*., 2006). In mangoes, reduced ethylene synthesis in response to P-Ca application increased fruit set and reduced fruit abscission (Mouco *et al*., 2010). Ethylene is the natural endogenous plant hormone regulating the ripening process of fruits (Kays and Paull, 2004). Ripening in fruit is generally associated with loss of firmness and changes in pigment content, as is the case with persimmons. Inhibition of ethylene synthesis therefore reduces the rate of fruit softening (Guis *et al.*, 1997). Hence, while P-Ca may advance ripening, it may also reduce storability by inhibiting GA biosynthesis. However, on the other hand, it may delay fruit ripening and prolong storage life by inhibiting ethylene synthesis.

The aim of this research was to assess P-Ca as a substitute for PBZ in advancing harvest maturity in 'Triumph' persimmon provided that its negative side-effects are reasonable compared to those associated with PBZ. Since no data is currently available on the use of P-Ca for advancing fruit maturity in persimmon, a wide range of P-Ca concentrations at various application dates were assessed. In addition, the effects of P-Ca on fruit keeping quality and tree vegetative growth were also assessed.

MATERIALS AND METHODS

2009-2010 season

Experiment 1: The experiment was conducted in a 'Triumph' persimmon (*Diospyros kaki* Thunb.) orchard at Simondium (latitude: 33° 3' S, longitude: 19° 9' E) in the Western Cape Province (Mediterranean-type climate) of South Africa. Trees on *D. virginiana* seedling rootstock were planted in 2002 at a spacing of 5 m x 2 m. In the 2009-10 season, treatments consisted of 1) untreated control, 2) 1.5 ml PBZ (Avocet™, 25% paclobutrazol, Fine Agrochemicals (Pty) Ltd, United Kingdom) drench (in 1.5 L water) per plant on 19 January, 3) 100 mg·L^{-1} P-Ca (Regalis®**,** 10% P-Ca, BASF (Pty) Ltd, South Africa) foliar application on 19 January, 4) 200 mg·L^{-1} P-Ca foliar application on 19 January, 5) 100 mg·L^{-1} P-Ca foliar application on 11 February, 6) 200 mg·L^{-1} P-Ca foliar application on 11 February, 7) 100 mg·L^{-1} P-Ca foliar application on 3 March, 8) 200 mg·L^{-1} P-Ca foliar application on 3 March, 9) 100 mg·L^{-1} P-Ca foliar application on 19 January, 11 February, 3 March, 10) 200 mg·L^{-1} P-Ca foliar application on 19 January, 11 February, 3 March, and 11) 1.5 g P-Ca drench (in 1.5L water) per plant on 19 January. The PBZ diluted in 1.5 liters of water was applied to the soil in the dripping area of the canopy along the dripper line.

Spray applications were applied by a handgun using a motorized pumping system. An average of a 5 L P-Ca solution was applied to each tree for all P-Ca treatments. Dash™ (C-65 methylester 406 $g \cdot L^{-1}$, BASF (Pty) Ltd, South Africa) was used as the wetting agent at a rate of 60 ml per 100 L of water. The treatments were randomised in 8 blocks with one tree per plot and guard trees and guard rows between treatment plots and rows, respectively. Commercial harvest was scheduled to commence during the first week of May.

Data collection: Trunk diameter was measured on 19 January 2010, 30 cm above ground using an electronic calliper and again after leaf drop during winter to determine trunk growth. The fruit were harvested and weighed per tree on each harvest date to determine harvest distribution. A sample of 20 fruit per plot was randomly collected from the second harvest to determine fruit size, colour and maturity. Flesh firmness, fruit colour and total soluble solids (TSS) were measured at harvest. Flesh firmness was determined on pared, opposite cheeks of fruit using a GUSS fruit texture analyser (GS, GUSS Manufacturing (Pty.) Ltd., Strand, South Africa) with an 11 mm plunger. Each fruit was pressed slightly using fingers to determine the percentage of soft fruit per sample. Fruit colour was determined by using the PPIS persimmon colour chart (values 1 to 8 where 1 = red/ orange and 8 = green). Slices cut from each side of the fruit were pooled and juiced and TSS measured using a refractometer (PR32, Atago Co. Ltd., Tokyo Japan). Fruit diameter was also measured using an electronic calliper and fruit weight was measured using an electronic balance per fruit. To determine fruit set in the subsequent season, four 30 to 45 cm-long one-year-old shoots per tree were randomly selected. Peduncles and remaining fruits were counted on 24 January 2011 to assess fruit set.

2010-2011 season

Experiment 2: The experiment was conducted in same orchard as experiment 1. Treatments consisted of: 1) untreated control, 2) 3 ml PBZ drench per plant on 1 December (in 1.5 L water), 3) 300 $mg \cdot L^{-1}$ P-Ca foliar application on 14 March, 4) 600 $mg \cdot L^{-1}$ P-Ca foliar application on 14 March, 5) 200 $mg \cdot L^{-1}$ P-Ca foliar application on

23 February, 2 March and 14 March and 6) 300 mg·L^{-1} P-Ca foliar application on 2 March and 14 March. The treatments were randomised in 8 blocks with one tree per plot and guard trees and rows between treatment plots and rows, respectively. An average of a 5 L P-Ca solution was applied to each tree for all P-Ca treatments as was done in experiment 1. Dash™ (C-65 methylester 406 g·L^{-1}, BASF (Pty) Ltd, South Africa) was used as the wetting agent at a rate of 60 ml per 100 L of water. Commercial harvesting was scheduled to commence early in April.

Data collection: Trunk diameter was measured at the beginning of the second season in December 2010, 30 cm above ground using a calliper and again after leaf drop during winter in June 2011 to determine trunk growth. Fruit were harvested and weighed per tree using an electronic balance on each harvest date to determine harvest distribution. A sample of 20 fruit per tree was collected for analysis from the first harvest. Half of the fruit (10 fruits) were used to determine fruit size, flesh firmness, fruit colour and total soluble solids (TSS) at harvest while the remaining fruit were used to conduct after shelf-life assessment after storage of 3 weeks at -0.5 ℃ plus 4 days shelf-life at room temperature (ca. 20 ℃). MCP was applied to all fruit for 24 hours at 20 ℃ in a sealed container on 13 April 2011. All the parameters were measured as for experiment 1.

Statistical analysis

Data were analysed with the General Linear Models (GLM) procedure in the SAS (Statistical Analysis System) computer program (SAS Enterprise Guide 4.0; SAS Institute, 2006, Cary, NC 27513, USA). Means were separated by LSD (5%). Trunk diameter was used as a covariate to amend for differences in vigour between trees. Single degree of freedom orthogonal polynomial contrasts were fitted where appropriate.

RESULTS AND DISCUSSION

The PBZ drench at 1.5 ml per tree significantly increased the proportion of the crop harvested on the first harvest date (12 April 2010) in the first season compared to all treatments except for a single P-Ca application at 200 $mg{\cdot}L^{-1}$ in March and three applications at 200 $mg{\cdot}L^{-1}$ in January, February and March (Table 1). The latter treatment increased the proportion of the crop harvested on the first harvest date compared to the control and 100 $mg{\cdot}L^{-1}$ P-Ca application in January. However, few fruit were mature at the first harvest date. The majority of the crop was harvested on the second (28 April 2010) and third (7 May 2010) dates, but no treatment differences were found (Table 1). There was quadratic interaction between P-Ca concentration and time of application with regards to the second and third harvest. The positive response to the multiple applications at 200 $mg{\cdot}L^{-1}$ suggested that P-Ca might be effective in advancing harvest maturity in 'Triumph' persimmons at higher application rates. During this season, orchard vigour was low since no fertiliser applications were made during the previous season. Probably due to the low vigour, treatment effects (including PBZ) were small as pointed out by Costa *et al*. (2004) who found the greatest responses to GA inhibitors in more vigorous orchards.

In the first season, treatments had no significant effect on fruit firmness, peel colour and TSS concentrations at harvest (Table 2). Although not significant, multiple applications of P-Ca at 200 $mg{\cdot}L^{-1}$ seemed to have hastened fruit colour development. This was also indicated by the higher percentage of the crop picked earlier (Table 1).

In 'Elstar' apples, higher P-Ca applications of 200 $mg{\cdot}L^{-1}$ were found to reduce flowering in the subsequent season (Basak, 2004) while at 250 $mg{\cdot}L^{-1}$ P-Ca reduced berry set in grapes (Giudice *et al*., 2004). Smit *et al*. (2005) found that P-Ca increased fruit set in 'Forelle' pears, but had a negative effect on return bloom in the subsequent season. P-Ca application had no effect on the average number of flowers per shoot and fruit set in the subsequent season (Table 2). The effect of high

P-Ca applications on flower numbers and fruit set of persimmons will be assessed during the next season.

The percentage of fruit picked on the first harvest date (8 April 2011) of the second season differed significantly between treatments (Table 3). The 3 ml PBZ drench in December and a single P-Ca application at 300 mg·L^{-1} in March significantly advanced the harvest maturity of the fruit as evidenced by the much greater proportion of fruit harvested on the first harvest date (53% and 42%, respectively) (Table 3) and the near completion of harvest of these two treatments on the second harvest date (14 April 2011). The PBZ application rate was double the standard application rate. Ben-Arie *et al*. (1997) found that higher concentrations of PBZ have a greater effect in advancing harvest maturity, but with a detrimental effect on fruit keeping quality and tree growth. No significant effects in advancing harvest were found with the high P-Ca 600 mg·L^{-1} application or with multiple applications of 200 or 300 mg·L^{-1}. The possible explanation could be that P-Ca at higher application rates inhibited ethylene action (Costa *et al*., 2006) thereby countering any positive effect on ripening. In mangoes, 1500 mg·L^{-1} P-Ca was found to be just as effective as 3000 mg·L^{-1}, but better than the control treatment in advancing harvest maturity (Mouco *et al*., 2010).

There were no significant differences between treatments on fruit picked on the second harvest date (14 April 2011) (Table 3). A significantly smaller proportion of the crop was picked on the third picking date (29 April 2011) for the 3 ml PBZ drench and 300 mg·L^{-1} P-Ca applied on 14 March compared to the untreated control and 200 mg·L^{-1} P-Ca applied in February and twice during March.

In 2010/2011, the 3 ml PBZ drench in December and multiple P-Ca applications at 200 mg·L^{-1} decreased the firmness of fruit at harvest compared to other treatments (Table 4). Although there were no significant treatment differences in firmness after shelf-life (p=0.0690), plant growth regulator treatments on average decreased firmness compared to the control (p=0.0108). Firmness at harvest was a significant covariant for firmness after shelf life indicating that differences in firmness after shelf-life were due to differences in firmness at harvest. Testoni (2002) also found that high PBZ applications of 2 g per plant reduced the storability of persimmon fruit by about four weeks with a rapid loss in fruit firmness and enhanced susceptibility to decay during shelf-life. However, contrary effects have been observed for P-Ca in pears, where Smit *et al.* (2005) found that P-Ca increased fruit firmness at harvest and this could be due to the ability of P-Ca to inhibit ethylene synthesis and action (Rademacher *et al*., 1995).

No significant treatment differences in colour chart values at harvest (p=0.0725) were noted in the 2010/2011 season, but fruit colour differed significantly after shelf-life (p=0.0466) (Table 5). On average, plant growth regulator treatments advanced fruit colour development compared to the control both at harvest and after-shelf-life. Amongst the P-Ca treatments, two applications at 300 $mg{\cdot}L^{-1}$ P-Ca in March increased fruit colour after shelf-life the most. In citrus, foliar application of P-Ca at 400 $mg{\cdot}L^{-1}$ also increased pre-harvest rind colour due to induction of chlorophyll degradation and carotenoid synthesis (Barry and le Roux, 2010).

The 3 ml PBZ drench at 20% incidence increased the percentage soft fruit compared to all treatments except for two applications of 300 $mg{\cdot}L^{-1}$ P-Ca in March (14.3%) (Table 4). The latter treatment did not differ significantly from the three applications of 200 $mg{\cdot}L^{-1}$ P-Ca in February and March. However, the percentage soft fruit of this treatment was much lower at 3.8% and not significantly different from the control and other P-Ca treatments. Although firmness at harvest was a significant covariant for the percentage soft fruit after shelf life, treatment differences remained significant indicating that firmness at harvest only to an extent affected the storability of fruit.

There were no significant treatment differences in TSS at harvest or after shelf-life in the 2011/2011 season. Medjdoub *et al*. (2003) found a linear decrease in TSS concentration in ‘Golden Delicious’ apples with increasing P-Ca concentrations from 100 $mg{\cdot}L^{-1}$ to 400 $mg{\cdot}L^{-1}$, but P-Ca had little effect on TSS in our experiments.

No significant treatment differences in trunk growth were observed (Table 3). Costa *et al*. (2004) indicated that tree vigour can limit treatment effectiveness; the effect of P-Ca on vegetative growth is less pronounced on less vigorous trees. In addition, P-Ca application in our study was done after most shoots had stopped growing. Although, P-Ca is not very persistent in the plant (Evans *et al*., 1999), the effect of high P-Ca applications in the 2010/2011 season on vegetative growth in the 2011/2012 season will be assessed relative to the effect of the PBZ drench.

Occurrence of diseases in fruit reduces quality and hence profit. Black spot caused by *Alternaria alternata* is the most severe postharvest disease in persimmon (Snowdown, 2000). This opportunistic disease impairs the quality and reduces the storability of the fruit (Kobiler *et al*., 2011). Research has indicated that up to 100 conidia *of A. alternata* can occur on each persimmon fruit at harvest (Prusky *et al*., 1981). Miller (1984) showed that apple trees treated with P-Ca are less susceptible to a number of diseases including the bacteria causing fire blight. P-Ca modifies flavonoid metabolism (Rademacher *et al*., 2006) by inhibiting the flavanone 3-hydroxylase (FHT) which is involved in the biosynthesis of anthocyanidins and other flavonoids (Rademacher *et al*., 2000). This induces the synthesis of phytoalexians such as luteoliflavan and luteoforol phytoalexians which are believed to be involved in disease resistance (Rademacher *et al*., 2006). P-Ca may therefore have an additional benefit in reducing the extent of black spot infection. Unfortunately, the incidence of black spot was not assessed in the two experiments.

CONCLUSION

P-Ca at 300 $mg \cdot L^{-1}$ applied 2 weeks before the onset of harvesting advanced harvest maturity of 'Triumph' persimmon fruit. Higher P-Ca concentrations and multiple applications were ineffective. P-Ca did not compromise fruit keeping quality (firmness and fruit softness) to the same extent as PBZ. It can be concluded that P-Ca is potentially a replacement for PBZ in advancing harvest maturity of persimmons, but further research is needed to assess the effect of P-Ca on the vegetative growth and return bloom in the season after application, the incidence of black spot, and the optimum rate and timing of P-Ca application.

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Table 1: Effect of a paclobutrazol (PBZ) drench and different prohexadione-Ca (P-Ca) application rates and timings on harvest distribution of 'Triumph' persimmon on D. *virginiana* rootstock in the Simondium area of the Western Cape province, South Africa in the 2009-10 season.

Treatments	Harvest 1 % (12 April 2010)		Harvest 2% (28 April 2010)	Harvest 3 % (7 May 2010)
Control	1.2	c [x]	66.1 [NS]	32.7 [NS]
PBZ drench @ 1.5 ml / tree in Jan	21.5	a	64.7	13.8
P-Ca drench @ 1.5 g / tree in Jan	6.3	bc	68.6	25.1
100 mg·L^{-1} P-Ca in Jan	1.2	c	68.3	30.5
200 mg·L^{-1} P-Ca in Jan	4.3	bc	78.9	16.8
100 mg·L^{-1} P-Ca in Feb	10.5	bc	60.9	28.6
200 mg·L^{-1} P-Ca in Feb	5.9	bc	61.9	32.2
100 mg·L^{-1} P-Ca in Mar	4.8	bc	75.2	20.0
200 mg·L^{-1} P-Ca in Mar	11.0	abc	68.6	20.5
100 mg·L^{-1} P-Ca in Jan, Feb & Mar	6.7	bc	52.3	41.0
200 mg·L^{-1} P-Ca in Jan, Feb & Mar	13.0	ab	65.7	21.3
Pr>F				
Treatment	0.0234		0.2973	0.1315
P-Ca 100 vs 200 mg·L^{-1}	0.5822		0.3241	0.1913
Time linear	0.7130		0.1440	0.2136
Time quadratic	0.4129		0.5438	0.9124
1 vs 3 applications	0.4386		0.8707	0.5283
P-Ca conc. * Time linear	0.1756		0.8874	0.4955
P-Ca conc * Time quadratic	0.7514		0.0081	0.0135
P-Ca conc. * Applications	0.2688		0.3476	0.7857

[NS] not significant

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

Table 2: Effect of a paclobutrazol (PBZ) drench and different prohexadione-Ca (P-Ca) application rates and timings on fruit quality, maturity, return bloom and fruit set in 'Triumph' persimmon on *D. virginiana* rootstock at harvest in the Simondium area of the Western Cape Province, South Africa in the 2009-10 season.

Treatments	Firmness (kg)	Colour [z]	TSS	Fruit set	Flower number
Control	9.6 [NS]	4.8 [NS]	20.4 [NS]	6.2 [NS]	6.7 [NS]
PBZ drench @ 1.5 ml / tree in Jan	9.4	4.8	20.7	7.2	8.1
P-Ca drench @ 1.5 g / tree in Jan	9.6	5.3	21.4	6.8	10.7
100 $mg \cdot L^{-1}$ P-Ca in Jan	9.5	4.8	20.1	8.7	11.2
200 $mg \cdot L^{-1}$ P-Ca in Jan	9.9	4.7	21.4	10.0	11.2
100 $mg \cdot L^{-1}$ P-Ca in Feb	9.7	5.0	20.2	9.2	10.7
200 $mg \cdot L^{-1}$ P-Ca in Feb	9.8	4.7	20.7	9.2	10.8
100 $mg \cdot L^{-1}$ P-Ca in Mar	10.0	5.2	21.1	8.3	10.5
200 $mg \cdot L^{-1}$ P-Ca in Mar	9.5	5.2	20.9	7.7	11.5
100 $mg \cdot L^{-1}$ P-Ca in Jan, Feb & Mar	9.4	4.8	20.8	8.3	13.5
200 $mg \cdot L^{-1}$ P-Ca in Jan, Feb & Mar	8.7	4.3	20.2	9.5	10.5
Pr>F					
Treatment	0.8110	0.2689	0.2111	0.7467	0.3454
P-Ca 100 vs 200 $mg \cdot L^{-1}$	0.5188	0.0371	0.9271	0.3801	0.6955
Time linear	0.4083	0.5040	0.8462	0.2846	0.9198
Time quadratic	0.5996	1.0000	0.8911	0.9739	0.8161
1 vs 3 applications	0.1343	0.6820	0.8465	0.6114	0.4481
P-Ca conc. * Time linear	0.9831	0.1843	0.1528	0.6107	0.7626
P-Ca conc * Time quadratic	0.5647	0.2492	0.1364	0.7686	0.9074
P-Ca conc. * Applications	0.1913	0.0445	0.0246	0.3337	0.2133

[NS] not significant

[z] Colour chart where 1 = red/ orange and 8 = green.

Table 3**:** Effect of paclobutrazol (PBZ) drench and different prohexadione-Ca (P-Ca) application rates and timings on harvest distribution and trunk growth of 'Triumph' persimmon on *D. virginiana* rootstock in the Simondium area of the Western Cape Province, South Africa in the 2010-11 season.

Treatments	Harvest 1 % (8 April 2011)	Harvest 2% (14 April 2011)	Harvest 3 % (29 April 2011)	Trunk growth (mm)
Control	21 b [x]	63 [NS]	16 a	4.0 [NS]
PBZ drench @ 3 ml / tree in Dec	53 a	46	1 b	2.4
300 $mg{\cdot}L^{-1}$ P-Ca in Mar	42 ab	53	5 b	2.7
600 $mg{\cdot}L^{-1}$ P-Ca in Mar	25 bc	65	10 ab	2.8
200 $mg{\cdot}L^{-1}$ P-Ca in Feb & twice in Mar	22 c	62	16 a	4.0
300 $mg{\cdot}L^{-1}$ P-Ca twice in Mar	24 c	68	8 ab	3.8
Pr>F				
Cov (Trunk diameter 1)	x	x	x	0.5603
Treatment	0.0028	0.1649	0.0412	0.3388
Control vs Rest	0.0690	0.5653	0.0451	0.1790
PBZ vs P-Ca	0.0009	0.0300	0.0416	0.3488
Control vs P-Ca	0.2765	0.9126	0.1141	0.2545

[NS] not significant

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

Table 4: Effect of paclobutrazol (PBZ) drench and different prohexadione-Ca (P-Ca) application rates and timings on fruit quality and maturity of ‘Triumph’ persimmon on *D. virginiana* rootstock at harvest and after shelf-life in the Simondium area of the Western Cape Province, South Africa in the 2010-11 season.

Treatments	Firmness (kg)		% Soft fruit
	At harvest	After shelf-life	after shelf-life
Control	10.9 ab [x]	7.8 [NS]	2.2 c
PBZ drench @ 3 ml / tree in Dec	9.5 c	5.0	20.0 a
300 mg·L^{-1} P-Ca in Mar	11.3 a	6.4	3.3 bc
600 mg·L^{-1} P-Ca in Mar	11.2 ab	6.1	1.7 c
200 mg·L^{-1} P-Ca in Feb & twice in Mar	9.8 c	6.6	3.8 bc
300 mg·L^{-1} P-Ca twice in Mar	10.3 bc	6.0	14.3 ab
Pr>F			
Treatment	0.0028	0.0690	0.0087
Control vs Rest	0.2497	0.0108	0.1389
PBZ vs P-Ca	0.0063	0.0674	0.0030
Control vs P-Ca	0.5817	0.0289	0.4090
Cov (Firmness at harvest)	x	0.0144	0.0230
Treatment	x	0.1318	0.0215
Control vs Rest	x	0.0216	0.1242
PBZ vs P-Ca	x	0.2633	0.0053
Control vs P-Ca	x	0.0382	0.3856

[NS] not significant

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

Table 5: Effect of paclobutrazol (PBZ) drench and different prohexadione-Ca (P-Ca) application rates and timings on fruit quality and maturity of 'Triumph' persimmon on *D. virginiana* rootstock at harvest and after shelf-life in the Simondium area of the Western Cape Province, South Africa in the 2010-11 season.

Treatments	Colour at harvest [z]	Colour after shelf life	TSS at harvest	TSS after shelf-life
Control	6.2 [NS]	5.1 a [x]	21.6 [NS]	21.6 [NS]
PBZ drench @ 3 ml / tree in Dec	4.8	3.7 b	21.6	21.9
300 mg·L^{-1} P-Ca in Mar	5.3	4.5 ab	20.9	22.1
600 mg·L^{-1} P-Ca in Mar	5.7	4.3 ab	21.0	22.0
200 mg·L^{-1} P-Ca in Feb & twice in Mar	5.2	4.5 ab	20.4	21.9
300 mg·L^{-1} P-Ca twice in Mar	5.3	4.0 b	21.9	22.2
Pr>F				
Treatment	0.0752	0.0466	0.9274	0.2689
Control vs Rest	0.0114	0.0093	0.6081	0.3599
PBZ vs P-Ca	0.1200	0.0683	0.6305	0.6457
Control vs P-Ca	0.0268	0.0252	0.5498	0.3236

[NS] not significant

[z] Colour chart where 1 = red/ orange and 8 = green.

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

PAPER 3: EFFECT OF REST BREAKING AGENTS ON BUD BREAK, FLOWERING, FRUIT MATURITY AS WELL AS VEGETATIVE GROWTH IN 'TRIUMPH' PERSIMMON

Abstract

Early 'Triumph' persimmon fruit sells at a higher price in the European market. Growth retardants such as paclobutrazol can be used to advance harvest maturity, but the storability of fruit is compromised. 'Triumph' persimmon trees in South Africa are planted on seedling rootstock resulting in uneven bud break and this possibly contributes to the large variability in fruit maturity between and within trees. In some of the warmer production regions in the Western Cape, the winter chilling may be borderline to satisfy the chilling requirement to release 'Triumph' persimmon buds from endodormancy. Insufficient winter chilling results in growth abnormalities in fruit trees such as delayed and uneven flowering, which delays and causes variable fruit maturity. In this trial, we investigated the use of rest breaking agents (RBA's) to advance harvest maturity, decrease variability in fruit maturity at harvest and to increase bud break and vegetative growth. The effect of 3% Lift, 0.5% Dormex, 3% Oil and a combination of 0.5% Dormex and 3% Oil applied on 13 August and 2 September as well as 6% KNO_3 and 2% Urea applied on 2 September on bud break, flowering, fruit maturity and quality as well as vegetative growth was assessed over one season (2010-2011) in a 'Triumph' persimmon orchard at Villiersdorp in the Western Cape Province of South Africa. RBA treatments did not increase or advance bud break percentage and flowering compared to the control treatment. Chilling was probably satisfied prior to treatment application as indicated by the number of chill units that had accumulated. As a result RBA had no effect on bud break, flowering and fruit set. Subsequently, RBA treatments did not increase yield and advance harvest maturity of persimmons. Therefore, RBA application after chilling satisfaction has no effect in promoting bud break and flowering as well as compressing or advancing harvest of persimmons. Another study should be carried out probably in a warmer area to determine the effect of Lift, Urea, Dormex and Oil

at increased concentrations on bud break, flowering and fruit maturity and at different timings from those used in the current study.

INTRODUCTION

Persimmon trees generally have a low chilling requirement of ca. 300 Richardson chilling units (Mowat *et al*., 1995). However, chilling may be insufficient in some years in some of the warmer production areas (Berg and Breede river valleys) in the Western Cape province of South Africa. Inadequate chilling for breaking endodormancy in deciduous fruit trees is one of the most serious problems in warm production regions (Westwood, 1978). Chilling is required to cause the transition of both vegetative and floral buds of temperate or semi-deciduous subtropical fruit species from the dormant to active state (George *et al.*, 2002) and this process is known as rest breaking. If winter chilling is insufficient, then growth abnormalities such as delayed and uneven blossoming occurs causing delayed and uneven fruit maturity (Mowat *et al*., 1995). A delay in fruit maturity might not be favorable considering that fruit from "late" areas arriving in the European market in July sell at a loss while "early" fruit arriving in May sell at US$ 1,000 per ton (S. F. Ungerer, personal communication).

Rest-break agents (RBA's) such as hydrogen cyanamide (HCN) can be used to manipulate the timing and uniformity of bud break in deciduous fruit (Fuchigami and Nee, 1987). When applied 13 weeks before expected full bloom, HCN at 3% advances harvest maturity in apples and full bloom was reached 30 to 51 days earlier in 'Anna' trees compared to untreated trees (Hasseeb and Elezaby, 1995). HCN applied to table grapes 8 to 10 weeks before natural budburst advanced fruit maturity by 8 to 14 days (George *et al*., 1988). HCN application at 3% 40 days before natural budburst advanced bud break by 10 days in 'Fuji' apples (Bound and Jones, 2004). However, when applied too close to natural bud break, HCN application may cause poor bud break and die-back of shoots if concentrations exceed the threshold level (Bound and Jones, 2004). An early application of mineral oil at 2% induced early reproductive sprouting and advanced the harvest date by 13 days in 'Royal Gala' apples (Manzi *et al*., 2010). A combination of HCN at 1.5% and oil at 4% was found to promote early vegetative and reproductive bud break in apples when applied at an early date (Costa *et al*., 2004). In 'Bourjasotte Noire' and 'Col de Damme Noire' figs, HCN and oil in combination was, however, found to decrease bud break (Theron *et al*., 2011). Thidiazuron (TDZ), a synthetic cytokine, is another RBA registered for use in apple. TDZ sprayed 5 to 6 weeks before full bloom at 3 to 4% advanced reproductive bud break in apple by approximately 2 weeks (Costa *et al*., 2004). A combination of potassium nitrate (KNO_3) and thiourea has been reported to advance harvesting by 4 days as well as to increase fruit size in 'Springtime' peach (Kuden *et al*., 1995). KNO_3 alone has only a mild rest-breaking ability (George *et al.*, 2002). In 'Fuyu' persimmon, a combination of KNO_3 at 50 g L^{-1} and Wainken® (fatty acid esters) at 40 ml·L^{-1} advanced bud break and flowering by 2 to 3 weeks (George *et al*., 2002). Zilkah *et al*. (1997) found that low-biuret 8% urea application in apples advanced bud break, increased the total number of reproductive buds and also increased yield by 48% compared to the untreated control.

Time of application is important in maximizing the effectiveness of RBA's (Siller-Cepeda *et al*., 1992; Manzi *et al*., 2010). An early application of Lift (TDZ) at 4% was found to advance bud break without significantly increasing the percentage bud break in plums (Costa *et al*., 2004). On the other hand, late application of an RBA such as HCN may result in condensed and delayed sprouting of buds compared to the control in apple trees (Manzi *et al*., 2010). Generally, early RBA application has a "forcing" effect, causing earlier foliation and blossoming while application closer to natural bud break has a "normalizing" effect, which tends to condense bloom (Saure, 1985).

The aim of this study was to investigate the effect of various RBA's on bud break, flowering and fruit maturity in order to advance and condense harvest maturity in 'Triumph' persimmons grown in warm production areas of South Africa. The effect of different RBA's on yield and vegetative growth was also assessed.

MATERIALS AND METHODS

Plant material: The experiment was conducted in a 'Triumph' persimmon (*Diospyros kaki* L) orchard at Villiersdorp (latitude: 33° 59' S, longitude: 19° 17' E) in the Western Cape Province (Mediterranean-type climate) of South Africa in the 2010-11 season. Trees were grafted to *D. lotus* rootstock and planted in 2003 at a spacing of 5 m x 2 m. The following treatments were evaluated: 1) untreated control, 2) Lift 3% (Lift®, thidiazuron 3 $g{\cdot}L^{-1}$, Almond Agro Chemicals, Kempton Park, South Africa) sprayed on 13 August, 3) Dormex 0.5% (Dormex®, Hydrogen cyanamide 520 $g{\cdot}L^{-1}$, Alzchem, Trostberg, Germany) sprayed on 13 August, 4) Oil 3% (Budbreak®, mineral oil 863.3 $g{\cdot}L^{-1}$, BASF Pty Ltd, Johannesburg, South Africa) sprayed on 13 August, 5) Dormex 0.5% + Oil 3% sprayed on 13 August, 6) Urea 2% (Urea™, 46% nitrogen, Omnia Nutriology, Bryanston, South Africa) sprayed on 2 September, 7) KNO_3 6% (Omni K™, 130 $g{\cdot}kg^{-1}$ nitrogen and 380 $g{\cdot}kg^{-1}$ potassium, Omnia Nutriology, Bryanston, SA) sprayed on 2 September, 8) Lift 3% sprayed on 2 September, 9) Dormex 0.5% sprayed on 2 September, 10) Oil 3% sprayed on 2 September, and 11) Dormex 0.5% + Oil 3% sprayed on 2 September. Spray applications were applied using a Stihl mist blower (SR 420, Waiblingen, Germany). Tree branches and limbs were sprayed to the point of run-off applying about 2 L of spray solution per tree. The treatments were randomised in 7 blocks with 3 trees per plot with guard trees and guard rows between treatment plots and rows, respectively.

Data collection: Two 30 to 45 cm-long one-year-old shoots per tree were randomly selected and tagged to assess bud break, flowering, fruit set and vegetative growth. Trunk diameter (30 cm above ground using an electronic calliper) and the number of buds per each one-year-old tagged shoot were determined on 9 September 2010. Bud break percentage as well as progression and uniformity of bud break were assessed weekly for six weeks from 16 September 2010. Flowering was assessed for 3 weeks from 11 November 2010. Fruit set assessments were also done on the same shoots. Peduncles and remaining fruits were counted on 24 January 2011 to assess fruit set. The fruit were harvested and weighed per tree on each harvest date (19 April 2011, 28 April 2011, 4 May 2011 and 10 May 2011) to determine harvest distribution. A sample of 10 fruit per plot was randomly collected from the second harvest (28 April 2011) to determine fruit size, colour and maturity. Flesh firmness, fruit colour and total soluble solids (TSS) were measured at harvest. Flesh firmness was determined on pared, opposite cheeks of fruit using a GUSS fruit texture analyser (GS, GUSS Manufacturing (Pty.) Ltd., Strand, South Africa) with an 11 mm plunger. Fruit colour was determined by using the PPIS persimmon colour chart (values 1 to 8 where 1 = red/ orange and 8 = green). Slices cut from each side of the fruit were pooled and juiced and TSS measured using a refractometer (PR32, Atago Co. Ltd., Tokyo Japan). Fruit diameter was measured using an electronic calliper and fruit weight was measured using an electronic balance. Trunk diameter was again measured after leaf drop during winter (28 June 2011) to determine trunk growth. Vegetative growth was assessed on 28 June 2011 by taking the following measurements on the two branches per tree that were used for fruit set assessments: branch diameter (1 cm from the intercalation between 2 and 1 year old growth), number of new shoots on each branch and the length of each shoot.

Statistical analysis: Data were analysed with the General Linear Models (GLM) procedure in the SAS (Statistical Analysis System) computer program (SAS Enterprise Guide 4.0; SAS Institute, 2006, Cary, NC 27513, USA). Means were separated by LSD (5%). Trunk diameter was used as a covariate to amend for differences in vigour between trees. Single degree of freedom orthogonal polynomial contrasts were fitted where appropriate. The first two treatment blocks were lost due to leaf burn and severe flower abscission resulting from commercial application of monoammonium phosphate (MAP) by the producer. These blocks were excluded from the statistical analysis.

RESULTS AND DISCUSSION

Treatments did not differ significantly in the percentage bud break (Table 1). In contrast, previous research done in various deciduous fruits such as grapevine (Shulman *et al*., 1986), apple (Petri and Stuker, 1995), peach (Kuden *et al*., 1995) and blueberry (Williamson *et al*., 2002) indicate that RBA's generally increase bud break compared to untreated plants. The Villiersdorp region accumulated 516.5

Richardson chill units or 701.0 Daily Positive Utah chill units (DPUCU) (Linsley-Noakes *et al*., 1995) from 1 May 2010 until 13 August 2010 and 607.0 Richardson chill units or 807.5 DPUCU from 1 May 2010 until 2 September 2010. This means that the purported chilling requirement of 300 Richardson chilling units for persimmon (Mowat *et al*., 1995) was fulfilled prior to treatment application. Considering that chilling was fulfilled prior to treatment application, it should have been easy to force early bud break. It is possible that the RBA treatment concentrations conservatively chosen for this trial so as not to damage trees was not sufficient to induce early bud break. This could also mean that application of RBAs after satisfaction of chilling does not have an effect on bud break of persimmons as noticed in peach by Siller-Cepeda *et al*. (1992) in a similar scenario.

The number of flowers per tagged shoot differed significantly between treatments (Table 1). Early Dormex 0.5% application on 13 August increased the number of flowers per tagged shoot compared to all treatments except for the Dormex Oil combination applied on 13 August. The combination treatment also increased the flower number compared to 3% Lift applied on 13 August. Generally though, RBA's did not increase flower numbers compared to the control and the time of application also had no effect on flower numbers. Spinzi (1995) found that early HCN application at 2% increased flower numbers in jojoba compared to late applications and the untreated control. The reason for the stimulating effect of early Dormex application on flower numbers is uncertain and requires further study.

There were no significant treatment differences in the number of days after application to onset of bud break on tagged shoots (Table 2). However, early RBA treatments on average advanced bud break compared to late applications. Although treatment differences were not significant ($p=0.0575$), it seems that Lift application on 13 August extended the duration of bud break. Treatments significantly differed in the number of days to the onset of flowering (Table 2). Dormex application on 2 September delayed the onset of flowering compared to all treatments except Lift and Oil application on the same date. On average, late RBA application delayed the onset of flowering compared to early application. Bound and Jones (2004) found that application of HCN too close to natural budburst delays flowering in 'Fuji' apples. The duration of flowering on tagged shoots did not differ between treatments.

There were no significant treatment effects for fruit set, fruit weight and total yield (Table 1). Fruit were picked on four dates over a period of three weeks (19 April 2011, 28 April 2011, 4 May 2011 and 10 May 2011). The harvest distribution over these dates did not differ significantly between treatments (Table 3). No control fruit were ready for harvest on the first harvest date (19 April 2011), 28.5% of the fruit was picked on the second date (28 April 2011), 65.9% on the third date (4 May 2011) and 5.6% on the fourth date (10 May 2011). The greater percentage of the fruit was picked on the third date for most of the treatments. RBA treatment on average significantly increased the proportion of the crop that was picked on the first date compared to the control treatment. However, the effect was slight and generally, RBA's had no major effect on harvest maturity. The general ineffectiveness of RBA treatments to significantly advance harvest maturity is not surprising considering that RBA's did not advance bud break and flowering. RBA application after satisfaction of chilling has been reported to have little or no effect on fruit maturity of peach (Siller-Cepeda *et al*., 1992).

There were no significant differences in peel colour at harvest indicating that fruit from different treatments was picked at similar maturity (Table 4). Firmness at harvest also did not significantly differ between treatments. TSS at harvest did not differ between treatments, but on average, early RBA treatment resulted in a lower TSS concentration compared to late RBA treatment. Bound and Jones (2004) also found that early RBA application reduced TSS concentration in 'Fuji' apple compared to later applications.

Treatments did not significantly differ in the increase in trunk diameter (Table 5). However, RBA treatments on average seemed to have increased trunk diameter compared to the control treatment (p=0.0895). No RBA treatment differed from the control treatment in branch diameter. Branch diameter was less for KNO_3 and

Dormex application on 2 September compared to Dormex and Oil in combination applied on either application date. Most of the RBA treatments except for early Lift at 3%, late Oil at 3% and late Dormex Oil combination recorded an increased number of new shoots compared to the control. Considering that RBA treatments had no effect on percentage bud break, the increase in shoot number induce by most of the RBA treatments can only be ascribed to more of the sprouting buds giving rise to shoots.

Oil applied late seemed to decrease the number of new shoots compared to all treatments except for the control and early Lift application. Urea and KNO_3 seemed to increase the average length of new shoots compared to Oil and the Dormex Oil combination applied early as well as Oil applied late ($p=0.0521$). The late Oil application seemed to have decreased average shoot length compared to the control, early Dormex, Urea and KNO_3. Judging from the effect of late Oil application on vegetative growth, it seems that this treatment might have had a phytotoxic effect. Late mineral oil application at 2% was reported to cause cane die-back in kiwifruit vines resulting in a reduction in fruit number and subsequently low yield (Blank *et al*., 1994). Urea and KNO_3 significantly increased total vegetative growth compared to the control. The possible explanation for the apparent increase in vegetative growth associated with nitrogenous RBAs could be the residual nitrogen in the trees following treatment application (Terblanche *et al*., 1979).

CONCLUSION

Due to the probable fulfilment of the chilling requirement prior to treatment application, the full potential of RBA application on bud break, flowering and yield was not realised. RBA treatments did not advance or increase bud break and flowering compared to the control. RBA treatments also did not increase yield, nor compress or advance harvest maturity of ‘Triumph’ persimmons. It can be concluded that RBA application after chilling satisfaction has no effect in promoting bud break and flowering as well as advancing harvest maturity of persimmons. It is recommended that the study is repeated in a warmer region to determine the effects of increased concentrations and different timings of Lift, Urea, Dormex and Oil on bud break, flowering and fruit maturity.

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Table 1: Effect of different rest breaking agents on percentage bud break, flower number, percentage fruit set, fruit weight and yield of 'Triumph' persimmon on *D. lotus* rootstock in the 2010-11 season.

Treatments	Date	% Bud break	Flower number		Fruit set %	Fruit weight (g)	Yield (ton ha^{-1})
Control		79.9 ^{NS}	9.3	bc^{x}	79.6 ^{NS}	142.8 ^{NS}	16.6 ^{NS}
Lift 3%	13 Aug	74.2	5.3	c	68.9	141.7	18.0
Dormex 0.5%	13 Aug	72.3	14.8	a	79.9	160.4	16.2
Oil 3%	13 Aug	72.3	6.5	bc	81.9	163.6	18.7
Dormex 0.5% + Oil 3%	13 Aug	69.7	10.5	ab	73.2	169.6	22.7
Urea 2%	2 Sept	68.2	6.2	bc	85.6	150.4	16.4
KNO_3 6%	2 Sept	71.7	9.3	bc	79.9	150.4	16.9
Lift 3%	2 Sept	78.1	7.6	bc	76.6	145.5	17.8
Dormex 0.5%	2 Sept	71.3	8.6	bc	75.9	132.8	19.3
Oil 3% 6	2 Sept	74.0	7.7	bc	69.3	153.3	16.0
Dormex 0.5% + Oil 3%	2 Sept	74.4	9.3	bc	87.1	129.1	16.7
Pr>F							
Treatment		0.1356	0.0123		0.5114	0.3842	0.8479
Control vs Rest		0.3156	0.6478		0.7869	0.5808	0.6952
Early vs Late		0.1306	0.3923		0.7762	0.8413	0.3672

^{NS} not significant

^{x} means followed by the same letter do not differ significantly at $p<0.05$.

Table 2: Effect of different rest break agents on time of bud break and full bloom of 'Triumph' persimmon on *D. lotus* rootstock in the 2010-11 season. Bud break for the control treatment commenced from 23 September 2010 and flowering commenced from 11 November 2010.

Treatments	Date	Days to onset of bud break from 9 Sept.	Duration of bud break (days)	Days to flowering from beginning of bud break	Duration of flowering period (days)
Control		13.5 ^{NS}	12.1 b	49.9 bc^{x}	9.6 ^{NS}
Lift 3%	13 Aug	13.1	16.8 a	48.8 bc	8.6
Dormex 0.5%	13 Aug	12.4	11.0 b	48.7 bc	10.7
Oil 3%	13 Aug	12.1	11.7 b	47.8 c	8.6
Dormex 0.5% + Oil 3%	13 Aug	11.4	13.5 ab	48.8 bc	10.5
Urea 2%	2 Sept	14.9	13.1 b	50.2 bc	8.9
KNO_3 6%	2 Sept	14.5	10.5 b	47.6 c	7.2
Lift 3%	2 Sept	11.8	12.6 b	51.3 ab	8.6
Dormex 0.5%	2 Sept	18.0	10.0 b	53.4 a	9.8
Oil 3%	2 Sept	15.4	13.3 ab	50.6 abc	10.3
Dormex 0.5% + Oil 3%	2 Sept	13.5	13.3 ab	49.5 bc	10.3
Pr>F					
Treatment		0.1196	0.0575	0.0261	0.4762
Control vs Rest		0.9034	0.7521	0.8169	0.8444
Early vs Late		0.0265	0.3127	0.0012	0.8812

^{NS} not significant

^{x} means followed by the same letter do not differ significantly at $p<0.1$.

Table 3: Effect of different rest break agents on harvest distribution of 'Triumph' persimmon on D. *lotus* rootstock in the Villiersdorp area of the Western Cape Province, South Africa in the 2010-11 season.

Treatments	Date	19 April (%)	28 April (%)	4 May (%)	10 May (%)
Control		0.0 [NS]	28.5 [NS]	65.9 [NS]	5.6 b [x]
Lift 3%	13 Aug	5.6	15.7	67.2	11.5 ab
Dormex 0.5%	13 Aug	13.4	29.3	57.8	4.5 b
Oil 3%	13 Aug	13.4	26.9	48.2	11.5 ab
Dormex 0.5% + Oil 3%	13 Aug	8.3	14.6	59.6	17.5 a
Urea 2%	2 Sept	13.7	26.4	55.1	4.8 b
KNO_3 6%	2 Sept	6.7	19.1	60.8	13.2 ab
Lift 3%	2 Sept	9.3	18.0	66.8	5.8 b
Dormex 0.5%	2 Sept	7.5	14.3	64.9	13.3 ab
Oil 3%	2 Sept	16.1	11.8	61.0	11.1 ab
Dormex 0.5% + Oil 3%	2 Sept	15.9	21.7	56.8	5.5 b
Pr>F					
Treatment		0.1998	0.3827	0.5747	0.0540
Control vs Rest		0.0156	0.1762	0.3562	0.1969
Early vs Late		0.4894	0.2288	0.2565	0.2983

[NS] not significant

[x] means followed by the same letter do not differ significantly at p<0.1.

Table 4: Effect of different rest break agents on fruit maturity and quality of ‘Triumph’ persimmon on D. *lotus* rootstock in the Villiersdorp area of the Western Cape Province, South Africa in the 2010-11 season.

Treatments	Date	Colour^{z} at harvest	Firmness (kg) at harvest	TSS at harvest (ºBrix)
Control		4.9 ^{NS}	9.9 ^{NS}	21.1 ^{NS}
Lift 3%	13 Aug	5.2	9.9	19.9
Dormex 0.5%	13 Aug	4.9	9.2	20.8
Oil 3%	13 Aug	5.0	10.3	19.2
Dormex 0.5% + Oil 3%	13 Aug	4.5	9.4	20.8
Urea 2%	2 Sept	4.8	9.1	20.9
KNO_3 6%	2 Sept	4.6	9.3	20.1
Lift 3%	2 Sept	4.5	9.3	21.3
Dormex 0.5%	2 Sept	4.9	9.8	20.3
Oil 3%	2 Sept	4.4	9.8	21.5
Dormex 0.5% + Oil 3%	2 Sept	4.3	9.5	21.9
Pr>F				
Treatment		0.3938	0.8990	0.0963
Control vs Rest		0.5840	0.5992	0.4874
Early vs Late		0.0589	0.8099	0.0126

^{NS} not significant
^{z} Colour chart where 1 = red/ orange and 8 = green.

Table 5: Effect of different rest break agents on vegetative growth of 'Triumph' persimmon on *D. lotus* rootstock in the 2010-11 season as quantified by measuring the increase in trunk diameter between 9 September 2010 and 28 June 2011 and also by assessing new shoot growth on 30 to 45 cm long one-year-old shoots per tree.

Treatments	Date	Increase in trunk diameter (mm)	Average shoot diameter (mm)	Number of new shoots	Average shoot length (cm)	Total vegetative growth (cm)
Control		5.6 ^{NS}	8.4 abc ^{x}	6.0 bc	16.3 ab	98.3 dc
Lift 3%	13 Aug	6.7	8.5 abc	7.6 bc	14.5 abc	100.0 cd
Dormex 0.5%	13 Aug	7.4	7.9 bc	9.2 a	17.1 ab	155.1 abc
Oil 3%	13 Aug	4.7	7.6 bc	8.4 a	12.7 bc	107.2 cd
Dormex 0.5% + Oil 3%	13 Aug	7.5	9.0 ab	9.6 a	11.5 bc	109.3 bcd
Urea 2%	2 Sept	7.5	7.8 bc	9.0 a	18.8 a	172.0 ab
KNO_3 6%	2 Sept	8.8	7.0 c	9.2 a	18.7 a	173,9 a
Lift 3%	2 Sept	6.4	8.2 bc	9.2 a	13.8 abc	121.6 abc
Dormex 0.5%	2 Sept	8.5	6.6 c	8.6 a	13.8 abc	125.8 abc
Oil 3%	2 Sept	8.6	7.2 bc	5.6 c	9.3 c	51.9 d
Dormex 0.5% + Oil 3%	2 Sept	7.8	10.2 a	8.0 ab	14.6 abc	118.9 abc
Pr>F						
Treatment		0.1824	0.0334	0.0138	0.0521	0.0187
Control vs Rest		0.0895	0.6049	0.0070	0.3966	0.2905
Early vs Late		0.1199	0.6841	0.1499	0.4575	0.4030

^{NS} not significant
^{x} means followed by the same letter do not differ significantly at $p<0.1$.

Paper 4: The effect of harvest maturity, harvest date and orchard location on storability and shelf life of 'Triumph' persimmon.

Abstract

'Triumph' persimmon fruit are highly perishable and have a relatively short shelf life. Variable post-harvest fruit quality has been a problem for the South African persimmon industry since the first exports more than a decade ago. There is a perception in the South African persimmon industry that 'Triumph' fruit that ripen and are harvested during the second half of the harvesting season, which stretches from the first week of April until mid-June, do not store as well as fruit harvested earlier in the season (April to mid-May). Also, storability of fruit purportedly differs between orchards. This experiment was therefore carried out with an aim to determine whether storability and shelf-life differ between "early" and "late" production areas in South Africa as well as between orchards within these areas. Further objectives were to determine the effect of fruit maturity at harvest on storability, the robustness of fruit colour as a maturity parameter, and whether the same colour parameters should be used for harvesting GA_3-treated fruit. Fruit from twelve 'Triumph' persimmon (*Diospyros kaki* Thunb.) orchards (four "early" orchards harvested late-April to early-May, four "late" orchards harvested late-May and four orchards treated with GA_3 and harvested early-June) were used. Fruit of four colour groups, i.e. colour group 1 (deep orange; colour chart value ~2, colour group 2 (yellow-orange; colour chart value 3 to 4), colour group 3 (yellow-green; colour chart value 5 to 6) and colour group 4 (green; colour chart value 7) were picked from each orchard. Fruit colour at harvest appeared to be a good indicator of fruit storage potential. However, the firmness of fruit from "late" orchards was about 1 kg lower compared to "early" fruit at the same colour chart values. Fruit from late orchards as well as GA_3-treated fruit picked at colour chart values <4 showed a high incidence (>20%) of fruit softening during storage and shelf life. These fruit should be picked at the yellow green stage (colour chart values 5 to 6) to improve storability. A delay in 1-MCP treatment and interruption of the cold chain seems to result in rapid softening of fruit during storage and shelf-life and further research is needed to verify this result.

INTRODUCTION

Persimmons generally have limited storability and a short shelf-life (Kitagawa and Glucina, 1984). 'Fuyu' persimmons can only be stored for 2 months under regular air storage at 0 to 2 °C and 90% relative humidity (Cia *et al*., 2006) while 'Triumph' persimmons stored for 4 months in modified atmosphere packaging (low-density polyethylene bags) at -1 °C maintained adequate firmness, but accumulation of acetaldehyde caused flesh browning (Prusky *et al*., 1997). Amongst the many factors that determine the storability of persimmons, fruit maturity at the time of harvest is the most important (Öz and Ergun, 2010). High flesh firmness at harvest plays a decisive role in the preservation of fruit quality during storage and shelf-life (Salvador *et al*., 2007).

As is the case in other climacteric fruits (Kader, 1999), ripening in persimmons is associated with a loss of firmness, changes in pigment content, and an increase in total soluble solids (TSS) concentration. Usually, more mature persimmons fruit have a well-developed peel colour implying a higher concentration of pigments such as carotenoids (Salvador *et al*., 2007). Since climacteric fruits can ripen off the tree and attain full colour during storage (Steyn, 2012), fruit producers generally harvest climacteric fruit at the green-mature stage or earlier and then transport it, often over long distances, to areas of consumption (Wills *et al*., 2007). This is also the case for 'Triumph' persimmon in South Africa, which are usually picked at the orange to yellowish-orange stage. The change from green to yellow colour due to preferential chlorophyll degradation appears to be a reliable indicator of fruit ripening (Gross, 1987) and the attainment of optimum eating quality (Wills *et al*., 2007). Therefore, fruit colour is often used as parameter to determine the maturity of fruit (Gross, 1987; Wills *et al*, 2007). Generally, an optimum stage of maturity for harvest is determined that will allow fruit to store well without compromising eating quality. This optimum harvest maturity is subsequently linked with a certain level of colour development that will ease the harvesting process and will allow the sorting of fruit based on maturity and potential storability.

However, fruit colour does not always correlate with fruit quality and maturity and may differ between production areas and seasons (Steyn, 2012). Steyn (2012) cited several studies that found that environmental conditions may affect the accumulation of carotenoids. In citrus, warm temperatures interfere with the loss of chlorophyll as well as the accumulation of carotenoids while cool temperatures enhance the desired colour changes (Young and Erickson, 1961). Sugiura *et al*. (1991) found that cooler temperatures (ca. 22 ℃) promote colour development in 'Hiratanenashi' persimmon while warmer temperatures delay this process.

This experiment was carried out with an aim to determine whether storability and shelf-life differ between "early" and "late" production areas in South Africa as well as between orchards within these areas. There is a perception in South Africa that 'Triumph' persimmon fruit harvested at the later stages (end of May until mid-June) of the harvesting season, do not store as well as fruit from earlier areas (April until mid-May). We considered that if such a difference in storability does exist, it may relate to changes in the relationship between fruit colour and maturity. Hence, we also wanted to assess the relationship between fruit colour and firmness at harvest in relation to the storability and shelf-life of 'Triumph' persimmons. The consistency of this relationship during the season and between orchards was assessed. We finally also endeavoured to establish the link between fruit colour and storability in orchards that received a pre-harvest gibberellic acid (GA_3) application. GA_3 delays fruit ripening and extends the harvesting window by 2 to 3 weeks in 'Triumph' persimmon when sprayed 10 days prior to harvesting (Ben-Arie *et al*., 1986) and is used in South Africa to improve the storability of persimmons.

MATERIALS AND METHODS

Plant material: Fruit from twelve 'Triumph' persimmon (*Diospyros kaki* Thunb.) orchards (four "early" orchards harvested late-April to early-May, four "late" orchards harvested late-May and four orchards treated with GA_3 and harvested early-June) were used for the experiment (Table 1). In South Africa, 'Triumph' persimmon fruit are normally harvested at colour chart values from 4 to 5 (Plant Protection and

Inspection Services (PPIS), Bet-Dagan, Israel; values 1-8 where 1 = red/ orange and 8 = green). Fruit of four colour groups, i.e. colour group 1 (deep orange; colour chart value ~2 (Figure 1)), colour group 2 (yellow-orange; colour chart value 3 to 4), colour group 3 (yellow-green; colour chart value 5 to 6) and colour group 4 (green; colour chart value 7) were picked from each orchard (Figure 2). Four replications of 30 fruits each were collected for each colour group per orchard. Fruits were selected for uniformity of size and colour and the absence of diseases and defects. The sample material was handled carefully after the harvest to minimize mechanical damage and transported to the laboratory at the Department of Horticultural Science, Stellenbosch University within 6 hours of harvest. Maturity indexing (MI) was conducted on half of the fruit immediately following harvest. The remainder of the fruit were treated with 1-MCP (Smartfresh^{TM}, 1-methylcycloprene 3.3%, Agro fresh, Pennsylvania, USA) for 24 hours at 20 ℃ in a seale d container. Fruit from orchards 1 and 2 were kept in storage at -0.5 ℃ for 7 days before 1-MCP treatment while fruit for the rest of the orchards were treated with 1-MCP within 24 hours of harvest. Fruit from all orchards were stored for a total of 6 weeks at -0.5 ℃ and MI (same measurements prior to storage) conducted after 4 days shelf life at room temperature (ca. 20 ℃).

Data collection: A sample of 15 fruit per each colour group from each orchard was used to determine fruit maturity. Flesh firmness, fruit colour and total soluble solids (TSS) were measured at harvest. Flesh firmness was determined on pared, opposite cheeks of the fruit using a GUSS fruit texture analyser (GS, GUSS Manufacturing (Pty.) Ltd., Strand, South Africa) with an 11 mm plunger. A Sinclair internal quality (IQ) firmness tester machine (Sinclair international Ltd., Norwich, England) was used for the non-destructive measurement of firmness (based on acoustics) after storage and after shelf-life. The Sinclair IQ machine was not available at harvest. Each fruit was pressed lightly with the fingers to subjectively determine the percentage of soft fruit per each sample. Fruit colour was assessed subjectively using the PPIS persimmon colour chart. Slices cut from each side of the fruit were pooled and juiced and TSS measured using a refractometer (PR32, Atago Co. Ltd., Tokyo, Japan). Fruit diameter was measured using an electronic calliper and fruit weight was measured using an electronic balance. Calyx condition was assessed subjectively according to the percentage of the total calyx area that was green. Generally, the calyx has to be in a good condition although there is no standard for the market. Marks and blemishes were visually assessed per sample both at harvest and after shelf life and the number of fruit that were blemished were expressed as a percentage of the total sample.

Statistical analysis: Data of the experiment were analysed with the General Linear Models (GLM) and Correlation (CORR) procedures in the SAS (Statistical Analysis System) computer program (SAS Enterprise Guide 4.0; SAS Institute, 2006, Cary, NC 27513, USA). Means were separated by LSD (5%). Three separate analyses were carried out using the GLM procedure, viz. 1) a two-way analysis with orchard (the 8 orchards not treated with GA_3) and colour group as factors 2), a two-way analysis with the four GA_3 orchards and colour group as factors, and 3) a two-way analysis with “early”, “late” and GA_3 orchards as one factor and colour group as the other. For each treatment, colour group and all treatments combined, correlations were done using the CORR procedure to correlate firmness and peel colour at harvest with after shelf-life firmness, peel colour, TSS, percentage green calyx, IQ score and percentage soft fruit.

RESULTS

“Early” versus “Late” orchards

Fruit maturity at harvest

The interaction between orchard and colour group was not significant for peel colour (Table 2) or TSS (Table 3) at harvest. Peel colour at harvest differed significantly between colour groups increasing from colour group 4 to 1. At the same colour group, fruit from “early” orchards were generally higher in flesh firmness compared to “late” orchards. Fruit firmness decreased with an increase in fruit colour across all the orchards. TSS at harvest significantly differed between orchards with fruit from early orchards generally having higher TSS.

Fruit maturity and quality after storage and shelf-life

There was a significant interaction between orchard and colour group for peel colour, fruit firmness, IQ score and percentage soft fruit after shelf-life while interaction was nearly significant ($p=0.0555$) for IQ scores after storage (Table 2).

With regards to peel colour, colour group 1 fruit from orchards 6 and 7 had lower colour chart values than fruit from orchards 2, 3 and 4 while fruit from orchard 5 had a lower chart value than fruit from orchards 3 and 4. Colour group 2 fruit from orchards 1, 6, 7 and 8 had lower chart values than fruit from other orchards. For colour group 3, orchards 1 and 8 had lower chart values than orchards 4, 5 and 6. Orchard 5 had a higher chart value than all orchards except for orchards 4 and 6. Colour group 4 fruit from orchard 7 had a lower chart value than fruit from orchards 4 and 8.

Fruit of orchards 3 and 4 had higher firmness after shelf life at each colour group compared to fruit of other orchards. Other than fruit from orchards 3 and 4, fruit from orchards 1 and 2 had lower firmness at colour group 4 compared to all other orchards, lower firmness at colour group 2 compared to orchard 8 and lower firmness at colour group 3 compared to all orchards except for orchard 8.

IQ scores after storage decreased sequentially from colour group 1 to 4. Colour group 1 and 2 fruit from orchards 3 and 4 had higher IQ scores after shelf-life than fruit from other orchards. Orchard 4 had higher IQ scores after shelf-life for colour group 3 and 4 than all other orchards.

Colour group 1 fruit of “late” orchards displayed a very high percentage (>50%) soft fruit. Orchard 1 had the highest percentage soft fruit among the “early” orchards. Apart from orchard 5, “late” orchards also had a higher percentage soft fruit compared to “early” orchards for colour group 2. No fruit of colour group 4 were soft after shelf life. The percentage soft fruit were not significantly different for colour groups 2 to 4 for “early” orchards and for colour groups 3 and 4 for “late” orchards, except for orchard 8, which had a significantly higher percentage soft fruit for colour group 3.

There was no significant interaction between orchard and colour group on TSS, percentage green calyx and the incidence of blemishes after shelf-life (Table 3). TSS differed considerably between orchards and was generally higher in “early” compared to “late” orchards. Colour groups differed significantly in TSS concentration after shelf-life. TSS decreased from colour group 1 to 4. Early fruit from orchards 3 and 4 had a significantly higher percentage of green calyx (>20%) compared to other orchards. Colour group had no significant effect on percentage green calyx or on the percentage blemishes and injuries after shelf-life. Orchard 1 and 2 had a significantly higher incidence of blemishes and injuries (>28%) compared to other orchards. Orchards 5 and 8 also had blemishes in excess of 10%.

GA_3 treated fruit

Fruit maturity at harvest

There was no significant interaction between orchard and colour group for peel colour at harvest (Table 4). Peel colour increased from colour group 1 to 4. A significant interaction was found between orchard and colour group for flesh firmness and TSS at harvest (Table 4). Colour group 1 fruit from orchards 1 and 4 were softer compared to fruit from orchards 2 and 3. Colour group 2 fruit from orchard 1 was softer than fruit from orchards 3 and 4 while for colour group 3, fruit from orchard 1 was softer compared to all other orchards. Fruit of colour groups 3 and 4 from orchard 3 were firmer compared to other fruit. Generally, TSS decreased from colour group 1 to 4, but the decrease was more gradual for orchard 1 compared to the other orchards.

Fruit maturity and quality after shelf-life

There was no significant interaction between orchard and colour group for IQ score after storage (Table 5) as well as for peel colour (Table 4), firmness, IQ score, the percentage soft fruit, TSS, the percentage green calyx and the incidence of blemishes after shelf-life (Table 5).

Peel colour significantly increased from colour group 1 to 4, but orchard had no significant effect on peel colour. Flesh firmness as well as IQ score after storage and after shelf-life significantly decreased while the percentage soft fruit increased from colour group 4 to 1. Fruit from orchards 1 and 2 were firmer after shelf-life compared to orchards 3 and 4. Orchard had no significant effect on IQ score after storage. Orchard 2 had a higher IQ score after shelf-life compared to other orchards. Orchard 1 had a greater percentage soft fruit than orchards 2 and 3.

Fruit from orchard 2 had higher TSS after shelf-life than other orchards while orchard 1 had higher TSS than orchard 3. Colour group had no significant effect on TSS after shelf-life. Orchard 3 and 4 had a significantly higher percentage green calyx compared to orchard 1 and 2. Percentage green calyx after shelf-life significantly increased from colour group 1 to 3. Percentage blemishes and injuries after shelf life were low and did not differ between colour groups or between orchards.

“Early” versus “late” versus GA_3-treated fruit

Fruit maturity at harvest

There was no significant interaction between treatment and colour group on peel colour (Table 6), flesh firmness and TSS (Table 7) at harvest. Treatment had no significant effect on peel colour at harvest, but peel colour significantly decreased from colour group 1 to 4. Fruit from “early” and GA_3-treated orchards were significantly firmer (0.8 - 1.3 kg) than fruit from “late” orchards. Firmness increased sequentially from colour group 1 to 4. Fruit from “early” orchards were the highest in

TSS at harvest while fruit from "late" orchards were higher in TSS than GA_3 fruit. Colour group had no effect on TSS.

Fruit maturity and quality after shelf-life

There was a significant interaction between treatment and colour group for peel colour and the percentage soft fruit after shelf-life (Table 6). Interaction for firmness, IQ scores, TSS, the percentage green calyx and blemishes was not significant (Table 7).

Although peel colour generally decreased from colour group 1 to 4, colour groups 1 and 2 of "late" orchards had lower colour chart values compared to fruit from "early" orchards. For colour group 2, "late" orchards also had lower colour chart values than GA_3-treated orchards. GA_3-treated orchards had a higher chart value for colour group 3 compared to "early" and "late" orchards. All the treatments had the same chart value for colour group 4.

All the treatments had the same low percentage soft fruit for colour groups 3 and 4. For colour group 1, "late" orchards had a significantly and considerably higher percentage soft fruit compared to "early" and GA_3-treated orchards. GA_3-treated orchards also had a significantly higher percentage soft fruit for colour group 1 compared to "early" orchards. For colour group 2, "late" orchards had a higher percentage soft fruit compared to "early" orchards. The percentage soft fruit of "early" orchards at colour group 2 was not significantly different from the percentage soft fruit at colour groups 3 and 4.

GA_3-treated fruit were firmer after-shelf-life compared to fruit from "late" orchards while fruit from "early" and "late" orchards did not differ significantly. Flesh firmness decreased from colour group 4 to 2, but was not significantly different between groups 2 and 1. GA_3-treated fruit had higher IQ scores after storage compared to other treatments. After shelf-life, IQ scores of early and GA_3-treated orchards were significantly higher than for “late” orchards. IQ scores after storage was higher for colour groups 4 and 3 compared to group 1. Colour group 4 also had a higher score than group 2. After shelf life, IQ scores for colour groups 4 and 3 were higher than for groups 2 and 1 and group 2 also had a higher score than group 1.

“Early” orchards had higher TSS after shelf-life compared to “late” orchards, which had higher TSS than GA_3-treated orchards. Colour group 4 had lower TSS than colour groups 1 and 2. A significantly higher percentage green calyx was recorded for “early” orchards compared to the other two treatments while colour group had no effect. Although not significantly different (p=0.0653), early orchards seemed to have a higher percentage blemishes, but colour group had no effect on the incidence of blemishes.

Correlation of fruit maturity and quality parameters

“Early” orchards

For all four orchards, peel colour at harvest showed a strong positive correlation with firmness at harvest and after shelf-life, peel colour after shelf life and IQ score after shelf life (Table 8). The correlations with IQ score after storage were generally weaker and not significant for orchard 2. Peel colour at harvest showed a weak positive correlation with percentage green calyx after shelf-life for orchard 2 and weak negative correlations with the percentage soft fruit for orchards 1 and 3.

Firmness at harvest correlated strongly with firmness after shelf life, but the correlations were not stronger than for peel colour at harvest (Table 8). Firmness at harvest correlated with IQ scores after storage and after shelf life, but the correlations after storage were weak for orchards 2 and 3. There was a strong negative correlation between firmness at harvest and percentage soft fruit for orchard 1 with weaker correlations for orchards 2, 3 and 4.

"Late" orchards

Peel colour at harvest showed a strong positive correlation with firmness at harvest. Peel colour and firmness at harvest showed strong positive correlations with peel colour after shelf-life, firmness after shelf-life, percentage green calyx, and IQ scores both after storage and after shelf-life for all four orchards (Table 9). A strong negative correlation was also found for peel colour and firmness at harvest with the percentage soft fruit after shelf life.

GA_3-treated fruit

Peel colour at harvest showed a strong positive correlation with peel colour after shelf-life, firmness at harvest and after shelf-life (Table 10). Most of the orchards except for orchard 2 showed a relatively strong correlation between peel colour at harvest and percentage green calyx. A positive correlation was also found between peel colour at harvest and IQ scores after storage and shelf life, but the correlations were weaker compared to correlations with firmness. Peel colour at harvest had a strong to moderate negative correlation with percentage soft fruit after shelf-life.

Firmness at harvest had a strong positive correlation with firmness and peel colour and a strong negative correlation with percentage soft fruit after shelf-life (Table 10). Firmness at harvest also showed weaker positive correlations with IQ scores after storage and shelf life with percentage green calyx.

All treatments

Strong positive correlations were found between peel colour at harvest and peel colour after shelf-life. Peel colour at harvest also showed a strong correlation with firmness, IQ scores and percentage soft fruit after shelf-life for late and GA_3-treated fruit (Table 11). Weaker correlations were found with percentage green calyx for late and GA_3-treated fruit and with IQ scores after storage for all treatments. For early orchards, peel colour showed weak correlations with firmness and percentage soft fruit after shelf life as well as with IQ scores after harvest and after shelf-life.

A strong positive correlation was found between firmness at harvest and peel colour as well as with firmness after shelf-life except for “early” fruit (Table 11). For “late” fruit, firmness at harvest also showed strong correlations with IQ scores at harvest and after shelf life and with percentage soft fruit after shelf life while a weaker correlation was found with percentage green calyx. GA_3-treated fruit also showed a strong correlation between firmness at harvest and percentage soft fruit while weaker correlations existed with IQ scores after harvest and after shelf-life and percentage green calyx after shelf-life. Early fruit firmness at harvest showed moderate to weak correlations with IQ scores and the percentage soft fruit.

DISCUSSION

Since there was no interaction between orchard and colour group for peel colour at harvest, it appears that sampling of fruit was consistent between orchards. Peel colour at harvest significantly increased from colour group 4 to 1 and colour group 3 corresponded to the colour at which fruit are commercially harvested.

Although the interaction between orchard and colour group was not significant for peel colour, orchard and colour group had an interactive effect on flesh firmness at harvest (Table 2). On average, fruit from “early” orchards were ca. 1 kg firmer compared to fruit from “late” orchards for all the colour groups. It seems that carotenoid synthesis is lower or delayed in fruit from “late” orchards. Temperatures decrease considerably from the onset of harvest in “early” orchards in April until the harvesting of “late” orchards by late May or early June, which is the onset of winter and the rainy season in the Western Cape Province. Thus indications are that low temperatures during fruit ripening in “late” orchards may have decreased or delayed colour development relative to flesh softening. This is contrary to Sugiura *et al*. (1991) who found that lower temperatures stimulated colour development in

'Hiratanenashi' persimmon. Generally, low temperatures stimulate carotenoid synthesis and chlorophyll breakdown as found in citrus (Young and Erickson, 1961). The implication of this finding is that fruit from "late" orchards may be harvested at a lower firmness than fruit from "early" orchards and this may give rise to an apparent difference in storability between "early" and "late" fruit. Our data indicate that "late" fruit picked at colour chart values of 5 up to 6 do attain sufficient (from a marketing perspective, S. F. Ungerer, personal communication) orange to yellow-orange colour (colour chart values 3 to 4) during storage and shelf life. Late season fruit could be harvested at a higher colour chart values to reduce the risk of fruit softening and increase storability. However, fruit of colour group 4 (colour chart 6) had a markedly lower TSS after shelf life compared to fruit with greater colour development at harvest. The difference in TSS between colour groups was less distinct at harvest, but while fruit of colour groups 1 to 3 increased in TSS during storage and shelf life, the TSS of colour group 4 fruit did not change. Care should be taken that harvesting at lesser maturity does not affect consumer acceptance of fruit taste.

Despite the lower firmness of "late" fruit at harvest and the strong correlation between firmness at harvest and after shelf life, it would be premature to conclude that "early" fruit would generally store and keep better than "late" fruit. There was significant interaction between orchard and colour group for firmness after shelf-life of "early" and "late" fruit (Table 2). This interaction was due to fruit from orchards 3 and 4 being much firmer compared to fruit from other orchards after shelf life while fruit from orchards 1 and 2 showed very poor storability. The sharp decrease in firmness and high percentage soft fruit of orchards 1 and 2 could be due to cold-storing fruit of these orchards for 7 days before interrupting the cold chain for 1-MCP treatment. 1-MCP effectiveness in improving fruit storability is dependent on the time of application (Wright and Kader, 1997) and Watkins (2008) indicated that a longer delay before 1-MCP treatment is associated with increasing ethylene concentration in the fruit which in turn limits fruit storability. A break in the cold chain generally reduces fruit keeping quality (Moggia and Pereira, 2007) and this was confirmed in the current study. Differences in storability between fruit of "late" orchards seemed to relate to differences in fruit colour and therefore maturity at harvest.

Interaction between orchard and colour group was nearly significant (p=0.0565) for peel colour of GA_3-treated orchards (Table 4). This suggests that the harvesting into the respective colour groups were not entirely consistent. However, the significant interaction between orchard and colour group for firmness at harvest did not seem to relate to this inconsistency in harvesting, but rather to differences in the relationship between firmness and fruit colour between the orchards. For example, fruit of colour groups 3 and 4 from orchard 3 were firmer compared to other orchards despite having comparable or lower colour chart values. Peel colour after shelf-life significant differed between different colour groups. Colour groups 1 and 2 had fruit with a significant advanced peel colour compared to colour group 3 and 4. A sharp increase in peel colour after shelf-life and a high percentage soft fruit (~50%) in fruit from colour group 1 for all the orchards indicates the ineffectiveness of GA_3 to retard ripening and improve storability when applied to fruit of more advanced maturity (Wright and Kader, 1997). To avoid postharvest losses through fruit softening, GA_3-treated fruit with colour chart values below 5 should not be considered for long term storage.

Strong positive correlations of peel colour at harvest with peel colour after shelf life, firmness at harvest and after shelf-life, IQ score after storage and shelf-life, and percentage soft fruit were found for “early”, “late” and GA_3-treated fruit. Fruit firmness after shelf-life increased sequentially with a decrease in the extent of fruit colour development at harvest. This is in agreement with the findings by Besada *et al*. (2009) who found that loss of firmness during storage is lower in fruit picked less ripe compared to fruit picked more ripe. Basil *et al*. (2005) also found that fruit ripening stage at harvest determines the extent to which change in fruit quality during storage and shelf-life occurs. Based on these strong correlations, peel colour generally seems to be a good external parameter for use in predicting the storability and shelf life potential of ‘Triumph’ persimmon fruit in South Africa. Fruit colour can be used as harvesting parameter and to discard fruit with potentially poor storability from the pack line, but care should be taken to account for differences between “early” and “late” fruit. Considering the high likelihood that fruit with a colour chart value of 2 and below will turn soft during storage and shelf life, such fruit should be culled during harvesting and on the pack line. Since nearly 25% of “late” fruit and 20% of GA_3-

treated fruit with a colour chart value of 3 turn soft, these fruit should also be culled. Despite the absence of differences in average colour between orchards treated with GA_3 after shelf life, firmness and the percentage soft fruit after shelf-life differed significantly between these orchards. This means that while peel colour may relate to storability of fruit of a particular orchard, the relationship between colour and storability may differ between orchards.

The generally strong correlations of IQ scores with peel colour and destructive fruit firmness measurements suggest that the Sinclair firmness tester may have potential for use as an automated non-destructive system to separate individual fruit on the pack line based on storability. Fruit from early and GA_3- treated orchards with an IQ score of ≤20 after storage and fruit from "late" orchards with a score of ≤25 were likely to become soft during shelf-life. Hence, "early" and GA_3-treated fruit with an IQ score below 25 and "late" fruit with an IQ score below 30 should be culled on the pack line. Further research is required in this regard also taking IQ scores at harvest.

Fruit from orchards (1 and 2) recorded higher percentage of soft fruit and also had a higher incidence of blemishes (~30%). This suggests that blemished fruit does not store well or that blemishes at harvest reduce fruit storability. Blemishes also reduce fruit storage quality and visual appeal (Barret *et al*., 2010) and hence marketability. Therefore blemished fruit should be culled on the pack line.

The percentage of the calyx that remained green was not assessed at harvest and could not be used to predict fruit storability. Nevertheless, fruit that became soft during shelf-life had completely dry calyx leaves. Calyx lobes play an important role in the gaseous exchange of persimmon fruit (Yakushiji and Nakatsuka, 2007), which might help in the maintenance of good fruit quality. Nakano *et al*. (2003) found that in persimmons, water loss induces ethylene production in the calyx, which subsequently stimulates autocatalytic ethylene synthesis in the other tissues of fruit resulting in fruit softening. It therefore seems important to maintain calyx leaves in good health and the demise of these leaves before harvest may portent storability problems. Further research is required in this regard.

CONCLUSION

Fruit colour at harvest provides a good indication of fruit storability and shelf life potential. However, colour development seems to be slower during the second half of the harvesting period resulting in harvesting of fruit at a lower firmness when harvesting according to the same colour chart value as earlier during the season. It should be considered to harvest fruit from late orchards at the yellow-green (colour chart values 5 to 6) stage to improve the storability of the fruit, providing that the taste of the fruit is not negatively affected. Fruit from late orchards with colour chart values <4 and GA_3-treated fruit with chart values <3 should be culled due to the high probability that these fruit will go soft during shelf life. Further research is required to establish the relationship between the percentage of the calyx that remains green at harvest and fruit storability. Also, results obtained with the Sinclair firmness tester seem promising and further assessment will be required. The finding that a delay in 1-MCP treatment and interruption of the cold chain seem to have had a disastrous effect on fruit storability needs to be verified in a separate experiment.

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Table 1: Orchard information and harvest dates for orchards included in an experiment aimed at determining the effect on orchard factors, harvest time and harvest maturity on fruit quality at harvest and after shelf life in the 2011 season. Simondium (latitude. 33° 3' S, longitude: 19°9' E), Vyeboom (latitude: 34° 02' S, longitude: 19°02' E), Villiersdorp (latitude: 33°59' S, longitude: 19 °17' E), Greyton (latitude: 34°02' S, longitude: 19°32' E) , Grabouw (latitude: 34°59' S, longitude: 18°00' E).

Orchard number	Farm name	Orchard Details	GA_3	Area	Harvest date
"Early" orchards					
1	Allee Bleue	*D. virginiana* seedling rootstock, planted 2006, 4.5 x 2.25 m spacing	No	Simondium	28 April
2	Allee Bleue	*D. virginiana* seedling rootstock, planted 2003, 5 x 2 m spacing	No	Simondium	28 April
3	Chiltern	*D. virginiana* seedling rootstock, planted 1999, 2 x 4.5 m spacing	No	Vyeboom	4 May
4	Vredelust	*D. lotus* seedling rootstock, planted 2003, 5 x 2 m spacing	No	Villiersdorp	4 May
"Late" orchards					
5	Sonderendsharon	*D. virginiana* seedling rootstock, planted 2004, 5 x 2.25 m spacing	No	Greyton	24 May
6	Jagersbos	*D. virginiana* seedling rootstock, planted 2005, 4.5 x 2.5 m spacing	No	Greyton	24 May
7	Chiltern	*D. virginiana* seedling rootstock, planted 1999, 2 x 4.5 m spacing	No	Vyeboom	24 May
8	Boesmansrug	*D. virginiana* seedling rootstock, planted 2006, 4.5 x 2 m spacing	No	Vyeboom	24 May
GA_3-treated orchards					
9	Boesmansrug	*D. virginiana* seedling rootstock, planted 2004, 4.5 x 2 m spacing	Yes	Vyeboom	1 June
10	Boesmansrug	*D. virginiana* seedling rootstock, planted 2004, 4.5 x 2 m spacing	Yes	Vyeboom	1 June
11	Maredale	*D. virginiana* seedling rootstock, planted 2006, 4.5 x 2 m spacing	Yes	Grabouw	1 June
12	Maredale	*D. virginiana* seedling rootstock, planted 2003, 4.5 x 2 m spacing	Yes	Grabouw	1 June

Table 2: The effect of orchard, harvest time and harvest maturity on fruit quality and maturity of ‘Triumph’ persimmons at harvest and after shelf-life in the Western Cape Province, South Africa in the 2010-11 season. “Early” orchards (orchards 1-4) were harvested on 28 April and 4 May while the “Late” orchards (5-8) where harvested on 24 May.

Orchard	Colour group	Colour at harvest [z]	Colour after shelf life	Firmness (kg) at harvest	Firmness (kg) after shelf-life	IQ firmness after storage	IQ firmness after shelf-life	Percentage soft fruit
1	1	1.8 l [x]	1.3 ghi	6.6 hi	0.4 q	16.2 l	9.9 ab	36.7 gh
	2	3.3 j	1.7 g	8.7 ef	0.9 opq	18.1 jkl	13.0 de	6.7 abcd
	3	4.3 hi	2.3 ef	9.9 cd	1.6 lmno	20.2 ijk	18.1 hi	8.4 abcd
	4	5.5 defg	4.0 ab	10.9 bc	3.2 hi	22.1 fghi	20.7 klm	0.0 a
2	1	2.1 kl	1.5 gh	7.9 fg	0.6 pq	17.8 kl	12.1 cd	13.4 bcde
	2	3.0 jk	2.4 ef	10.3 bcd	1.0 nopq	23.0 efgh	16.8 gh	10.0 abcd
	3	4.9 fgh	2.7 de	10.7 bc	1.6 lmno	20.8 ghij	17.6 h	3.3 ab
	4	7.0 a	3.9 ab	11.6 a	2.6 ijk	23.6 cdef	22.0 mno	1.7 a
3	1	2.1 kl	1.6 g	8.0 fg	2.8 ij	19.6 ijk	17.8 h	16.7 def
	2	3.3 j	2.1 f	9.4 de	3.7 gh	21.2 ghi	19.9 jk	10.0 abcd
	3	5.0 fgh	2.6 de	10.5 bcd	5.6 cd	21.0 ghi	20.4 jkl	5.0 abc
	4	6.2 abcd	3.8 ab	10.9 bc	9.1 a	23.3 defg	23.2 o	0.0 a
4	1	2.0 l	2.1 f	6.7 h	3.1 hi	20.6 hij	20.2 jk	10.0 abcd
	2	3.6 ij	2.4 ef	8.8 ef	4.3 fg	23.0 efgh	22.8 no	6.7 abcd
	3	4.5 ghi	3.0 cd	10.2 bcd	6.3 c	24.9 bcde	24.8 p	3.4 ab
	4	6.2 abcd	4.2 a	11.1 b	8.2 b	25.8 bcd	25.7 p	0.0 a
5	1	1.5 l	1.1 hi	5.4 j	0.7 pq	19.5 ijk	12.9 de	78.3 j
	2	2.9 jkl	2.1 f	8.6 ef	1.8 lmn	24.5 cdef	17.4 gh	15.0 cde
	3	5.0 fgh	3.1 c	11.0 bc	4.0 fg	27.4 ab	20.4 jkl	1.7 a
	4	6.7 ab	3.9 ab	11.6 a	5.3 de	28.8 a	22.3 no	0.0 a
6	1	2.2 kl	1.0 i	4.9 j	0.5 pq	18.3 jkl	11.2 bc	70.0 j
	2	3.1 jk	1.7 g	7.0 gh	1.3 mnop	25.1 bcde	16.2 g	35.0 g
	3	5.5 defg	3.0 cd	10.0 cd	3.2 hi	25.7 bcd	20.2 jk	3.4 ab
	4	6.6 abc	3.6 b	10.3 bcd	4.5 ef	26.3 abc	21.6 lmn	1.7 a
7	1	2.2 kl	1.0 i	5.4 j	0.6 pq	15.2 l	9.3 a	71.7 j
	2	2.9 jkl	1.5 gh	7.0 gh	1.2 mnop	17.6 kl	11.2 bc	46.7 h
	3	5.5 defg	2.7 de	8.8 ef	2.5 ijk	19.7 ijk	13.8 ef	8.3 abcd
	4	6.0 bcde	4.0 ab	10.0 cd	4.2 fg	20.9 ghij	14.5 f	0.0 a
8	1	1.9 l	1.3 ghi	5.7 hij	0.9 opq	16.3 l	10.2 ab	53.4 j
	2	3.1 jk	1.7 g	7.9 fg	1.9 klm	20.0 ijk	12.7 de	26.7 fg
	3	4.3 hi	2.3 ef	8.2 f	2.1 jkl	21.1 ghi	14.2 f	21.7 ef
	4	5.6 cd	4.2 a	10.0 cd	5.6 cd	25.0 bcde	19.2 ij	0.0 a
Pr>F								
Orchard		0.1862	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Colour		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Orchard*Colour		0.4595	0.0011	0.0033	<0.0001	0.0555	0.0250	<0.0001
Early vs Late		0.9517	0.0003	<0.0001	<0.0001	0.0655	<0.0001	<0.0001

[z] Colour chart where 1 = red/ orange and 8 = green.
[x] means followed by the same letter do not differ significantly at $p<0.05$.

Table 3: The effect of orchard and harvest maturity on TSS at harvest and after shelf-life as well as on the percentage of the calyx that was green, and the percentage blemishes of ‘Triumph’ persimmon after shelf life in the 2010-11 season. “Early” orchards (orchards 1-4) were harvested on 28 April and 4 May while the “late” orchards (5-8) where harvested on 24 May.

Main factor	TSS at harvest	TSS after shelf-life	% Calyx green after shelf-life	% Blemishes and injuries after shelf-life
Orchard				
1	20.9 b [x]	21.7 b	0.1 b	28.8 a
2	22.0 a	22.8 a	0.2 b	30.0 a
3	19.8 c	19.4 e	23.1 a	3.8 d
4	18.7 de	19.2 e	24.4 a	1.3 d
5	19.0 d	20.2 d	2.5 b	12.1 b
6	20.1 c	21.1 c	1.6 b	5.8 cd
7	18.1 e	18.3 f	1.6 b	3.3 d
8	18.5 de	18.9 e	3.1 b	10.4 bc
Colour group				
1	20.1 [NS]	20.9 a	5.5 [NS]	14.2 [NS]
2	19.5	20.5 b	7.0	12.7
3	19.6	20.0 c	7.7	11.3
4	19.4	19.4 d	8.1	9.6
Pr>F				
Orchard	<0.0001	<0.0001	<0.0001	<0.0001
Colour	0.0588	<0.0001	0.1516	0.1893
Orchard*Colour	0.4677	0.2908	0.9954	0.7133
“Early” vs “Late”	<0.0001	<0.0001	-	-

[NS] not significant

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

Table 4: The effect of orchard and GA_3 application on fruit quality and maturity at harvest and after shelf- in of 'Triumph' persimmon after shelf life in the 2010-11 season. Fruit was harvested on 1 June.

Orchard	Colour group	Colour at harvest [z]	Firmness (kg) at harvest	TSS at harvest
1	1	1.9 g [x]	5.6 i	18.5 bc
	2	2.9 ef	7.8 fg	18.6 bc
	3	4.7 bc	9.3 de	18.1 cd
	4	6.1 a	10.0 cd	17.5 de
2	1	2.2 fg	6.8 h	19.5 a
	2	3.4 de	8.5 ef	18.7 b
	3	4.4 bc	10.1 c	17.6 de
	4	6.2 a	10.3 bc	17.2 e
3	1	2.7 ef	7.1 gh	17.9 d
	2	2.9 ef	9.1 e	17.7 de
	3	3.7 cd	12.0 a	16.8 f
	4	5.3 b	12.0 a	15.8 g
4	1	2.2 fg	5.7 i	18.7 b
	2	2.6 fg	8.7 e	17.8 d
	3	4.3 c	10.2 bc	17.2 e
	4	6.2 a	11.0 b	16.5 f
Pr>F				
Orchard		0.2097	<0.0001	<0.0001
Colour		<0.0001	<0.0001	<0.0001
Orchard*Colour		0.0565	0.0360	0.0455

[NS] not significant

[z] Colour chart where 1 = red/ orange and 8 = green.

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

Table 5: The effect of harvest time on fruit quality and maturity of 'Triumph' persimmons at harvest and after shelf-life on GA_3 fruit in the Western Cape Province, South Africa in the 2010-11 season. Fruit was harvested on 1 June.

Main factor	Colour after shelf life [z]	Firmness (kg) after-shelf life	IQ firmness after storage	IQ firmness after shelf-life	Percentage soft fruit	TSS after shelf-life	% Calyx green after shelf-life	% Blemishes and injuries after shelf-life
Orchard								
1	2.5 [NS]	4.4 ab [x]	23.2	19.4 b	23.3 a	17.9 b	1.4 b	3.8 [NS]
2	2.3	4.9 a	24.9	21.5 a	12.1 b	18.5 a	1.8 b	1.7
3	2.3	3.8 c	25.1	18.1 b	14.9 b	17.3 c	4.3 a	0.0
4	2.4	4.0 bc	23.4	18.1 b	18.3 ab	17.7 bc	4.2 a	0.0
Colour group								
1	1.1 d	1.6 d	21.2 c	14.9 c	43.6 a	17.0 [NS]	0.8 c	2.5 [NS]
2	1.7 c	2.7 c	23.2 b	17.6 b	19.6 b	18.1	1.5 c	1.7
3	2.8 b	5.8 b	25.7 a	21.7 a	5.5 c	17.9	3.8 b	0.8
4	3.9 a	7.2 a	26.5 a	22.9 a	0.0 c	17.6	5.4 a	0.4
Pr>F								
Orchard	0.2703	0.0005	0.0526	0.0003	0.0362	0.0004	<0.0001	0.0988
Colour	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.3406	<0.0001	0.6209
Orchard*Colour	0.8449	0.2016	0.8438	0.5005	0.1839	0.5785	0.1033	0.7006

[NS] not significant

[z] Colour chart where 1 = red/ orange and 8 = green.

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

Table 6: The effect of harvest time, GA_3 application and harvest maturity on fruit colour at harvest and after shelf-life as well as percentage soft fruit in the “Early” and “Late” orchards and GA_3 fruit in the 2010-11 season.

Treatment	Colour group	Colour at harvest ^{z}	Colour after shelf life	Percentage soft fruit
“Early” fruit	1	2.0 e ^{x}	1.6 e	19.2 d
	2	3.3 cd	2.2 d	8.4 de
	3	4.7 b	2.7 c	5.0 e
	4	6.3 a	4.0 a	0.4 e
“Late” fruit	1	2.0 e	1.1 f	68.3 a
	2	3.0 d	1.8 e	30.9 c
	3	5.1 b	2.8 c	8.8 de
	4	6.2 a	3.9 a	0.4 e
GA_3-treated fruit	1	2.3 e	1.4 f	43.6 b
	2	3.0 d	2.2 d	19.6 cd
	3	4.3 c	3.3 b	5.5 e
	4	6.0 a	4.0 a	0.0 e
Pr>F				
Treatment		0.2792	0.0031	<0.0001
Colour		<0.0001	<0.0001	<0.0001
Treatment*Colour		0.1753	0.0154	<0.0001

^{NS} not significant

^{z} Colour chart where 1 = red/ orange and 8 = green.

^{x} means followed by the same letter do not differ significantly at p<0.05.

Table 7: The effect of harvest time, GA_3 application and harvest maturity on fruit quality and maturity at harvest and after shelf-life of 'Triumph' persimmons in the 2010-11 season.

Main factor	Firmness (kg) at harvest		Firmness (kg) after shelf-life		IQ firmness after storage		IQ firmness after shelf-life		TSS at harvest		TSS after shelf-life		% Calyx green after shelf-life		% Blemishes and injuries after shelf-life
Treatment															
"Early"	9.5	a [x]	3.4	ab	21.3	b	19.1	a	20.4	a	20.8	a	11.9	a	15.9 NS
"Late"	8.2	b	2.5	b	22.0	b	15.5	b	19.0	b	19.6	b	2.2	b	7.9
GA_3	9.0	a	4.3	a	24.2	a	19.3	a	17.8	c	17.8	c	2.9	b	9.5
Colour group															
1	6.3	d	1.3	c	19.0	c	13.6	c	19.3 NS		20.2	a	4.0 NS		14.2 NS
2	8.5	c	2.3	c	22.1	b	16.7	b	19.0		19.8	a	5.2		11.9
3	10.1	b	4.1	b	23.6	ab	19.7	a	19.1		19.2	ab	6.4		10.1
4	10.8	a	6.0	a	25.2	a	21.7	a	18.5		18.5	b	7.2		8.2
Pr>F															
Treatment	0.0002		0.0058		0.0032		0.0010		<0.0001		<0.0001		0.0021		0.0653
Colour	<0.0001		<0.0001		<0.0001		<0.0001		0.7685		0.0251		0.7764		0.5055
Treatment*Colour	0.5653		0.7708		0.7789		0.9969		0.9814		0.9882		0.9982		0.9972

NS not significant

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

Table 8: Correlations of peel colour and firmness at harvest with fruit quality and maturity parameters for “Early” ‘Triumph’ persimmon fruit.

	Orchard 1		Orchard 2		Orchard 3		Orchard 4	
	r^z	Pr>F	r	Pr>F	r	Pr>F	r	Pr>F
Peel colour at harvest								
Firmness at harvest	0.68	0.0036	0.80	0.0002	0.89	<0.0001	0.85	<0.0001
Firmness after shelf-life	0.78	0.0005	0.89	<0.0001	0.91	<0.0001	0.91	<0.0001
Peel colour after shelf-life	0.76	0.0006	0.87	<0.0001	0.93	<0.0001	0.85	<0.0001
IQ firmness after storage	0.69	0.0030	0.41	0.1121	0.63	0.0083	0.84	<0.0001
IQ firmness after shelf-life	0.81	0.0002	0.76	0.0006	0.78	0.0004	0.83	<0.0001
% soft fruit	-0.56	0.0248	-0.38	0.1514	-0.52	0.0410	-0.42	0.1077
% green Calyx	0.10	0.7056	0.57	0.0225	0.08	0.7723	0.09	0.7277
Firmness at harvest								
Firmness after shelf-life	0.84	<0.0001	0.75	0.0007	0.82	0.0001	0.91	<0.0001
Peel colour after shelf-life	0.83	<0.0001	0.91	<0.0001	0.85	<0.0001	0.81	0.0002
IQ firmness after storage	0.82	0.0001	0.57	0.0215	0.60	0.0146	0.88	<0.0001
IQ firmness after shelf-life	0.82	0.0001	0.82	0.0001	0.72	0.0018	0.88	<0.0001
% soft fruit	-0.83	<0.0001	-0.55	0.0260	-0.58	0.0185	-0.53	0.0356
% green Calyx	0.40	0.1239	0.23	0.3954	0.09	0.7481	0.24	<0.0001

[z] Pearson Correlation Coefficients / Prob > |R| under Ho: Rho=0 / N where n = 16

Table 9: Correlations of peel colour and firmness at harvest with fruit quality and maturity parameters for “Late” ‘Triumph’ persimmon fruit.

	Orchard 1		Orchard 2		Orchard 3		Orchard 4	
	r^z	Pr>F	r	Pr>F	r	Pr>F	r	Pr>F
Peel colour at harvest								
Firmness at harvest	0.89	<0.0001	0.85	<0.0001	0.90	<0.0001	0.85	<0.0001
Firmness after shelf-life	0.94	<0.0001	0.96	<0.0001	0.78	0.0003	0.79	0.0002
Peel colour after shelf-life	0.91	<0.0001	0.91	<0.0001	0.80	0.0002	0.81	0.0001
IQ firmness after storage	0.90	<0.0001	0.62	0.0099	0.90	<0.0001	0.88	<0.0001
IQ firmness after shelf-life	0.90	<0.0001	0.83	<0.0001	0.77	0.0005	0.87	<0.0001
% soft fruit	-0.76	0.0007	-0.66	0.0054	-0.9	<0.0001	-0.75	0.0008
% green Calyx	0.78	0.0004	0.63	0.0086	0.68	0.0039	0.64	0.0082
Firmness at harvest								
Firmness after shelf-life	0.93	<0.0001	0.93	<0.0001	0.83	<0.0001	0.73	0.0013
Peel colour after shelf-life	0.89	<0.0001	0.91	<0.0001	0.86	<0.0001	0.85	<0.0001
IQ firmness after storage	0.92	<0.0001	0.80	0.0002	0.88	<0.0001	0.96	<0.0001
IQ firmness after shelf-life	0.91	<0.0001	0.93	<0.0001	0.84	<0.0001	0.88	<0.0001
% soft fruit	-0.90	<0.0001	-0.83	<0.0001	-0.92	<0.0001	-0.87	<0.0001
% green Calyx	0.72	0.0018	0.62	0.0108	0.70	0.0025	0.70	0.0023

^{z} Pearson Correlation Coefficients / Prob > |R| under Ho: Rho=0 / N where n = 16

Table 10: Correlations of peel colour and firmness at harvest with fruit quality and maturity parameters for GA_3-treated 'Triumph' persimmon fruit.

	Orchard 1		Orchard 2		Orchard 3		Orchard 4	
	r[z]	Pr>F	r	Pr>F	r	Pr>F	r	Pr>F
Peel colour at harvest								
Firmness at harvest	0.87	<0.0001	0.80	<0.0002	0.78	0.0004	0.80	0.0002
Firmness after shelf-life	0.95	<0.0001	0.89	<0.0001	0.83	<0.0001	0.92	<0.0001
Peel colour after shelf-life	0.95	<0.0001	0.88	<0.0001	0.83	<0.0001	0.88	<0.0001
IQ firmness after storage	0.70	0.0023	0.69	0.0031	0.61	0.0113	0.52	0.0398
IQ firmness after shelf-life	0.85	<0.0001	0.87	<0.0001	0.77	0.0005	0.60	0.0132
% soft fruit	-0.80	0.0002	-0.74	0.0011	-0.73	0.0012	-0.68	0.0034
% green Calyx	0.71	0.0021	0.46	0.0703	0.60	0.0144	0.72	0.0015
Firmness at harvest								
Firmness after shelf-life	0.88	<0.0001	0.92	<0.0001	0.92	<0.0001	0.94	<0.0001
Peel colour after shelf-life	0.89	<0.0001	0.89	<0.0001	0.89	<0.0001	0.88	<0.0001
IQ firmness after storage	0.71	0.0020	0.47	0.0631	0.78	0.0003	0.56	0.0234
IQ firmness after shelf-life	0.84	<0.0001	0.75	0.0009	0.78	0.0003	0.79	0.0003
% soft fruit	-0.91	<0.0001	-0.75	0.0009	-0.78	0.0003	-0.84	<0.0001
% green Calyx	0.65	0.0069	0.57	0.0146	0.73	0.0015	0.63	0.0085

[z] Pearson Correlation Coefficients / Prob > |R| under Ho: Rho=0 / N where n = 16

Table 11: Correlations of firmness at harvest with fruit quality and maturity parameters for “Early”, “Late” and GA_3-treated ‘Triumph’ persimmons.

	“Early” fruit		“Late” fruit		GA_3-treated fruit	
	r	Pr>F	r	Pr>F	r	Pr>F
Peel colour at harvest						
Firmness at harvest	0.91	<0.0001	0.92	<0.0001	0.78	0.0004
Firmness after shelf-life	0.80	<0.0001	0.84	<0.0001	0.86	<0.0001
Peel colour after shelf-life	0.4	0.0002	0.87	<0.0001	0.79	<0.0001
IQ firmness after storage	0.60	<0.0001	0.78	<0.0001	0.66	<0.0001
IQ firmness after shelf-life	0.56	<0.0001	0.82	<0.0001	0.66	<0.0001
% soft fruit	-0.62	<0.0001	-0.86	<0.0001	-0.78	<0.0001
% green Calyx	-0.01	0.9895	0.64	<0.0001	0.64	<0.0001
Firmness at harvest						
Firmness after shelf-life	0.83	<0.0001	0.85	<0.0001	0.90	<0.0001
Peel colour after shelf-life	0.55	<0.0001	0.83	<0.0001	0.89	<0.0001
IQ firmness after storage	0.55	<0.0001	0.65	<0.0001	0.48	<0.0001
IQ firmness after shelf-life	0.60	<0.0001	0.70	<0.0001	0.74	<0.0001
% soft fruit	-0.45	0.0002	-0.75	<0.0001	-0.72	<0.0001
% green Calyx	0.06	0.6274	0.61	<0.0001	0.48	<0.0001

[z] Pearson Correlation Coefficients / Prob > |R| under Ho: Rho=0 / N where n = 64

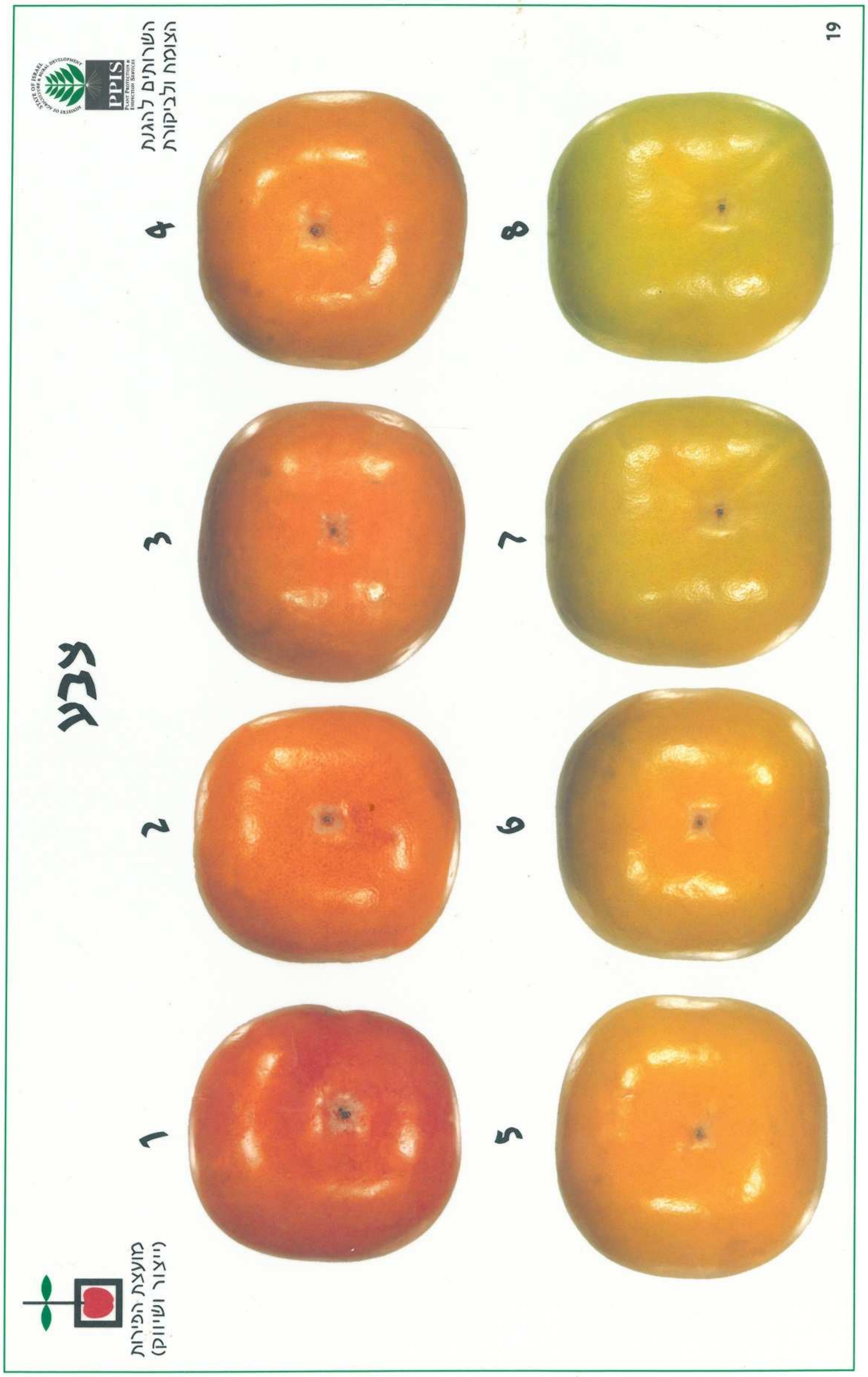

Figure 1: Plant Protection and Inspection Services (PPIS) colour chart. ‘Triumph’ persimmon fruit in South Africa is harvested at chart values 4 and 5.

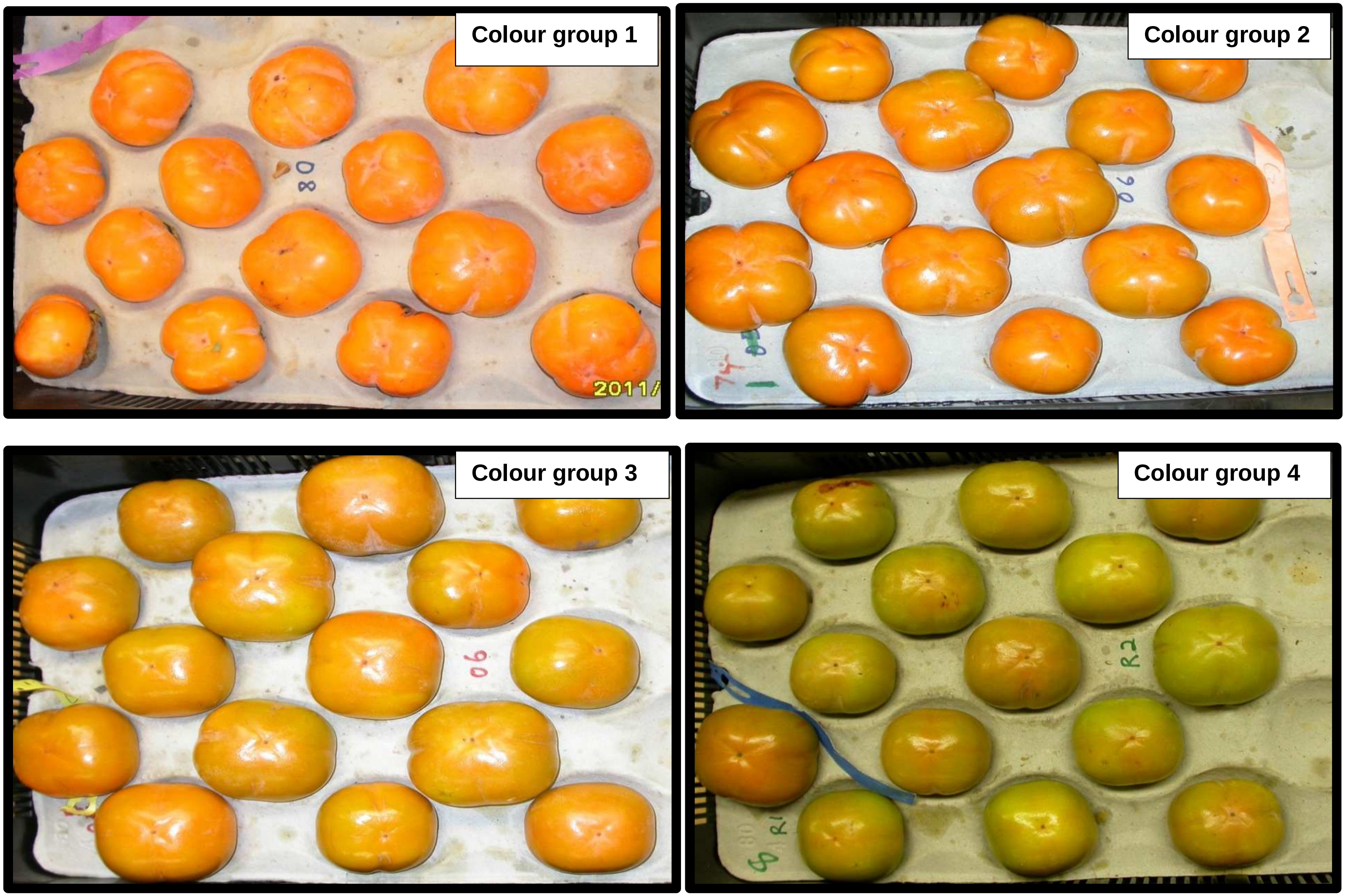

Figure 2: Four different colour groups of ‘Triumph’ persimmon from “early” orchards used in the experiment.

GENERAL DISCUSSION AND CONCLUSION

The profitability of ‘Triumph’ persimmon production in South Africa would benefit considerably if harvesting could be advanced so that the majority of the crop arrives in the European market before northern hemisphere summer fruits. Part of this study thus focused on investigating the use of the plant growth regulators (PGRs) paclobutrazol (PBZ) and prohexadione-Ca (P-Ca) and rest break agents (RBAs) to advance ripening of ‘Triumph’ persimmons.

The current industry practice used to advance harvest maturity of ‘Triumph’ persimmons is a drench application of PBZ at 1.5 g per tree. Unfortunately, this treatment decreases fruit storability and stunts vegetative growth in the subsequent season, which exposes more fruit to direct sunlight thereby increasing the risk of sunburn and secondary *Alternaria alternata* infection. The effect of PBZ at lower application rates (lowest rate of 0.75 g per tree) was therefore investigated. Our evaluation, carried out over two seasons, indicated that PBZ advanced harvest maturity of ‘Triumph’ persimmons regardless of application rate in the season of application. As was the case with other studies on persimmon (Ben-Arie *et al.*, 1997; Eshel *et al*., 2000; Testoni, 2002) higher application rates (1 g per plant and above) accelerated fruit softening during storage and shelf-life. The current work also confirmed previous findings by Ben-Arie *et al*. (1997) on ‘Triumph’ persimmon that high application rates of PBZ (1 and 2 g per plant) decreased fruit firmness after shelf-life in spite of 1-MCP application before storage. At these highest application rates, the effects of PBZ on harvest maturity carried through to the subsequent season while at 0.75 ml per plant, the effect of PBZ was limited to the season of application. It was also observed that lower PBZ application rates of 0.375 ml and 0.75 ml per plant did not decrease vegetative growth in the season following application. Therefore, it appears that South African persimmon growers should use lower PBZ application rates of 0.75 ml per plant than the current norm. Further research is needed to assess the extent to which the reduction in vegetative growth due to PBZ treatment increases the percentage fruit with sunburn and black spot

(*Alternaria alternata*) because this may provide further evidence for using lower application rates of PBZ.

P-Ca is another GA inhibitor commonly used to advance fruit harvest. Contrary to stunted growth associated with the use of PBZ, P-Ca was observed to advance harvest maturity with no negative effects on tree growth in avocadoes (Salazar-García *et al*., 2007) and mangoes (Mouco *et al*., 2010). Thus, the effect of P-Ca at various concentrations and timings as a possible substitute for PBZ in advancing harvest maturity in 'Triumph' persimmon was investigated. A positive response in the advancement of harvest to three applications of P-Ca at 200 $mg \cdot L^{-1}$ in the first season seemed promising. P-Ca did not have negative effects on fruit maturity and quality at harvest in contrast to PBZ. Previous research by Barry and le Roux (2010) indicted that P-Ca advances harvest by accelerating fruit ripening through the induction of chlorophyll degradation and carotenoid synthesis. After another season's work it was confirmed that a single application of P-Ca at 300 $mg \cdot L^{-1}$, 2 weeks before the onset of harvesting, can be used to advance harvest maturity of 'Triumph' persimmon to the same extent as PBZ without compromising fruit keeping quality. The research also indicated that P-Ca had no negative effects on vegetative growth. We, however, would suggest that future studies should be carried out to further assess the effects of P-Ca on the vegetative growth and return bloom in'Triumph' persimmon in the season after application. Since high concentrations of P-Ca have been found to affect secondary metabolism (Rademacher, 2006), the effect of P-Ca on the incidence of black spot should also be assessed.

Persimmon trees generally have a low chilling requirement of ca. 300 Richardson chilling units (Mowat *et al*., 1995). Insufficient chilling unit accumulation during winter results in delayed and uneven blossoming causing delayed and uneven fruit maturity (Mowat *et al*., 1995). Rest breaking agents (RBAs) are commonly used counteract this problem in many fruit trees (Saure, 1985). Early application of RBAs can induce early bud break thereby advancing harvest maturity (Saure, 1985). An investigation was carried out to assess the effects of various RBAs on bud break, flowering, fruit maturity and quality as well as vegetative growth. RBA application did not advance bud break or meaningfully advance harvesting. This might be attributed to the concentrations of RBA treatments having been too low to induce bud break considering that it should have been easy to force bud break if chilling was fulfilled prior to treatment application. Being cognisant that RBA application may cause damage to trees (Blank *et al*., 1994) and considering that not much information exist for RBA application to persimmons, we opted to apply RBAs at lower concentrations than would be the case for apples. However, it is also possible that application of RBAs after satisfaction of chilling does not have an effect on bud break of persimmons, as noted in peach by Siller-Cepeda *et al*. (1992) in a similar scenario. We recommend that the study should be repeated in a warmer region at higher RBA concentrations.

Persimmons generally have a limited storability and a short shelf-life (Kitagawa and Glucina, 1984). 'Triumph' persimmons can be stored for 4 months at -1 ℃ in a modified atmosphere. However, during this period flesh browning occurs due to accumulation of acetaldehyde (Prusky *et al*., 1997). In South Africa, it seems that 'Triumph' persimmon fruit harvested at the later stages of the harvesting season, which stretches from the first week of April until mid-June, do not store as well as fruit from earlier areas. In the current study it was confirmed that fruit colour is a good indicator of fruit storage potential. Due to delayed colour development associated with the second half of the harvest period, late fruit is less firm compared to fruit picked early at the same colour chart value. Considering that firmness after shelf life strongly correlates with firmness at harvest, late fruit can be expected to store and keep worse than early fruit. In agreement with Wright and Kader (1997), applying GA_3 to fruit at a more advanced stage of maturity was not effective in improving storability. Due to the high propensity of late and GA_3-treated fruit of colour chart values 3 and below to go soft during storage and shelf life, such fruit should be culled. When picked yellow-green at colour chart values 5 to 6 as opposed to the industry standard chart values of 4 to 5, fruit from late orchard and GA_3-treated fruit not only store well, but also attain a good orange to yellow orange colour (colour chart values 3 to 4) suitable for the market.

Fruit with a lower percentage of the calyx that remained green after shelf-life were generally softer. Nakano *et al*. (2003) found that in persimmons, water loss-induced ethylene production in the calyx stimulates autocatalytic ethylene synthesis in other tissues of fruit resulting in fruit softening. Further research is required to determine whether calyx condition at harvest can be used as a basis to downgrade fruit with susceptible storability. It seems that the Sinclair firmness tester may have potential for the grading of fruit on the pack line based on firmness. Further validation of our research is required. Lastly, it seems that persimmon storability is compromised by a delay in 1-MCP treatment and interruption of cold chain. Watkins (2008) also found that 1-MCP application after cold-storing fruit renders the chemical ineffective.

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