THE ROLE OF HARVEST TIME AND MATURITY, ORCHARD AND SIMULATED WIND ON POSTHARVEST QUALITY OF 'TRIUMPH' PERSIMMON FRUIT, AND THE POTENTIAL OF NIR AS NON-DESTRUCTIVE SORTING TOOL

by

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Declaration

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SUMMARY

Production of the South African 'Triumph' persimmon grown as a counter season supply to European markets declined from 740 ha in 2008 to 550 ha in 2011 due to, among other factors, quality variation observed when the fruit arrives at the market. Variation in fruit quality affects acceptability, hence profitability. The aim of this study was to investigate the effects of time of maturity (influenced by region and paclobutrazol treatment), stage of maturity at harvest (colour), orchard differences and wind on 'Triumph' persimmon storage potential (6.5 weeks at -0.5 ^{o}C and after 4 days shelf-life at 20 ^{o}C) as well as evaluation of near-infrared spectroscopy (NIRs) as an objective tool to sort fruit of various maturity stages.

The first study compared storage potential of fruit from an early region treated with paclobutrazol, an untreated early region and a late region harvested at 4 stages of maturity determined by the Perishable Product and Inspection Services (PPIS) persimmon colour chart. Harvesting South African 'Triumph' persimmon at colour group 3 (PPIS colour chart values 5-6 compared to commercial harvest at 4-5) demonstrated the potential to improve fruit storage potential regardless of the maturity time.

The second trial compared storage potential of fruit harvested at colour group 3 from 4 orchards on each maturity time in the 2012 season and 5 orchards on adjacent farms in the 2013 season. The results demonstrated that, although harvesting fruit at PPIS colour chart values 5-6 improved the general post-harvest quality, significant quality variation resulting from orchard factors could occur.

The third trial investigated the effect of wind on storage potential of 'Triumph' persimmon fruit by simulating wind and wind damage by blowing trees for 10 min, shaking trees for 2 min, defoliating half of the trees and twisting fruit stalks. Wind simulations increased soft fruit after cold storage, decreased titratable acidity (TA) and total soluble solids (TSS) after shelf-life and delayed fruit colour development after storage and after shelf-life. The effect of wind simulation and simulated damage on storage potential varied per season and should be studied further in more detail. However, orchard practices that reduce wind power may improve quality of stored 'Triumph' persimmon fruit.

The fourth trial investigated the possibility of using near infra-red spectroscopy (NIRs) as an alternative or complimentary non-destructive fruit sorting tool. Near infra-red (NIR) spectra were obtained over the wavelength range of 800-2500 nm. Flesh firmness, Sinclair (IQ) firmness, TSS, TA and fruit colour were determined using conventional methods after spectral measurements. All measured quality parameters showed that PPIS colour chart alone may not categorise fruits into precise distinctive maturity stages. NIR calibration and validation models proved that NIRs predicts TSS and fruit colour throughout post-harvest storage of 'Triumph' persimmon fruit.

In conclusion, this study found that harvesting South African 'Triumph' persimmon at PPIS colour chart values 5-6, orchard management for post-harvest quality, reducing wind damage and using

NIRs as complimentary maturity indexing tool may improve storage potential of the South African 'Triumph' persimmon fruit.

OPSOMMING

Die produksie van Suid-Afrikaanse 'Triumph' persimmons om die Europese markte te voorsien gedurende die tyd van die jaar wanneer daar geen vrugte op die mark is nie, het afgeneem vanaf 740 ha in 2008 tot 550 ha in 2011. Een van die faktore wat 'n rol gespeel het in die afname van produksie is die variërende kwaliteit van vrugte op die mark. Vrugkwaliteit variasie affekteer die bemarkbaarheid van vrugte, en dus winsgewendheid. Die doel van die studie was om die effek van tyd van oesrypheid (soos bepaal deur kleur en beïnvloed deur produksie area en paclobutrazol behandeling), boordvariasie en wind op 'Triumph' persimmon opberging (6 weke en 3 dae by -0.5 ^{o}C) en rakleeftyd (4 dae by 20 ^{o}C) te bepaal. Die studie het ook die geskiktheid van naby-infrarooi spektroskopie (NIRs) as 'n objektiewe sorteringsinstrument van verskeie rypheidsstadia getoets.

Die eerste proef vergelyk opbergingspotensiaal van vrugte uit 'n vroeë produksie area behandel met paclobutrazol, onbehandelde vrugte uit 'n vroeë produksie area, en vrugte uit 'n laat produksie area geoes by 4 verskillende stadia van rypwording soos bepaal deur die Bederfbare Produkte en Inspeksie Dienste (Perishable Product and Inspection Services (PPIS)) se persimmonkleurkaart. Die oes van Suid-Afrikaanse persimmons by kleurkaartgroep 3 (PPIS kleurkaart waardes 5-6 in vergelyking met kommersiële oes by 4-5) het die potensiaal om vrugopbergbaarheid te verbeter onafhanklik van produksie area.

Die tweede proef vergelyk opbergbaarheid van vrugte van 4 boorde in elke rypwordings tyd / area (2012 seisoen) en 5 boorde op aangrensende plase (2013 seisoen) wat by kleurgroep 3 geoes is. Die resultate demonstreer dat alhoewel vrugkwaliteit na-oes beter behou word wanneer vrugte by PPIS kleurkaartwaardes van 5-6 ge-oes word, betekenisvolle kwaliteitsvariasie bestaan as gevolg van boordverskille.

Die derde proef ondersoek die effek van gesimuleerde wind en windskade op die opbergbaarheid van 'Triumph' persimmonvrugte. Dit is gedoen deur bome vir 10 min te blaas met lug met behulp van 'n kommersiële boordspuitpomp, hard te skud vir 2 min, deur die helfte van die blare te stroop, en deur die vrugstele te wring. Windsimulering verhoog die persentasie sagte vrugte na koueopberging, verminder titreerbare sure (TS) en totale oplosbare vastestowwe (TOVS) na rakleeftyd en vertraag vrugkleurontwikkeling na opberging en rakleeftyd. Die effek van windsimulering en geassosieerde skade op opbergbaarheid het baie gevarieer tussen seisoene en moet verder en in meer detail bestudeer word. Boordpraktyke wat windkrag verminder mag egter 'n verbetering in die kwaliteit van 'Triumph' persimmonvrugte tot gevolg hê.

Die vierde proef bestudeer die geskiktheid van NIRs as 'n alternatiewe of aanvullende nie-destruktiewe vrugsorteringsapparaat. NIR spektra is ingesamel tussen 800-2500 nm. Fermheid, Sinclair (IQ) fermheid, TOVS, TA en vrugkleur is bepaal deur konvensionele metodes na spektrale metings. Alle vrugkwaliteitsparameters het gewys dat die PPIS kleurkaart nie alleen die vrugte in presiese rypheidsklasse kan indeel nie. NIR kalibrasie en validasie modelle bewys dat NIRs TOVS en vrugkleur 'Triumph' persimmon na-oes kwaliteit kan voorspel.

In gevolgtrekking het die studie bevind dat die oes van Suid-Afrikaanse persimmonvrugte by PPIS kleurkaartwaardes van 5-6, boordbestuurspraktyke vir die behoud van na-oes kwaliteit, windskade vermindering en die gebruik van NIRs as ‘n aanvullende rypheidsindekseringsapparaat die opbergingsvermoë van Suid Afrikaanse ‘Triumph’ persimmons mag verbeter.

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DEDICATION

This thesis is dedicated to my niece Janet, my late mother Joina and my late sister Jealous.

TABLE OF CONTENTS

GENERAL INTRODUCTION

The persimmon (*Diospyros kaki* Thunb.) is a deciduous tree that originated in China and is very popular in the Far East, Japan, South Korea and China (Jackson and Morley-Bunker, 1999). It is commercially grown in China, Japan, Brazil, Italy, Spain, USA, New Zealand, Australia, Chile, Georgia, Iran, Israel (Arisa, 2006; Collins et al., 1993) and South Africa. In South Africa, serious large scale cultivation of the fruit started in 1998 (Rabe, 2003) when Israel, which dominates the Northern hemisphere supply of the astringent 'Triumph' persimmon fruit, recognised the opportunity available to South African producers to become counter season suppliers of 'Triumph' persimmon fruit to the Northern hemisphere markets (Arisa, 2006). Since South African 'Triumph' persimmon production is export oriented, the focus is therefore on meeting quality specification demanded by the market. The South African persimmon industry has been struggling to satisfy these requirements since the inception of persimmon export (Bill, 2012). Post-harvest quality variability was cited as one of the main factors that contributed to the decline of the South African persimmon production area from 740 ha in 2009 to 550 ha in 2011 (Ungerer, 2013 pers. comm.).

In a quest to determine the possible causes of variable post-harvest fruit quality of the South African 'Triumph' persimmon, a literature study on pre-harvest factors that affect fruit quality with special reference to persimmon was conducted. The study was prompted by the knowledge that post-harvest product quality to a large extent is determined during pre-harvest growth and development stages and is maintained, or improved by post-harvest technologies (Hewett, 2006). Ferguson et al. (1999) suggested that identification of these pre-harvest factors raises the probability of producing fruit with a lower predisposition to post-harvest disorders. Factors that are prevalent and assumed to have effects on post-harvest quality of 'Triumph' persimmon in the South African persimmon production situation were experimentally investigated.

South African persimmon is produced in the Mediterranean-type climate of the Western Cape Province (Bill, 2012). The production area presents two meso-climatic regions evidenced by the time 'Triumph' persimmon is ready for harvesting as early and late regions. A third group according to this classification is fruit of the early region that is chemically induced to mature earlier (Bill, 2012). Chemically induced or paclobutrazol (PBZ) treated fruit is harvested mid to late April in early region, early region untreated fruit is harvested mid April to mid May and late region fruit is harvested late May to mid June. All three maturity times are harvested at the same stage of maturity according to fruit colour. However, Kitagawa and Glucina (1984) noted that in Japan, persimmon fruit colour is influenced by the production area. 'Fuyu' persimmons from northern districts of Japan were found to have good colouration whereas those from southern districts have a fairly pale colour (Kitagawa and Glucina, 1984). Apart from its effect on development of pre-harvest persimmon fruit colour, production area was also found to influence potential quality and post-harvest life of fruits. Kitagawa and Glucina (1984) found that 'Fuyu' persimmon fruit grown in very warm region of Japan were tasteless whereas warm temperature and high sunshine hours were required to produce fruit that were completely free of astringency. Warm temperatures in late summer and early autumn in the two month before harvesting were found to be important for fruit maturity (Kitagawa and Glucina, 1984). Generally, quality at harvest influences storability (Wills et al., 2007). Therefore, this study investigated the effect of time of maturity/harvest on post-harvest quality of 'Triumph' persimmon by comparing storage potential of PBZ treated, early and late fruits.

South African 'Triumph' persimmons are harvested using fruit colour as maturity index. Fruit colour changes from yellowish green to deep orange red. The Plant Protection and Inspection Services (PPIS) persimmon colour chart that is used to determine harvesting have colour grades that run from 1 for deep orange red fruit to 8 for yellowish green fruit and values 4-5 (Figure 1, paper 1) are regarded as the correct colour stages at which harvesting can be done. On climacteric fruits, harvest maturity is the stage at which the fruit has reached a minimum level of development such that it has sufficient life to withstand transportation and ripening and yet will still ripen normally to produce a fruit of good quality (Wills et al., 2007). Bill (2012) reported that post storage quality of fruit harvested at the same colour chart value vary significantly. Wills et al. (2007) reported that ground colour as judged against colour charts, is a useful index of maturity (apple, pears, stone fruit and mango), but is not entirely reliable because it is influenced by factors other than maturity. This study therefore, investigated storage potential of fruit harvested at different stages of maturity (colour groups) at different times of maturity (PBZ treated, early and late) so as to establish if using different stage of maturity to harvest fruit that mature at different times could improve post-harvest quality of 'Triumph' persimmon fruit.

In New Zealand, orchard management was found to have a greater effect on fruit quality than the districts in which the fruit were grown (Mowat and Chee, 2011). Kader (2002) pointed out that if poor orchard management decisions are made, the quality of the product that reaches the consumer may be undesirable. This study also investigated the effect of orchard by comparing storage potential of 'Triumph' persimmon fruit harvested at the recommended stage of maturity at different orchards in the same region or area.

In South Africa, 'Triumph' harvesting time coincides with the onset of frontal weather and this is a time of high wind flow. Kitagawa and Glucina (1984) reported that persimmons are sensitive to wind. Wind rub was found to be the major blemish that reduces marketability of persimmon fruit in Australia and New Zealand (Collin et al., 1997). Apart from physical wounding that can be graded against at harvest, plants or plant parts are known to experience mechanical perturbation that originates from different sources and is characterized by the absence of direct physical wounding of the tissue (Kays and Paull, 2004). Perturbment is known to increase ethylene synthesis (Kays and Paull, 2004) as well as to effect significant changes in the synthesis of gibberellic acid (Suge, 1978), which both presents sequential responses after initial sensory reception and action (Kays and Paull, 2004). It is also assumed that the early stages of the response to perturbment involve a rapid change in membrane permeability and bioelectrical potential (Kays and Paull, 2004). Precheur et al. (1978) found that the same source of mechanical stress resulted in mechanical perturbment at one level and wounding at another level and wind was cited as an example. This study investigated the effect of pre-harvest simulated wind-induced damage on the quality of 'Triumph' persimmon fruit after storage and shelf-life.

Since fruit colour as judged by colour chart did not always correlate with fruit quality, an investigation to assess the possibility of using NIR spectroscopy (NIRs) as an alternative non-destructive tool for maturity determination as well as assessment of persimmon fruit quality was conducted. Amongst other non-destructive tools used in quality determination in fruit, NIRs was found to be more promising and has got wide application (Liew and Lau, 2012). Regardless of its wide application, the author does not know of any study where NIR was evaluated on persimmon fruit. This study therefore investigated the applicability of NIRs in predicting persimmon fruit quality at harvest, after storage and after shelf-life.

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LITERATURE REVIEW

PRE-HARVEST FACTORS THAT AFFECT POST-HARVEST QUALITY OF FRUIT WITH SPECIAL REFERENCE TO PERSIMMON (*Diospyros kaki Thunb.*)

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1. INTRODUCTION

Persimmon (*Diospyros kaki Thunb.*) is a deciduous tree that originated in China and its fruit is very popular in Japan, South Korea and China (Jackson and Morley-Bunker, 1999). It is commercially grown in China, Japan, Brazil, Italy, Spain, USA, New Zealand, Australia, Chile, Georgia, Iran, and Israel (Arisa, 2006) where summers are warm and winters provide sufficient chilling to overcome a short dormancy requirement (Jackson and Morley-Bunker, 1999). In South Africa, large scale commercial cultivation of the fruit only started in the mid-1990s when Israel, which dominates the Northern hemisphere supply of the astringent 'Triumph' fruit, recognised the tremendous opportunity available to South African producers to become the chief counter season suppliers of 'Triumph' persimmons to the Northern hemisphere markets and formed a partnership with South Africa (Arisa, 2006).

The South African - Israeli partnership resulted in the formation of a group of producers of Sharon™ persimmon fruit (Sharon Growers Group) that produce fruit from a controlled number of hectares, ensuring high quality fruit in limited quantities (Rabe, 2003), and establishment of a multinational enterprise that built a pack house and cold storage facility. They produced, packed and sold persimmons from Israel and South Africa according to industrial standards such as ISO 9000, ISO 1400, Global Gap and Tesco Nature's Choice (Arisa, 2006).

Despite all this effort to ensure high fruit quality, several quality problems have been observed since the inception of persimmon export more than a decade ago (Bill, 2012). Some of these problems have also been noted in other persimmon producing countries. In Brazil, Neuwald et al. (2009) identified softening and skin browning as storage and shelf-life quality problems of persimmons that affect acceptance by consumers. In Japan, Kitagawa and Glucina (1984) noted that it is fairly difficult to obtain uniform persimmon fruit after storage.

Post-harvest product quality develops during pre-harvest growth and development stages and is maintained (Hewett, 2006) or improved by post-harvest technologies. Development of physiological disorders during post-harvest ripening and storage of fruit can be influenced by a range of pre-harvest factors. Identification and rectification of these pre-harvest factors reduces the probability of producing fruit predisposed to post-harvest disorders (Ferguson et al., 1999). Woolf et al. (1999) noted that there are only a few post-harvest disorders of fruit (e.g. carbon dioxide injury) that are completely independent of pre-harvest factors. Thompson (2003) reported that issues that influence produce quality include obvious things such as harvest maturity and cultivar, but also climate and soil in which it was grown, chemicals which have been applied to the crop and plant water status. Kader (2002) pointed out that if poor management decisions are made during crop production, the quality of the product that reaches the consumer may be undesirable. In some well-documented disorders such as bitter pit in apples, the pre-harvest factors have been relatively well defined, but in others, they are largely speculative. This study therefore, reviews the role played by the environment, climatic factors and harvest maturity on post-harvest quality of 'Triumph' persimmons.

2. PERSIMMON FRUIT

2.1 DESCRIPTION OF THE FRUIT

The persimmon fruit is a berry resembling a tomato in shape and size, but the seeds are large, almond shaped and few in number in older cultivars and absent in newer cultivars (Kitagawa and Glucina, 1984). The epidermis is thin as in tomato and the fruit has an enlarged calyx that adheres to its base (Kitagawa and Glucina, 1984). Horticulturally, persimmons are divided into two types, viz. astringent and non-astringent. Astringent types are inedible at harvest and must be treated to remove astringency. Non-astringent types lose their astringency before harvest time. Astringent types generally can be stored longer than non-astringent types but artificial astringency removal shortens shelf-life (Itoo, 1986). 'Triumph' (Sharon^{TM} fruit) persimmon is a deep orange, waxy fruit with orange flesh colour, sweet flavour after astringency removal and possesses an apple like crunch when firm (Anon, 2012). The fruit is medium to large (150-220 g), square shaped in longitudinal section and round in cross section. 'Triumph' is astringent at harvest and hence needs artificial astringency removal for consumption (Kitagawa and Glucina, 1984). It can be eaten firm like an apple or soft as a peach, with or without the peel (Anon, 2012).

2.2 QUALITY ATTRIBUTES OF A PERSIMMON FRUIT

The following are considered important quality attributes for persimmon fruit:

Size - Size is important especially if the fruit is to be exported to markets where large variation in prices occur between different fruit sizes (Kitagawa and Glucina, 1984; Crisosto, 2008). A desirable size for 'Fuyu' is 230-250 g and the minimum marketable size for the cultivar is 200 g (Kitagawa and Glucina, 1984). 'Triumph' persimmon is medium to large (150-220 g) in size. In European markets, the minimum size irrespective of quality class is 40 mm in diameter, but the range in size between produce in the same package should not exceed 10 mm for "Extra" class and 20 mm for Class 1 (UNECE, 2012). The current New Zealand persimmon industry-preferred standards are for fruit to be greater than 200 g for non-astringent cultivars (Mowat and Chee, 2011) and 160-180 g for astringent cultivars (Jackson and Morley-Bunker, 1999)

Colour - The peel colour of some persimmon cultivars is more orange (e.g. Jiro) and does not become red even after maturity, but fruit of other cultivars (e.g. Shizi) become deep vermilion at maturity (Crisosto, 2008). Cultivars that redden contain high lycopene concentration, which is the carotenoid pigment responsible for determining the attractive colouration of persimmons (Kitagawa and Glucina, 1984). Peel colour is usually measured with a prepared colour chart (Wills et al., 1989) and in South Africa, 'Triumph' persimmon is harvested according to the Plant Protection and

Inspection Services (PPIS) persimmon colour chart (Bet-Dagan, Israel) with values 1-8 where 1 = red/ orange and 8 = green and at the colour chart values 4 to 5 (Bill, 2012), which is a yellowish peel colour. The European markets require persimmons to be of uniform colour characteristic of the variety (UNECE, 2012). In New Zealand, the current persimmon industry-grade standards require export fruit at harvest to be of colour chart value 5 (Mowat and Chee, 2011). In South Africa, the Perishable Products Control Board (PPECB) requires that the colour of export 'Triumph' fruit at the calyx end be at least slightly red and have a minimum orange colour development on the PPIS colour chart of 6.

Firmness - The fruit should be firm with a penetration force of 2.3 kg, using 8 mm tip, for 'Fuyu' and similar cultivars (Crisosto, 2008). The minimum requirement subject to the provisions for each class and the tolerances allowed by the Economic Commission for Europe (ECE) is that the persimmon must be firm according to the variety (UNECE, 2012). Salvador et al. (2005) noted that firmness of 10 N (1.02 kg) is not acceptable from a commercial point of view for the persimmon cultivar Rojo Brillante. In South Africa, the PPECB standard requires a minimum firmness for export 'Triumph' persimmon fruit of 5 kg and an optimum firmness of 7 kg with 11.1 mm plunger.

Blemishes - The fruit should be free from growth cracks, calyx separation, mechanical injuries and decay. Kitagawa and Glucina (1984) reported that the most important post-harvest disease affecting persimmons in New Zealand is *Penicillium* and this pathogen invades the fruit mainly through wounds on the fruit peel. Flesh firmness decrease in storage particularly if ethylene gas is present and ethylene appears to be generated from any damaged part of the fruit (Kitagawa and Glucina, 1984). In South Africa, *Alternaria alternata* is the most common and important pathogen (Bill, 2012) and can affect fruit in the orchard, especially where sunburn occurred or growth cracks or mechanical damage affected the fruit and incidence may increase during shelf-life. The ECE requires that persimmons in high classes ("Extra" class, class i and class ii) must have solid perfectly sound flesh, free from damage caused by pest and diseases, be of the shape characteristic of the variety, with the calyx and free from damage to the peel where the fruit attaches to the branch. However, slight defects in shape, development, lack of turgidity and peel defects are tolerated for class i and ii (UNECE, 2012).

Soluble solids - Soluble solids of 21-23 % in 'Hachiya' and 18-20 % in 'Fuyu' and similar non-astringent cultivars are recommended (Crisosto, 2008). Mowat and Chee (2011) stated that the New Zealand persimmon industry grade standards require export fruit at harvest to have a soluble solids average of 14 % and a minimum of 12 %. In South Africa, PPECB requires a minimum of 14 ^{o}Brix for export 'Triumph' persimmon.

Sweetness - Fruit should be free from astringency (Crisosto, 2008). Mowat and Chee (2011) stated that the absence of residual astringency is one of the other preferred standards. One of the minimum requirements for the ECE is for the fruit to be free of any foreign taste (UNECE, 2012). Toplu et al. (1997) noted that consumers enjoy the fruit because of its flavour and aroma.

3. PRE-HARVEST FACTORS THAT AFFECT FRESH PRODUCE QUALITY

Fresh produce quality is influenced by environmental factors that include chiefly harvest maturity and cultivar or variety, but also the climate and soil in which it was grown, chemicals applied to the crop and its water status (Thompson, 2003). Thompson (2003) reported that many of these factors may interact with time such as when fertiliser or irrigation was applied or the weather condition near to the time of harvesting. Kader (2002) pointed out that if poor management decisions are made during crop production, the production environment would be less conducive and the quality of the product which reaches the consumer may be unsatisfactory.

3.1 HARVEST MATURITY

The stage at which the fruit is harvested is the most important post-harvest quality determinant factor (Wills et al., 1989). Harvest maturity is the point at which the fruit has reached a minimum level of development such that it withstand transportation and ripening, yet will still ripen normally to produce a fruit of good eating quality (Burdon, 1997). Harvest maturity of a fruit depends on its required post-harvest life (Burdon, 1997). Since quality of some fruits cannot be improved after harvest but only maintained (Bachmann and Earless, 2000), it is important to harvest fruit at the proper stages and size (Wills et al., 1989). Immature fruit might not ripen and shrivel during storage but fruit harvested in this stage will be hard and are excellent for handling and storage (Kader, 2002). Overmature produce may not last long in storage (Bachmann and Earless, 2000).

In fresh produce, there is horticultural maturity and commercial maturity based on price, season, distance,and storage as well as maturity for consumption (Ferguson et al., 1999). All fruits with the few exceptions like avocados, bananas and pears reach their best eating quality stages when fully ripened on the tree (Kader, 1977). Ripe fruit cannot survive the post-harvest handling system, hence fruit are usually picked mature but not ripe (Kader, 2002). It is recommended to pick the fruit partially ripe instead of at early mature stage so as to provide the consumer with better flavour and nutrional quality (Kader, 2002). Ahmed et al. (2001) found significant evidence that the more mature 'Robusta' bananas had much better organoleptic properties. In contrast to this general trend, late harvested 'Braeburn' apples were more susceptable to flesh and core browning (Rabus and Streif, 2000).

Maturity whether viewed as physiological maturity or harvestable maturity, can have a pronounced influence on the appearance of fruits and vegetables (Kays, 1998). When harvested at an immature stage, the normal complement of pigments is not synthesised and the product appearance is substandard (Kays, 1998).

Harvest maturity plays a central role in flavour development particularly of climacteric fruits where ripening is regulated by ethylene (Mattheis and Fellman, 1999). Production of volatile compounds that contribute to aroma and flavour change dramatically as ripening progresses. Fruit harvested at an immature stage produce many of these compounds at rates too low to achieve characteristic flavour (Mattheis and Fellman, 1999). Early harvest is advantageous commercially to maintain texture during storage, handling and transport but comes at the expense of flavour development during storage (Mattheis and Fellman, 1999). Early harvest of apples and tomato fruit resulted in a time lag until ripening related volatile production begins, and the amount of volatiles produced does not approach that of fruit harvested at a more mature stage (Baldwin et al., 1999; Brown et al., 1968). Mattheis and Fellman (1999) reported that tomato fruit picked at a relatively immature stage and allowed to ripen are less sweet, more sour, less tomato like and have more off-flavour compared to vine ripened fruit.

Palatability and taste of fruits and vegetables are closely associated with the amount and type of chemical constituents and the physical nature of the commodity at the time of harvest (Pantastico, 1975). During development, the individual units of a product exhibits a progressive increase in size, hence size is sometimes considerd a critical harvesting index (Kays, 1998). Wills et al. (1989) defined a ripe fruit as a fruit that has developed the maxmum desired eating quality. A criteria for judging maturity have been used or suggested and include peel or flesh colour, flesh firmness, electrical or light transmittance characteristics, chemical composition, size and shape, respiratory behaviour or time to ripen, time from flowering or planting and heat units (Wills et al., 1989).

In 'Rojo Brillante' persimmon, harvest time had an influence on chilling injury. Chilling injury sympoms (decrease in firmness, internal browning, darkening of the peel and an increase of ethylene and carbon dioxide production) were found in fruit stored at 1 ^{o}C only when the fruit were harvested at early maturity stages (Salvador et al., 2005). Testoni (2002) pointed out that, in Italy persimmon fruit picked at the correct ripening stage stored for 60 days without loss of quality or decay and peel browning disorder were found on fruit harvested when fruit have not reached the turning stage of colour.

3.2 TEMPERATURE

The temperature at which a fruit develops can affect its quality and post-harvest life (Thompson, 2003). Sweetness (sugar concentration) determines the quality of many fruits and generally, low temperature helps in the accumulation of sugars while high temperature causes its degradation hence lower temperature adds to the sweetness of the fruit. The process of conversion of sugar to starch and also its final degradation to carbon dioxide and water are affected adversely by low temperature (Kays and Paull, 2004; Singh, 1997). Under high temperature, increased rate of sugar breakdown lowers its concentration in the fruit (Singh, 1997*)*. Temperature at the time of harvest of horticultural products, thus greatly influence the quality through adjustment of sweetness (Singh, 1997*)*.

Pre-harvest temperatures significantly influence post-harvest susceptibility to low temperature injury and response to conditioning treatments (Wills et al., 2007). Cameron and Lange (1997) reported that some whole fruit and green plant tissues have been shown to withstand lower post-harvest temperatures when conditioned by pre-harvest exposure to temperatures that are low but above those which induce injury. Smith and Glennie (1987) in Thompson (2003) reported that in pineapple grown in places where night time temperatures fall below 21 ℃, internal browning of the fruit was detected after cold storage.

During the maturation period, temperature is the most important factor for obtaining good fruit quality for the persimmon fruit (Kitagawa and Glucina, 1984). An average annual temperature of 14.5 ℃ was proposed for commercial production of 'Fuyu' (Itoo, 1986). 'Fuyu' persimmons grown in warmer areas had better colour and sweetness (Kitagawa and Glucina, 1984), but production of dark tannin spots in the flesh was considered a draw-back (Itoo, 1986). Jackson and Morley-Bunker (1999) reported that persimmon colour development in the temperate zone is often better in cooler areas. Pigmentation was found to be influenced by temperature in a manner quite distinct from the ripening changes indicating that colour changes may not be proportional to fruit ripening (Singh, 1997). Itoo (1980) in Kitagawa and Glucina (1984) reported that autumn frost can also cause peel blemishes on the persimmon fruit and if early defoliation occurs due to autumn frost, the sugar content of the fruit begins to rapidly decrease. However, non-astringent cultivars require higher temperatures to mature than do astringent types hence cultivation of non-astringent cultivars in the southern regions in Japan (Kitagawa and Glucina, 1984). It is therefore important to know the optimum temperature of the fruit at maturity, harvest and post storage.

3.3 LIGHT

The duration, irradiation level and quality of light affect fruit quality. Fruit on the parts of the tree that are constantly exposed to the sun may be of different quality and have different post-harvest characteristics than those on the shady side of the tree or those shaded by the leaves (Woolf et al., 2000). In tomatoes, leaf shading of fruit produced a deeper red colour during the ripening period than in the case of those exposed to the field light (Demsen, 1948). The effect of light on fruit quality has been well documented in citrus by Sites and Reitz (1949, 1950). They found that fruit that were exposed to the sun were lighter in weight, with thinner rind, higher in solids, and lower in acids and fruit juice than those that were shaded or those that were inside the canopy. Pantastico

(1975) indicated that these relationships are true for mangoes and other fruit trees in which leaf overlapping cannot be avoided. In avocado ripening at 20 °C, fruit that have been exposed to the sun showed a delay of 2-5 days in their ethylene peak compared to shaded fruit (Woolf et al., 2000). The side of the fruit that have been exposed to the sun was generally firmer than the non-exposed side, and the average firmness was higher than that of the shaded fruit. Singh (1997) noted that very high irradiance destroys chlorophyll, increases transpiration rate, retards cell division and cell enlargement and may also cause sunburn and fading of colour of flowers and fruit.

Generally, most fruit develop better colour when exposed to sunlight (Jackson, 1999) and the ultraviolet component of light is especially significant in inducing colour formation (Singh, 1997; Jackson., 1999). Fruit grown at higher altitudes or in desert climates are often more colourful and heavily shaded fruit tend to remain green and have a minimum development of other colours (Jackson, 1999). However, cherries, strawberries and many grapes were mentioned as exceptional examples to this general rule since they develop colour almost as well when shaded (Jackson, 1999). Kader (2002) mentioned irradiance level as one of the pre-harvest factors that have a strong influence on the nutritional quality of fruits where the lower the irradiance, the lower the ascorbic acid content of the plant tissues.

Persimmon fruit quality was found to be influenced by light. Isoda (1979) found that exposure of immature persimmon fruit to ultraviolet radiation cause black spots to develop on the fruit surface. Irradiance level of 25-30 % of full sun within the canopy was reported adequate for inducing the red peel colour of mature ‘Fuyu’ fruit (Chujo, 1971). Collins and George (1997) reported that the incidence of sunburn in persimmons increases under high radiation levels (25 $MJ/m^2/day$) and severe sunburn remains visible when the fruit is fully coloured, and the sunburned area softens more quickly when stored. Micro cracking that result from sunburn serve as entry point for *Alternaria* that remains latent during fruit development and the infection only becomes evident during storage and shelf life (Bill, 2012).

3.4 RAINFALL AND WATER AVAILABILITY

Rainfall affects the water supply to the plant and this may influence the composition of the harvested plant part and its susceptibility to mechanical damage during subsequent harvesting and handling operations. Under non-irrigated conditions where water is in short supply, trees often produce small fruit of excellent keeping quality. However, under such conditions, a year with more than average rainfall may result in large fruit with poor colour and storage potential (Burden and Thompson, 1995). Bitter pit in apple is often found in large fruit on light crop trees and is thought to be induced when the fruit is unable to compete with the foliage for water and calcium (Burden and Thompson, 1995). In apples, drought spot is a special disorder related to boron deficiency that is most likely to appear when irrigation has been less than optimal (Burden and Thompson, 1995).

Generally crops that have higher moisture content have a lower storage potential (Burden and Thompson, 1995). Singh (1997) reported that excessive water supply induces the development of large sized cells. The first effect of the increased supply of water leads to undue stretching of cells. With large supply, growth cracks occur due to the breaking of cell walls occasioned by high pressure (Singh, 1997). The cracks are also seen under conditions of high absorption of water combined with low transpiration (Singh, 1997). Burden and Thompson (1995) reported that if bananas are allowed to mature fully before harvest and harvesting occurs shortly after rainfall or irrigation, the fruit can easily split during handling operations, allowing micro-organisms infection and post-harvest rotting. If oranges are too turgid at harvest, the oil glands in the skin can be ruptured, releasing phenolic compounds and causing oleocellosis (Burden and Thompson, 1995). In a study of water stress applied at 45 and 30 days before harvesting on 'Haden' mangoes (Burden and Thompson, 1995), it was found that 45 days stress applied before harvest exhibited fruit with a higher incidence and severity of internal darkening, firmer, with higher TA and a redder peel than 30 days prior to harvest drought stressed fruit.

Petal adherence marks, a persimmon disorder, was found to be accentuated if the trees and fruits are under water stress (Itoo, 1986). In Japan, the incidence of cuticular cracking in persimmon fruit increased with irrigation and other factors stimulating excessive persimmon fruit growth during growth stage three (Kitagawa and Glucina, 1984).

3.5 WIND

Wind damage can be separated into two general categories based upon the severity and frequency, viz. damage caused by relatively infrequent severe storms (typhoon/hurricane), and that caused by much more frequent winds of intermediate strength (Kays, 1998). High intensity winds result in leaf defoliation, which in fruit crops routinely leads to small fruit, poor fruit colour, and increased surface blemishes such as friction marks on kiwi fruits, wind scab in European plum and wind rub of persimmons (Kays, 1998). Singh (1997) reported that severe storms in the early spring knocked off many leaves and fruit from mango trees whereas heat or dryness accompanied by winds caused high water loss.

Persimmons are very sensitive to wind (Kitagawa and Glucina, 1984). Blemishes were reported to be the major quality defects of persimmon both in Australia and New Zealand, of which, wind rub caused the greatest reduction in marketable fruits (Collins and George, 1997). Wind rub causes dark blemishes or lesions on the peel and this downgrades the fruit for export (Kitagawa and Glucina, 1984). The severity of wind-rub marks increases with wind run over the fruit developmental period (George and Nissen, 1992). Persimmon plants not adequately sheltered can be prematurely defoliated by strong winds in the late summer and autumn and this leads to poor fruit quality (with lower sugar levels) and may affect fruit production in the following season (Kitagawa and Glucina, 1984). Choi et al. (2003) reported that fruit colour of defoliated persimmon trees were slightly worse than that of intact trees and tended to improve as fruit thinning percentages increase. Hirata and Karooka (1974) in Choi et al. (2003) reported that 50 and 100% defoliation inhibited colour development of persimmon fruits. Choi et al. (2003) reported that 100% tree defoliation caused fruit to soften faster as judged by loss of firmness. Contrary to that, Kays and Paull (2004) pointed out that mechanical stress caused by wind increases the extent to which collenchyma cell walls thicken.

3.6 FERTILISATION/NUTRITION

Orchard nutrition can profoundly affect storage quality. The amount of fertiliser that produces the best tree growth and highest yields may not give the best storing fruit (Looney and Jackson, 1999). As a general rule, high nitrogen (N) application depresses fruit quality. Looney and Jackson (1999) reported that excessive application of N will delay the disappearance of chlorophyll from the peel, stimulate shoot growth and thus increase fruit shading and may even directly suppress red colour development.

The soil type and its fertility affect the chemical composition of a crop. Excess or deficiencies of certain elements from the crop affect its quality and its post-harvest life. Many storage disorders of apples are associated with an imbalance of chemicals within the fruit at harvest (Thompson, 2003). The physiological disorder of stored apples called bitter pit is principally associated with calcium (Ca) deficiency during the period of fruit growth and may be detectable at harvest or sometimes only after protracted periods of storage (Atkinson et al., 1980; De Freitas et al., 2010). In some cases, the mineral content of fruit can be used to predict storage quality (Thompson, 2003). Link (1980) showed that high N application rates to apple trees could adversely affect the flavour of the fruit. In tomato fruit, dry matter and soluble solids content increased as potassium (K) rate increased, but there was no significant difference in TA at different K rates (Chiesa et al., 1998). Hofman and Smith (1993) found that application of K to citrus affected the shape of the fruit and increased their acidity. Lacroix and Carmentran (2001) reported that K generally increased acidity in strawberries, but the effect varied between cultivars. 'Niitaka' pear fruit from trees that were supplied with liquid Ca fertiliser were firmer after storage than fruit from untreated trees, fruit weight loss was also reduced following liquid Ca fertiliser treatment, but there was no effect on soluble solids content (Moon et al., 2000). High Ca levels reduced the acidity of strawberries and played a part in loss of visual fruit quality after harvest (Lacroix and Carmentran, 2001).

Persimmons do not have a high fertiliser requirement, but relatively high amounts of K and rather low amounts of phosphorus (P) are required (Itoo, 1986). A large amount of K is transferred into the fruit during its growth and if K supplies are low, fruit growth is reduced whilst on the other hand, excessively high K content leads to rough skin and poor fruit quality (Itoo, 1986).

3.7 PEST/DISEASES

Almost all post-harvest pests originate from field infestations, and if the storage conditions are conducive they can multiply on or in the crop (Thompson et al., 1973). Field infestations of yam tubers with parasitic nematodes were shown to increase when the tubers were stored in the tropical ambient conditions resulting in areas of necrotic tissues, but when stored at 13 °C there was no increase in nematode population in tubers and hence no increase in necrosis (Thompson et al., 1973). Mealy bugs on pineapples occur in the marketing chain from field infestation (Thompson et al*.,* 1973). Physical damage to an apple or pear caused by codling moth for example, can cause ethylene to be produced, which initiates ripening (Jackson, 1999). Jackson (1999) reported that damage of leaves will sometimes increase light penetration or reduce assimilates flow to the fruit.

In Australia, spotting of persimmons fruit were found to be caused by numerous causes ranging from pathogens such as *Anthracnose* and *Botrytis* to insect damage such as fruit fly, fruit piercing moth or green vegetable bug (Collins and George, 1997). Mealy-bug damage below the calyx leaves goes unobserved, but results in premature ripening of damaged fruit during ripening and storage (Bill, 2012). Prusky et al. (2010) noted that *Alternaria alternata* was initially described as the most economically important post-harvest disease of 'Triumph' persimmon fruit in all growing regions of Israel. The fungus infects the fruit in the orchard and remains quiescent until harvest, and the pathogen slowly colonizes the fruit during storage at 0 °C to elicit black spot symptoms after 2-3 months in storage. A good spray programme was found to reduce the carry-over of diseases into storage and a reduction in physical damage and bruising was found to reduce disease agents entering the fruit (Thompson, 2003).

3.8 GROWTH REGULATORS

While use of growth hormones is positive, it can have negative effects. Ethephon alters apple form (Bae et al*.,* 1995 in Kays, 1998) and orange fruit pigmentation (Kays, 1998). Gibberellic acid (GA_3) has been shown to alter grapefruit colour (McDonald et al., 1997), to decrease the fruit size of pear (Kays 1998), and increase apricot fruit weight (Southwick and Fritts, 1994). Khader (1990) reported that gibberellic acid reduced mango eating and nutritional quality. In nectarines, gibberellic acid improved firmness but affected soluble solids concentration (SSC) content (Zilkah et al., 1997).

Pre-harvest application of Aminoethoxy-vinylglycine (AVG) helped delay harvest time and improved quality of peaches (Kim et al., 2004). A concentration of 75 ppm GA_3 sprayed on strawberry produced fruits that were more or less cylindrical in form (Misra and Sharma, 1970).

Watermelons sprayed with cycocel (CCC) yielded the sweetest fruits, with an increase in TSS (Choudhury and Elkholy, 1970). Pre-harvest Ethrel application in tomatoes increased resistance to cracking and decay aside from the usual early ripening effect (Russo et al., 1970).

On persimmons, spraying gibberellic acid on branches 10 days before the arranged harvest date delayed fruit growth, chlorophyll degradation and carotenoids development, the effects of which were delayed harvest, better firmness, good storability and better quality after storage (Ben-Arie et al., 1997). Paclobutrazol (PBZ) applied to the roots, advanced fruit ripening by 2-3 weeks without any detrimental effects on fruit size but the post-harvest rate of deterioration was accelerated (Ben-Arie et al., 1997; Bill, 2012). The rate of ethylene evolution and fruit softening of 'Triumph' persimmon was reduced by treatment of fruit with 1-methylcycloprene (1-MCP) in an 80 % carbon dioxide atmosphere (Ben-Arie et al., 1997).

3.9 CHEMICAL SPRAY

The control of infection in the field can have considerable effect on post-harvest life of the crop (Thompson, 2003). Chemicals can sometimes be applied to certain crops as treatments to prevent development of certain disorders, which may or may not manifest post-harvest, whereas some are applied as growth regulating chemicals. Spraying of lead arsenate post bloom on grapefruit produced a 30 to 40 % reduction in acidity of grapefruit but increased non-reducing sugars and total flavonoid content of its juice (Deszyck and Ting, 1960). Decrease in acidity was also reported from calcium arsenate application on Valencia oranges (Thompson et al., 1973). The biochemical basis for arsenate action could be as a phosphate competitor leading to phosphorylation uncoupling and interference in citric acid accumulation (Vines and Oberbacher, 1965).

Petroleum oil sprays are extensively used to control citrus pests (Thompson, 2003). Trammel and Simanton (1966) found that they have detrimental effects on fruit quality; soluble solids decreased and acidity increased. The other pesticide that was found to affect citrus fruit quality is parathion. Fruit sprayed with parathion de-greened earlier and had a deeper orange colour and more total soluble solids than the unsprayed control (Harding, 1953).

4. CONCLUSION

It is evident that a diverse range of pre-harvest factors affect quality of fruit. Any factor, whether climatic or non-climatic should be at its optimum level to give high yield of good quality. It is therefore important to identify these optimum levels so as to manage the orchards in a manner that ensure good fruit quality.

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PAPER 1

'TRIUMPH' PERSIMMON STORAGE POTENTIAL INFLUENCED BY TIME OF MATURITY DUE TO REGION OR PACLOBUTRAZOL TREATMENT AND HARVEST MATURITY

ABSTRACT

The aim of this study was to determine whether 'Triumph' persimmon in the Western Cape, South Africa that ripen at different times of the season due to region or paclobutrazol (PBZ) treatment (maturity time) have a similar storage potential or should be harvested at different colour groups (maturity stages) in order to improve storage and shelf-life. Fruit were harvested from PBZ (Cultar®) treated orchards in an early region, non-treated orchards in an early region and orchards in a late region. The fruit were harvested at four maturity stages determined by fruit colour according to Plant Protection and Inspection Services (PPIS) persimmon colour chart as, colour group 1 = PPIS colour chart value 1-2, colour group 2 = PPIS colour chart value 3-4, colour group 3 = PPIS colour chart values 5-6 and colour group 4 = PPIS colour chart values 7-8. One third of the fruit were evaluated at harvest and the remainder was stored for 6 weeks and 3 days at -0.5 ^{o}C after de-astringification with 90% carbon dioxide and treatment with 500 ppb 1-methylcylopropene (SmartFresh^{TM}). After storage, half of the stored fruit was evaluated and the other half was evaluated after 4 days of ripening at 20 ^{o}C. When the fruit were harvested at colour groups 2 and 3, total soluble solids (TSS), soft fruit percentage, flesh firmness and calyx green percentage showed that, fruit from the late region had the highest quality followed by PBZ-treated fruit and the early region non-treated fruit had the lowest quality after storage and shelf-life. In spite of the maturity time, fruit harvested at colour group 1 had significantly high percentage of soft fruit throughout post-harvest period and the fruit harvested at colour group 2 had high soft fruit percentage after shelf-life. Fruit harvested at colour group 3 had lower soft fruit percentage and firm fruits. Fruit harvested at colour group 4 remained firm but failed to develop the characteristic fruit colour for ripe fruit. Fruit colour at harvest showed a strong correlation with flesh firmness throughout post-harvest, but it did not show strong correlations with other quality parameters. Although fruit harvested at colour groups 2 and 3 showed that fruit from the late region store better than fruit from the early region, harvesting the South African 'Triumph' persimmon at colour group 3 has the potential to improve fruit storability regardless of when the fruit matures.

Keywords: *Diospyros kaki,* harvesting colour, ripening potential, flesh firmness, soft fruit, fruit damage.

INTRODUCTION

Triumph is an astringent persimmon (*Diospyros kaki*) cultivar grown in South Africa as a counter season supply to the European market. Prolonged storage due to transit to this distant market results in variable quality after storage, such as softening and peel browning affecting acceptability of persimmon fruit by consumers (Neuwald et al., 2009). To counteract these effects, South African 'Triumph' persimmon fruit is harvested at early stages of maturity (Bill, 2012) with ripening occurring in storage (Ben-Arie and Zutkhi, 1992). Minimum maturity of persimmon is determined by peel colour changes (Crisosto et al., 2013). During storage, the colour of the fruit intensifies, flesh firmness decreases slightly (Kitagawa and Glucina, 1984), ethylene production increases and development of gel like consistency may occur in the flesh (Arnal and Del Rio, 2004).

In climacteric fruit, the stage at which a fruit is harvested is the most important post-harvest quality determinant factor (Wills et al., 1989; Ramin and Tabatabaie, 2003). Generally, fruit harvested at early maturity stages are usually excellent for handling and storage but may fail to ripen and may shrivel during storage, whereas fruit harvested at late stages of maturity may not last long in storage even though they are associated with good eating quality (Kader, 2002; Mattheis and Fellman, 1999). 'Rojo Brilliante' persimmon harvested at early maturity had lower firmness, internal browning, dark peel colour and increased ethylene and carbon dioxide production after storage and ripening (Salvador et al., 2005).

Although it is fairly difficult to obtain uniform persimmon fruit after storage (Kitagawa and Glucina, 1984), persimmons harvested at the correct stage of maturity can be stored for longer periods of time without loss of quality (Testoni, 2002). 'Fuyu' persimmon can be stored for 2 months in air at 0 to 2 ^{o}C and 90% relative humidity, while 'Triumph' persimmon can be stored for 4 months in modified atmosphere packaging (low density polyethylene bags at -1 ^{o}C) (Prusky et al., 1997). In South Africa, 'Triumph' persimmons are harvested according to the Plant Protection and Inspection Services (PPIS) colour chart (PPIS, Bet-Dagan, Israel) at values 4 to 5 (Fig. 1); however, post-harvest quality variation is common (Bill, 2012).

Although persimmon fruit colour could be a good index to determine the optimum stage for harvesting since colour changes in the peel of persimmon are closely related to an increase in sugar and decrease in fruit firmness, persimmon fruit colour can vary according to production area (Kitagawa and Glucina, 1984; Bill, 2012). 'Fuyu' persimmons from northern districts (lower average temperature) of Japan have good colouration whereas those from southern districts (higher average temperature) have fairly pale colour (Kitagawa and Glucina, 1984). As a result, 'Fuyu' persimmons are harvested at different stages of maturity in these areas. 'Fuyu' in New Zealand is generally harvested when the colour of the cheek of the fruit is at stage 6 and at the apex at stage 7.5, but in Auckland and the Bay of Plenty areas, the fruit are harvested when the cheek and apex colour of mature fruit corresponds to stage 5 and 6, respectively on the Japanese persimmon colour chart (Kitagawa and Glucina, 1984).

In Western Cape, South Africa, 'Triumph' persimmon matures at three different times. Two of the maturity times are related to meso-climatic regions (early region and late region) where persimmons are typically grown. 'Triumph' matures from mid-April to mid-May in the early region and from mid-May to early June in the late region. A third maturity time emanates from the crop of the early region that is treated with paclobutrazol (PBZ) (Cultar®: 250g·L^{-1} active paclobutrazol (triazole); Syngenta SA (Pty) Ltd. Halfway House, South Africa) to advance maturity, hence maturing even earlier (mid to end-April) than the untreated crop (Bill, 2012). At all three harvesting times, the fruit are of the same stage of maturity (colour chart value 4-5). Fruit that mature at different times are likely to differ in quality and storage potential if they are harvested using fruit colour as maturity index because fruit colour is influenced by the temperature and therefore the production area and hence do not always correlate with fruit maturity (Kays and Paull, 2004).

Research found that, apart from its effect on the development of pre-harvest persimmon fruit colour, production area also influences potential quality and post-harvest life of the fruit (Kitagawa and Glucina, 1984; Bill, 2012). 'Fuyu' persimmon grown in very warm regions of Japan tended to be tasteless whereas warm temperature and high sunshine hours were required to produce fruit that were completely free of astringency. Warm temperatures in late summer and early autumn, two months before harvesting, were found to be important for fruit maturation (Kitagawa and Glucina, 1984). Both fruit quality and post-harvest life are likely to differ with production region.

The South African persimmon industry has been faced with problems associated with variation in fruit quality since the beginning of persimmon exports more than a decade ago (Bill, 2012). This study was carried out to investigate if storage and shelf-life potential of 'Triumph' persimmon fruit differs for different maturing times during the season in the Western Cape, South Africa. Whether storage potential can be improved by harvesting these different maturity times at different colour groups (stages of maturity) was also tested. To assess if 'Triumph' persimmon fruit colour at harvest could be a good maturity indexing tool, this study also correlated the fruit peel colour at harvest to other quality attributes at harvest, after storage and after shelf-life. It is assumed that additional maturity indexing tools and or a combination of tools may be more accurate determinant of harvest maturity.

MATERIALS AND METHODS

Plant material

'Triumph' persimmon fruit were harvested from the early production region (Simondium - 33°3'S, 19°9'E) and the late production region (Grabouw - 34°59'S, 18°00'E) in the Western Cape province of South Africa. In the early region, fruit were harvested from 4 orchards that were treated with PBZ

(Cultar®: 250 g·L^{-1} active paclobutrazol (triazole); Syngenta SA (Pty) Ltd. Halfway House, South Africa) and 4 non-treated orchards, and in the late region, fruit were harvested from 4 orchards (Table 1). For the early orchards that were treated, 3 mL Cultar® (250 g·L^{-1} active paclobutrazol) was diluted in 1.5 L of water and was applied to the soil in the dripping area of each canopy along the dripper line in mid-December 2011. Maturity time (PBZ, early and late) was determined according to commercial standard, when 30 % of the fruit in the orchard had attained acceptable colour. PBZ treated orchards were harvested during week 15 of 2012 (19-24 April), early orchards were harvested during week 17 of 2012 (01-07 May) and late orchards were harvested during week 19 of 2012 (17-23 May) (Table 1). In each orchard, fruit were harvested at 4 maturity stages (colour groups) determined by fruit colour according to the PPIS persimmon colour chart (PPIS, Bet-Dagan, Israel) as follows: Colour group 1 = PPIS colour chart value 1-2, colour group 2 = PPIS colour chart value 3-4, colour group 3 = PPIS colour chart values 5-6 and colour group 4 = PPIS colour chart values 7-8 (Fig.1) with 1 = red/ orange and 8 = green. Four replicates of 30 fruit each were collected for each colour group per orchard (4 replicates x 30 fruit x 4 colour groups x 3 maturity times x 4 orchards). Ten fruit per replicate were evaluated at harvest whilst the remainder was de-astringefied with 90% carbon dioxide for 24 h in a hermetically sealed metal box whilst being treated with 500 ppb 1-methylcyloprene (1-MCP) (Smartfresh™, Agro Fresh, Pennsylvania, USA) and stored for 6 weeks and 3 days at -0.5 °C. After storage, 10 fruit per replicate were evaluated and the last 10 fruit per replicate were evaluated after ripening for 4 days at 20 °C simulating shelf-life.

Physicochemical measurements

Fruit size, fruit colour, flesh firmness, total soluble solids (TSS), titratable acid (TA), damaged fruit percentage, the percentage of soft fruit, calyx colour and the percentage of green calyx were measured. Fruit size was determined by measuring fruit diameter at the widest point of the equatorial region using an electronic caliper (Guss Manufacturing (Pty) Ltd, Strand, South Africa) as well as by measuring fruit weight on an electronic balance (Güss Manufacturing (Pty) Ltd, Strand, South Africa). Fruit colour was determined by PPIS persimmon colour chart (PPIS, Bet-Dagan, Israel) with colour values 1 to 8 where 1 is the most orange/ red and 8 the green stage. A chromameter (Chromameter CR-400, Minolta Co., Ltd, Osaka, Japan) was also used to determine fruit colour as hue angle by directing the scan on the peel of the fruit on the two equatorial regions (most coloured and least coloured sides) and at the stylar end of the fruit. To determine flesh firmness, three positions on the fruit were measured; two equatorial positions opposite to each other and the stylar end of the fruit using a Güss fruit texture analyser (11.1 mm plunger) (Güss Manufacturing (Pty) Ltd, Strand, South Africa). The average of measurements taken on each fruit was calculated. Sinclair internal quality firmness tester (SIQFT) machine (Sinclair International Ltd, Norwich, England) was used as a non-destructive firmness measuring tool on the same three positions described for the Güss fruit texture analyser determining internal quality (IQ) firmness.

The average (IQ) firmness was calculated for each fruit. The soft fruit percentage was determined by slightly pressing the equatorial region of the fruit between the fingers. The number of soft fruit per replicate was expressed as a percentage of the total. Slices were obtained from equatorial regions of the fruit, pooled per replicate and juiced. A drop of juice from each replicate was placed on the prism plate of a temperature controlled digital refractometer (PR 32, Atago Co, Ltd. Tokyo, Japan) measuring TSS in ^{o}Brix. The remaining juice per replicate was used for TA analysis. TA was determined using the automatic titrator (719 S Titrino with automatic sample changer model - 760, Metrohm South Africa (Pty) Ltd, Gallo Manor, South Africa), which determines malic acid equivalents (%) titrating 10 g aliquot of the juice with 0.1 M NaOH to a pH of 8.2. Blemishes and marks were visually assessed based on their presence or absence. The number of blemished fruit per replicate was expressed as the percentage damaged fruit of the total. Calyx green percentage was visually assessed estimating the percentage of green colour on the calyx. Calyx colour was assessed by measuring the hue angle using a chromameter (Chromameter CR-400, Minolta Co, Ltd, Osaka, Japan).

Statistical procedures

Data were analysed with the General Linear Models (GLM) and correlation (CORR) procedures in the Statistical Analysis System (SAS) computer programme (SAS Enterprise Guide 4.0; SAS Institute, 2006, Cary, NC 27513, USA). Means were separated by least squares difference (LSD) at 5% level of significance. Normality of data was tested in the Statistical Analysis System (SAS) computer program (SAS Enterprise Guide 4.0; SAS Institute, 2006, Cary, NC 27513, USA). A two factor factorial experimental design with time of maturity (PBZ treated, early and late) and stage of maturity (colour group) at harvest as factors was analyzed using GLM procedure. The Pearson correlation procedure was used to correlate fruit colour at harvest with persimmon quality parameters (flesh firmness, (IQ) firmness, soft fruit percentage, TSS, TA, fruit colour, fruit diameter, fruit mass, green calyx percentage and damaged fruit percentage) at harvest, after cold storage and after shelf-life.

RESULTS

Time of maturity and stage of maturity (colour group) at harvest

At harvest

The interaction of time of maturity and stage of maturity at harvest was not significant for fruit flesh firmness, soft fruit percentage, IQ firmness and percentage of green calyx (Table 2). Firmness measured by penetrometer and Sinclair IQ firmness showed contrasting results with early fruit presenting significantly higher values than PBZ treated and late fruit when measured with the SIQFT, compared to higher flesh firmness for PBZ treated and late fruit compared to early fruit when measured with the penetrometer. Late fruit had significantly lower soft fruit percentage compared to PBZ treated and early fruit although the incidence of soft fruit was very low (3%). However, the soft fruit percentage for early fruit was not significantly different from PBZ treated fruit. Late fruit had significantly lower percentage of green calyx compared to early and PBZ treated fruit. The calyx green percentage for early and PBZ treated fruit was not significantly different. Firmness, IQ firmness and percentage of green calyx decreased significantly with an increase in maturity from colour group 4 to colour group 1. Soft fruit percentage of fruit harvested at colour group 1 was significantly higher than that of fruit harvested at less mature stages (colour groups 2 - 4).

Fruit harvested at all the three maturity times (PBZ treated, early and late) at colour group 1 and colour group 4 showed no significant difference in fruit colour (Table 3). PBZ treated and early fruit harvested at colour group 2 showed no significant difference in fruit colour, however, the PBZ teated fruit were significantly more orange than the late fruit. Early and late fruit harvested at colour group 3 were not significantly different in fruit colour but the colour of both was significantly less orange compared to the PBZ treated fruit. Generally, fruit gradually increased in orange colour from colour group 4 to colour group 1 for all maturity times.

TSS for late fruit harvested at colour group 1 was not significantly different from that of early fruit; however, early fruit had significantly higher TSS than PBZ treated fruit (Table 3). Early fruit harvested at colour group 2 had significantly higher TSS compared to PBZ treated fruit and early fruit harvested at colour groups 2 and 3 had significantly higher TSS compared to late fruit. TSS for PBZ treated and late fruit harvested at colour groups 2 and 3 were not significantly different. PBZ treated fruit harvested at colour group 4 had significantly higher TSS compared to late fruit; however, TSS for early and late fruit as well as PBZ treated and early fruit harvested at this colour group were not significantly different. Generally, TSS increased with increase in fruit maturity (from colour group 4 to colour group 1).

TA values were significantly lower for PBZ treated fruit at all maturity stages compared to late fruit (Table 4). With the exception of fruit harvested at colour group 4, PBZ treated fruit also had significantly lower TA values than early fruit. TA values for early fruit were significantly lower than that of late fruit for fruit harvested at colour groups 1 and 4; however, there was no significant difference between early fruit and late fruit for fruit harvested at colour groups 2 and 3. Generally, TA decreased with maturity from colour group 4 to colour group 1.

Damaged fruit percentage for PBZ treated and early fruit was significantly higher than that of late fruit when the fruit was harvested at colour groups 1 and 2 (Table 4). When harvested at colour group 3, there was a significantly higher damaged fruit percentage in PBZ treated fruit compared to late fruit; however, the damaged fruit percentage of both PBZ treated and late fruit was not significantly different from that of early fruit. Damaged fruit percentage for fruit harvested at colour group 4 was significantly higher for PBZ treated compared to early and late fruit. However, there was no significant difference on damaged fruit percentage between PBZ treated and early fruit for fruit harvested at colour groups 1, 2 and 3. Early and late fruit have shown a general increase of damaged fruit percentage with increase in fruit maturity, however, PBZ treated fruit had a higher damaged fruit percentage for fruit harvested less mature at colour group 4 compared to colour group 3.

After cold storage

There was a significant interaction of time of maturity and stage of maturity at harvest on fruit colour, TSS (Table 3), damaged fruit percentage, TA (Table 4), flesh firmness, IQ firmness, soft fruit percentage and percent green calyx (Table 5). Fruit colour for fruit harvested at colour groups 1, 2 and 4 did not differ significantly among the different maturity times (Table 3). Fruit colour for fruit harvested at colour group 3 was more developed in early than in PBZ treated and late fruit. However, there was no significant fruit colour difference between PBZ treated fruit and late fruit for fruit harvested at colour group 3. Fruit colour generally increased in orange colour from colour group 4 to colour group 1 for all maturity times.

TSS increased with maturity (as measured by colour change from colour group 4 to colour group 3) for all maturity times (PBZ treated, early, late). The difference in TSS with time of maturity was greatest for the intermediate maturity stages (colour groups 2 and 3) (Table 3). Late and early fruit harvested at colour group 2, had TSS that was not significantly different from PBZ treated fruit, however, late fruit had significantly lower TSS compared to early fruit. Harvested at colour group 3, TSS of late and PBZ treated fruit was not significantly different, but TSS for both was significantly lower compared to early fruit. TSS for fruit harvested at colour groups 1, and 4 did not differ significantly among times of maturity (Table 3).

Early and late fruit did not differ in the percentage damaged fruit at any colour group, but both had significantly lower percentages of damaged fruit at colour groups 1 and 2 compared to PBZ treated fruit (Table 4). The percentage damaged fruit for fruit harvested at colour group 3 was significantly lower for early fruit (8% compared to PBZ treated fruit (18%). No significant difference was found among times of maturity for fruit harvested at colour group 4 (Table 4). Generally, damaged fruit percentage decreased with an increase in maturity from colour group 1 to colour group 4 within all maturity times.

Harvested at colour group 1, TA value of late fruit was not statistically different from that of PBZ treated fruit but both TA values for late and PBZ treated fruit were significantly higher than that of early fruit (Table 4). When harvested at colour group 2, TA value of early fruit was not significantly different from that of both PBZ treated and late fruit but PBZ treated fruit had a significantly higher TA value compared to late fruit (Table 4). TA values for early and late fruit harvested at colour group 3 were not significantly different and both early and late fruit had TA values that were significantly lower than that of PBZ treated fruit (Table 4). Fruit harvested at colour group 4 showed no significant difference in TA values with different times of maturity (Table 4).

Early fruit harvested at colour group 1 had significantly higher IQ value than late fruit but not significantly different from PBZ treated fruit, however, the IQ value for late fruit was not significantly different from PBZ treated fruit (Table 5). When harvested at colour groups 2 and 3, early fruit had higher IQ values than both PBZ treated and late fruit. The IQ values for early and late fruit harvested at colour group 4 did not differ statistically but early fruit had significantly higher IQ firmness than PBZ treated fruit. Generally, Sinclair IQ firmness after cold storage had higher IQ values allocated to higher scales of colour and the firmest fruits were of colour group 4.

Fruit firmness decreased with a decrease in colour group for all maturity times. Fruit firmness for fruit harvested at colour groups 1, 2 and 4 did not differ significantly with time of maturity (Table 5). Late fruit harvested at colour group 3 were significantly firmer than PBZ treated and early fruit whereas no significant firmness difference between PBZ treated and early fruit was recorded.

Late fruit harvested at colour group 1 had significantly higher soft fruit percentage than PBZ treated fruit and early fruit was not significantly different from both PBZ treated and late fruit (Table 5). Soft fruit percentage for early fruit harvested at colour group 2, was not significantly different from both late and PBZ treated fruit; however, soft fruit percentage for late fruit was significantly higher than that of PBZ treated fruit (Table 5). Soft fruit percentage for fruit harvested at colour groups 3 and 4 did not differ significantly with time of maturity and had lower soft fruit percentage than the maximum commercial standard (10 %) (UNECE, 2012). Soft fruit percentage after cold storage had an inverse relation with stage of maturity with higher percentage of soft fruit allocated to lower scales of colour; the highest percentages were of fruit harvested at colour group 1, with values higher than the maximum commercial standard (10 %) (UNECE, 2012) for all the three maturity times (Table 5).

Calyx green percentages of PBZ treated and early fruit harvested at colour group 1 were not significantly different and were significantly higher than that of late fruit (Table 5). PBZ treated and late fruit harvested at colour group 2 did not differ significantly but had a significantly lower percentage of green calyx compared to the early fruit (Table 5). However, on fruit harvested at colour group 3, late fruit had a significantly higher calyx green percentage than both early and PBZ treated fruit but the calyx green percentage for early and late fruit did not differ significantly. Harvested at colour group 4, late fruit had a significantly higher calyx green percentage than both early and PBZ treated fruit and early fruit had a significantly higher calyx green percentage than PBZ treated fruit.

After shelf-life

The interaction of time of maturity and stage of maturity was significant for fruit colour, TSS (Table 3), fruit flesh firmness, IQ firmness, soft fruit percentage and green calyx percentage (Table 5) after shelf-life. However, the interaction was not significant on damaged fruit percentage and TA (Table 6).

Fruit colour after shelf-life presented a similar pattern at all maturity times where the characteristic orange colour decreased in intensity from colour group 1 to colour group 4 (Table 3). There was no significant colour difference between times of maturity.

TSS for PBZ treated and early fruit was not significantly different but TSS for both was significantly higher than late fruit for fruit harvested at colour groups 1 and 3 (Table 3). Fruit harvested at colour group 2 did not show significant difference between times of maturity. PBZ treated fruit harvested at colour group 4 had significantly higher TSS than both early and late fruit but TSS for early and late fruit harvested at this stage did not differ significantly. TSS was generally higher for fruit harvested more mature at colour group 1 decreasing to less mature harvested fruit at colour group 4.

Colour group 1 presented no significant difference of fruit firmness between times of maturity (Table 5). Late and PBZ treated fruit harvested at colour groups 2 and 4 were significantly firmer than early fruit. Late fruit harvested at colour group 3 was firmer than both PBZ treated and early fruit and PBZ treated fruit was significantly firmer than early fruit. Generally, fruit firmness after shelf-life was lowest for the most mature fruit at colour group 1 and highest for less mature fruit in colour group 4 for all times of maturity.

Sinclair IQ firmness for fruit harvested at colour groups 1, 2 and 3 did not differ significantly with times of maturity (Table 5). PBZ treated fruit harvested at colour group 4 had significantly higher IQ firmness compared to late fruit but not significantly different to early fruit (Table 5). Generally, Sinclair IQ firmness was highest for fruit harvested least mature at colour group 4 and decreasing in value with maturity towards colour group 1.

The highest soft fruit percentages after shelf-life were found in early fruit harvested at colour groups 1, 2 and 3, which were significantly higher than PBZ treated and late fruit (Table 5). Soft fruit percentage of PBZ treated fruit did not differ significantly with that of late fruit for the fruit harvested at colour groups 2 and 3 (Table 5). Soft fruit percentage of fruit harvested at colour group 4 did not differ significantly between times of maturity. Generally, soft fruit percentage after shelf-life increased with harvest maturity from colour group 4 to colour group 1 for all times of maturity (Table 5).

Calyx green percentages of PBZ treated and late fruit were significantly higher than that of early fruit whereas calyx green percentages of PBZ treated and late fruit did not differ significantly for fruit harvested at colour groups 1 and 2 (Table 5). However, for fruit harvested at colour groups 3 and 4, late fruit had a significantly higher calyx green percentage than both early and PBZ treated fruit and early and PBZ treated fruit did not differ significantly on their calyx green percentages. There was a general decrease of calyx green percentage from colour group 4 to colour group 1, although this was not significant for PBZ treated and late fruit (Table 5).

TA varied with time of maturity as well as stage of maturity at harvest (Table 6). PBZ treated fruit had the highest TA value followed by late fruit and early fruit had the lowest TA value. Fruit harvested at colour group 1 had the highest TA value whereas TA values for fruit harvested at colour groups 2, 3 and 4 were not significantly different.

Damaged fruit percentage varied with stage of maturity but did not vary with time of maturity (Table 6). Fruit harvested most mature at colour group 1 had the highest number of damaged fruit (58.3 %) whereas damaged fruit percentage of fruit harvested at colour groups 2, 3 and 4 did not differ significantly.

Correlation of fruit colour at harvest with fruit quality

At harvest

There was a strong positive correlation between fruit colour (chart value) and fruit hue angle, flesh firmness as well as IQ firmness with correlation coefficients of 91 %, 72 % and 67 %, respectively (Table 7). TA and green calyx percentage had a low positive correlation with fruit colour at harvest. However, TSS, soft fruit percentage, fruit diameter, fruit mass and damaged fruit percentage had low negative correlation with fruit colour at harvest.

After cold storage

The strong positive correlation of fruit colour (chart value) at harvest and fruit hue angle, flesh firmness as well as IQ firmness observed at harvest was maintained after cold storage with correlation coefficients of 88 %, 82 % and 67 %, respectively (Table 8). Correlation of fruit colour at harvest and TA which was low and positive changed to still low but negative after cold storage. The possible cause of this change is not known. The correlation between fruit colour at harvest and TSS as well as soft fruit percentage remained negative but slightly high with correlation coefficients 55 % and 56 %, respectively. This could be due to increase in TSS and loss of firmness as the fruit ripen. Fruit diameter, fruit mass and damaged fruit percentage had low negative correlation with fruit colour at harvest. Green calyx percentage correlated positively but weakly with fruit colour at harvest.

After shelf-life

The correlation of fruit colour (chart value) at harvest and fruit hue angle, flesh firmness and IQ firmness remained positive and high with correlation coefficient of 86%, 80 % and 70 %, respectively (Table 9). There was a slightly high negative correlation between fruit colour at harvest and TSS as well as fruit colour at harvest and soft fruit percentage with correlation coefficients of 54 % and 51 %, respectively. The correlation of fruit colour at harvest and TA was negative and low with a correlation coefficient of 24 %. Fruit diameter, fruit mass and damaged fruit percentage had a negatively low correlation with fruit colour at harvest. Green calyx percentage had positively low correlation with fruit colour at harvest (Table 9).

DISCUSSION

Time of maturity and the colour stage at harvest (stage of maturity) interact as they affect post-harvest quality of 'Triumph' persimmons. However, some quality parameters do not show this interaction if measured at harvest but only after storage and shelf-life. Firmness, soft fruit percentage, Sinclair IQ firmness and percentage of green calyx were not affected by the interaction of time of maturity and stage of maturity at harvest but they were all affected after storage and shelf-life. TA and damaged fruit percentage were affected by the interaction of time of maturity and stage of maturity at harvest and after cold storage, but both were not affected when assessed after shelf-life. Late fruit had slightly higher soft fruit percentage compared to early fruit after cold storage for fruit harvested at colour groups 1 and 2 but generally lower percentages than early fruit after shelf-life. Although this could be a result of change of fruit quality in storage (Wills et al., 2007), it may also suggest that time of maturity and stage of maturity at harvest also interacts with storage environment.

At harvest, PBZ treated and late fruit were significantly firmer than early fruit, suggesting that PBZ treated and late fruit were harvested less mature than early fruit. Since time of maturity of persimmon fruit is influenced by climatic factors of the production area (Kitagawa and Glucina, 1984), harvesting of late fruit should have been done when the fruit was less mature. In South Africa, 'Triumph' persimmon harvesting coincides with the autumn season with late fruit harvesting taking place during cooler times of the season; from end-May to mid-June (Bill, 2012). Since fruit colour does not always correlate with quality and maturity (Steyn, 2012), it is therefore possible that late fruit were harvested when their optimum fruit colour was attained but the fruit still firm. Treatment with PBZ advances maturity by promoting rapid fruit colour development (Bill, 2012); therefore firmer fruit observed at harvest for this treatment may suggests that rapid fruit colour development incited by PBZ does not correspond with the decrease in firmness.

Firmness measured by penetrometer and Sinclair internal quality firmness tester (SIQFT) showed a contrasting result. Early fruit had significantly higher values than PBZ treated and late fruit when measured with SIQFT and PBZ treated and late fruit had significantly firmer fruit compared to early untreated fruit when measured with the penetrometer. This contrasting result could be attributed to the difference in attributes of firmness that are measured by these devices (Harrison, 2003). Sinclair internal quality firmness tester (SIQFT) measures tissue elasticity by applying low mass impact sensor whereas destructive Magness and Taylor (penetrometer) measures tissue failure through the introduction of a cylindrical head into the flesh of a peeled fruit to measure the maximum penetration force (Khalifa et al., 2011). Although penetrometer is the most accepted firmness tool (Khalifa et al., 2011), the possibility of non-destructive tools such as SIQFT is being investigated.

Fruit colour for fruit harvested at colour group 1 and 4 did not vary with time of maturity when measured at harvest. However, there were significant variation of fruit colour with time of maturity for fruit harvested at colour groups 2 and 3. This suggests that, when fruit are harvested very mature or very green, the final fruit colour of 'Triumph' persimmon fruit is not influenced by the production region. However, fruit colour was influenced by production area when the fruit were harvested at the intermediate maturity stages (colour groups 2 and 3) due to their ability to mature further (Kader, 2002).

The results also demonstrated that, post-harvest fruit quality is dependent on fruit quality at harvest. Late fruit that had a lower TSS than early fruit at harvest generally had a lower TSS than early fruit again after shelf-life. Late fruit had significantly lower soft fruit percentage compared to PBZ treated and early fruit at harvest and firmer fruit after storage and shelf-life compared to early fruit. Fruit harvested at an intermediate maturity stage (colour group 3) showed that late fruit that were firm at harvest were firmer than both PBZ treated and early fruit after storage and shelf-life. PBZ treated fruit that were firmer than early fruit at harvest remained generally firmer than early fruit after shelf-life. Conversely, green calyx condition has shown a different trend where late fruit had lower calyx green percentage at harvest and a generally higher green calyx percentage after shelf-life. Since late fruit had a significantly lower calyx green percentage compared to PBZ treated and early fruit at harvest and a significantly higher calyx green percentage after shelf-life, it can be assumed that, the decomposition rate of the green calyx colour of late fruit in storage could be lower than that of PBZ treated and early fruit.

Late fruit proved to store better than both PBZ treated and early fruit. Generally late fruit had firmer fruit than PBZ treated and early fruit throughout post-harvest period. After shelf-life, late fruit harvested at colour groups 2, 3 and 4 were significantly firmer than early fruit. Late fruit had lower soft fruit percentage than PBZ treated and early fruit after shelf-life. After shelf-life, the highest soft fruit percentages were found in early fruit harvested at colour groups 1, 2 and 3, which were significantly higher than PBZ treated and late fruit. Although fruit harvested at colour group 2 did not differ significantly with times of maturity, TSS for PBZ treated and early fruit were significantly higher than that of late fruit for fruit harvested at colour groups 1 and 3 after shelf-life. Generally, higher TSS is associated with more mature and less firm fruit. Late fruit had generally high calyx green percentage after shelf-life. Calyx green percentage of PBZ treated and late fruit was significantly higher than that of early fruit for fruit harvested at colour groups 1 and 2 and late fruit had a significantly higher calyx green percentage than both early and PBZ treated fruit for fruit harvested at colour groups 3 and 4. Calyx is assumed to help in gaseous exchange as well as auxin synthesis (Kitagawa and Glucina, 1984) and the more it remains green, the more the fruit is considered fresh by consumers.

Fruit harvested at colour group 3 proved to store better for all maturity times. When fruit was harvested at colour group 2, soft fruit percentage was above the commercial standard (10 %) (UNECE, 2012) after storage for early and late regions. However after storage and shelf-life, soft fruit percentage for fruit harvested at colour group 3 did not differ significantly with time of maturity and had lower soft fruit percentage than the maximum commercial standard (10 %) (UNECE, 2012). A larger fraction of the South African 'Triumph' persimmon is exported to the European countries and the Perishable Produce Export Control Board (PPECB) (a local board) enforces export standards, in order to ensure fruit quality from South African originating fruit. Although late fruit harvested at colour group 3 was significantly firmer than PBZ treated and early fruit after shelf-life, firmness values for all the three maturity times were above 5 kg (PPECB minimum acceptable level). The maximum acceptable persimmon firmness at harvest is 7 kg (PPECB) and firmness decrease slightly in storage (Kitagawa and Glucina, 1984). However, the results demonstrated that damaged fruit percentage was high (40%) after shelf-life for all maturity times. Although the effect of stage of maturity on damaged fruit percentage was proved, factors such as the experience of harvesters as well as handling could also have contributed to the amount of damaged fruit (Wills, 2007). Fruit harvested at colour group 4 remained firm and failed to develop the characteristic fruit colour for ripe fruit throughout post-harvest life. Fruit harvested at colour group 1 have shown significantly high soft fruit percentage throughout post-harvest period.

The results showed significantly high positive correlation between fruit colour chart values at harvest and flesh firmness as well as significantly weak relationship between fruit colour chart values at harvest and other quality parameters throughout post-harvest life of the fruit. Hue angle was not correlated with other maturity parameters in this study. Hue angle is however a finer and more objective measure of colour and may have provided an even stronger correlation. Hue angle correlations to maturity indices should therefore also be evaluated in future studies, to perhaps provide a more accurate pack house pre-sorting tool in order to predict fruit storage potential. However, Wills et al. (2007) reported that ground colour as judged against colour charts, is a useful maturity index for fruits such as apple, pears, stone fruits and mango but is not entirely reliable because it is influenced by factors other than maturity. In persimmon fruit, cool temperatures that are associated with autumn season which usually coincide with fruit harvesting, influence rapid fruit colour development (Mowat, 1992). It may be assumed that the autumn conditions hasten fruit colour development but not the development of other quality parameters and this imbalance is therefore maintained throughout post-harvest life of the fruit (Mowat, 1992).

CONCLUSION

Time of maturity and stage of maturity at harvest interact as they affect post-harvest quality of 'Triumph' persimmons. However, some quality parameters do not show this interaction if measured at harvest even though significant interaction manifests in storage and shelf-life. The effect of interaction of time of maturity and stage of maturity at harvest is greatest on intermediate maturity stages (colour group 2 and 3). 'Triumph' persimmon fruit start softening at colour group 1 stage and hence harvesting at this colour group could not be possible for fruit destined for storage. Fruit harvested at colour group 4 remained firm and failed to develop the characteristic fruit colour for ripe fruit throughout post-harvest life. Fruit harvested at colour group 2 had commercially unacceptable soft fruit percentage level. Harvesting 'Triumph' persimmon fruit at colour group 3 has the potential to ensure better fruit quality after cold storage and shelf-life. However, further study aimed at reducing fruit damage is recommended. According to TSS, soft fruit percentage, fruit flesh firmness and calyx green percentage after shelf-life, late fruit store better than both PBZ and early fruit and PBZ fruit store better compared to early fruit.

With the exception of flesh firmness, 'Triumph' persimmon fruit colour does not correlate with other quality parameters. A combination of fruit colour and other harvesting indices may therefore ensure that, fruit within a maturity time complies with export standards for a certain harvest stage. More uniform and accurate colour identification at harvest will therefore translate into good firmness maintenance and post-harvest fruit quality.

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TABLES AND FIGURES

Table 1: Harvest dates for different orchards included in the experiment according to time of maturity of 'Triumph' persimmon fruits in the Western Cape province of South Africa in the 2012 season.

Treatment	Orchard Number	Name of the farm	Area	Harvest date
PBZ	1	Allee Bleue	Simondium	19/04/2012
	2	Boesmansrug	Vyeboom	19/04/2012
	3	Allee Bleue	Simondium	23/04/2012
	4	Boesmansrug	Vyeboom	23/04/2012
Early	1	Allee Bleue	Simondium	02/05/2012
	2	Allee Bleue	Simondium	02/05/2012
	3	Chiltern	Vyeboom	07/05/2012
	4	Chiltern	Vyeboom	07/05/2012
Late	1	Auldearn	Grabouw	17/05/2012
	2	Auldearn	Grabouw	17/05/2012
	3	Mardale	Grabouw	22/05/2012
	4	SES	Grabouw	22/05/2012

Table 2: The effect of time of maturity (PBZ treated, early and late) and stage of maturity (colour group) of 'Triumph' persimmon fruit at harvest on fruit flesh firmness, soft fruit (%), Sinclair internal quality firmness and percentage of green calyx at harvest.

Treatment	Firmness (kg)	Soft fruit (%)	Sinclair internal quality firmness (IQ value)	Percentage of green calyx
PBZ	9.1a*	3a	35.3b	55.4a
Early region	8.6b	3a	37.0a	53.4a
Late region	9.0a	0.8b	35.8b	40.3b
<u>Colour group</u>				
1^	6.7d	6.7a	32.7d	42.2d
2	8.4c	1.8b	35.3c	46.0c
3	9.7b	0.4b	36.5b	51.8b
4	10.8a	0.0b	39.7a	58.7a
			Pr >F	
Treatment	<.0001	0.0164	<.0001	<.0001
Colour group	<.0001	<.0001	<.0001	<.0001
Treatment x colour group	0.2938	0.0801	0.3337	0.0701

* Means followed by the same letter in the same column do not differ significantly at $P < 0.05$

^ Fruit were harvested into four colour groups which are group 1 = colour chart value 2, group 2 = colour chart value 3-4, group 3 = colour chart values 5-6 and group 4 = colour chart values 7-8 (Plant Protection and Inspection Services (PPIS), Bet-Dagan, Israel; values 1 = red/orange and 8 = green).

Table 3: The effect of time of maturity (PBZ treated, early and late) and stage of maturity (colour group) of 'Triumph' persimmon fruit at harvest on fruit colour based on colour chart and total soluble solids (TSS) at harvest, after cold storage and after shelf-life.

Treatment	Colour Group	Fruit colour at harvest	Fruit colour after cold storage	Fruit colour after shelf-life	TSS (%) at harvest	TSS (%) after cold storage	TSS (%) after shelf-life
PBZ	1^	1.9e*	2.0def	1.8f	19.3bc	17.7a	18.2a
	2	2.6de	2.7cd	2.8cde	19.2bc	16.7bc	17.4abc
	3	3.7c	4.2b	3.4bc	19.1bc	16.0de	16.7bc
	4	6.6a	6.4a	6.0a	18.9cd	15.5fe	15.9de
Early region	1	2.4e	1.7f	1.8f	20.2a	17.8a	18.2a
	2	3.4cd	2.5cde	2.4ef	20.0a	17.2ab	17.5ab
	3	4.6b	3.1c	3.0bcd	19.7ab	16.7bc	16.9bc
	4	6.7a	6.2a	5.7a	18.3de	15.0f	15.0fg
Late region	1	2.3e	2.0ef	1.8f	19.7ab	17.2ab	16.7cd
	2	3.4c	2.7c	2.4de	19.3bc	16.4cd	16.7bc
	3	4.8b	4.3b	3.5b	18.9cd	15.8de	15.5ef
	4	6.3a	5.8a	5.4a	18.2e	14.9f	14.4g
					Pr >F		
Treatment (T)		<0.0001	<0.0001	0.0062	<0.0001	<0.0001	<0.0001
Colour Group (CG)		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
T x CG		0.0025	<0.0001	0.0027	<0.0001	<0.0001	0.0252

* Means followed by the same letter in the same column do not differ significantly at P < 0.05

^ Fruit were harvested into four colour groups which are group 1 = colour chart value 2, group 2 = colour chart value 3-4, group 3 = colour chart values 5-6 and group 4 = colour chart values 7-8 (Plant Protection and Inspection Services (PPIS), Bet-Dagan, Israel; values 1 = red/orange and 8 = green).

Table 4: The effect of time of maturity (PBZ treated, early and late) and stage of maturity (colour group) of ‘Triumph’ persimmon fruit at harvest on percentage of damaged fruit and titratable acid (TA) at harvest and after cold storage

Treatment	Colour Group	Damaged fruit (%)[z] harvest	Damaged fruit (%) after cold storage	TA (%) at harvest	TA (%) after cold storage
PBZ	1[^]	40ab*	58.1a	0.23f	0.16a
	2	33.8abc	33.8b	0.24ef	0.14bcde
	3	26.3cd	18.1cde	0.26de	0.14bcde
	4	31.9bcd	10.0ef	0.28bc	0.14bcde
Early region	1	44.4a	30.6bc	0.25de	0.14bcde
	2	27.5cd	14.4de	0.27cd	0.14bcde
	3	20.0de	7.5f	0.27cd	0.13def
	4	0.6f	0.0f	0.29b	0.12f
Late region	1	24.4cd	27.5bcd	0.28bc	0.15ab
	2	11.9ef	16.9de	0.28bc	0.13def
	3	9.4ef	10.0ef	0.29b	0.13def
	4	3.8f	8.8ef	0.30a	0.12f
			Pr >F		
Treatment (T)		<.0001	<.0001	<.0001	<.0001
Colour group (CG)		<.0001	<.0001	<.0001	<.0001
T x CG		0.0002	0.0013	0.0031	0.0156

* Means followed by the same letter in the same column do not differ significantly at P < 0.05

^ Fruit were harvested into four colour groups which are group 1 = colour chart value 2, group 2 = colour chart value 3-4, group 3 = colour chart values 5-6 and group 4 = colour chart values 7-8 (Plant Protection and Inspection Services (PPIS), Bet-Dagan, Israel; values 1 = red/orange and 8 = green).

Table 5: The effect of time of maturity (PBZ treated, early and late) and stage of maturity (colour group) of 'Triumph' persimmon fruit at harvest on fruit flesh firmness (kg), Sinclair internal quality firmness (IQ firmness), soft fruit (%) and percentage of the green calyx at harvest, after cold storage and shelf-life.

Treatment	Colour Group	Firmness (kg) after cold storage	Firmness (kg) after shelf-life	IQ Firmness after cold storage	IQ Firmness after shelf-life	Soft Fruit (%)[z] after cold storage	Soft Fruit (%) after shelf-life	Green Calyx (%) after cold storage	Green Calyx (%) after shelf-life
PBZ	1^	4.1e*	3.0fg	21.0de	16.1fgh	26.3bc	28.1c	34.6bcd	33.4bcd
	2	5.7d	4.7e	22.1d	17.9ef	5.6ef	19.4cd	32.4cde	31.8cde
	3	7.5c	6.7d	24.4c	21.1c	5.0ef	8.1de	31.1de	29.3def
	4	10.4a	10.6a	27.6b	27.6a	1.3f	0.6e	27.6ef	32.5bcd
Early region	1	3.8e	2.4g	22.5d	15.8gh	31.3ab	68.1a	37.7abc	24.6ef
	2	5.1d	3.7f	24.9c	18.5de	14.4de	42.5b	38.8ab	24.5f
	3	7.3c	5.4e	26.8b	20.7c	7.5ef	29.4c	36.6abcd	25.1ef
	4	10.2a	9.6b	29.7a	25.9ab	0.0f	9.4de	36.5abcd	28.1def
Late region	1	3.4e	3.0fg	19.6e	14.8h	40.0a	46.9b	25.1f	33.4bcd
	2	5.8d	5.1e	21.3de	17.4efg	20.6cd	25.6c	31.5de	38.2bc
	3	9.2b	8.1c	24.7c	20.5cd	3.8f	10.0de	41.4a	39.5ab
	4	11.0a	10.6a	28.0ab	24.3b	0.0f	3.8e	39.6ab	45.6a
						Pr > F			
Treatment		<.0001	<.0001	<.0001	<.0001	0.0042	<.0001	<.0001	<.0001
Colour group		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0441	0.0003
Treatment vs CG		0.0008	<.0001	0.0105	0.0102	<.0001	<.0001	<.0001	0.0014

* Means followed by the same letter in the same column do not differ significantly at $P < 0.05$

^ Fruit were harvested into four colour groups which are group 1 = colour chart value 2, group 2 = colour chart value 3-4, group 3 = colour chart values 5-6 and group 4 = colour chart values 7-8 (Plant Protection and Inspection Services (PPIS), Bet-Dagan, Israel; values 1 = red/orange and 8 = green).

Table 6: The effect of time of maturity (PBZ treated, early and late) and stage of maturity (colour group) of 'Triumph' persimmon fruit at harvest on fruit titratable acidity (TA) and damaged fruit percentage after shelf-life.

Treatment	TA (%)	Damaged fruit (%)
PBZ	0.15a*	47.20
Early region	0.10c	46.10
Late region	0.13b	40.50
Colour group		
1^	0.13a	58.30a
2	0.12b	45.21b
3	0.11b	40.60b
4	0.11b	34.20b
	Pr >F	
Treatment	<.0001	0.1544
Colour group	<.0001	<.0001
Treatment vs colour group	0.9474	0.4509

* Means followed by the same letter in the same column do not differ significantly at P < 0.05

^ Fruit were harvested into four colour groups which are group 1 = colour chart value 2, group 2 = colour chart value 3-4, group 3 = colour chart values 5-6 and group 4 = colour chart values 7-8 (Plant Protection and Inspection Services (PPIS), Bet-Dagan, Israel; values 1 = red/orange and 8 = green).

Table 7: Correlation of 'Triumph' persimmon fruit colour at harvest and fruit quality parameters (fruit firmness, soft fruit percentage, TSS, TA, fruit diameter, fruit weight, blemished fruit percentage and the percentage of green calyx) at harvest.

Quality attribute	Correlation coefficient	Pr<F
TSS at harvest	-0.40	<0.0001
TA at harvest	0.37	<0.0001
Percentage of green calyx at harvest	0.46	<0.0001
Fruit diameter at harvest	-0.27	0.0002
Fruit weight at harvest	-0.23	0.0012
Fruit flesh firmness at harvest	0.72	<0.0001
Sinclair internal quality firmness at harvest	0.67	<0.0001
Soft fruit percentage at harvest	-0.33	<0.0001
Calyx colour (hue angle) at harvest	0.45	<0.0001
Fruit colour (hue angle) at harvest	0.91	<0.0001
Blemishes percentage at harvest	-0.36	<0.0001

Table 8: Correlation of 'Triumph' persimmon fruit colour at harvest and fruit quality parameters (fruit firmness, soft fruit percentage, TSS, TA, fruit diameter, fruit weight, blemished fruit percentage and the percentage of green calyx) after cold storage.

Quality attribute	Correlation coefficient	Pr<F
TSS after cold storage	-0.55	<.0001
TA after cold storage	-0.36	<.0001
Percentage of green calyx after cold storage	0.20	<.0001
Fruit diameter after cold storage	-0.17	0.0200
Fruit weight after cold storage	-0.20	0.0047
Fruit flesh firmness after cold storage	0.82	<.0001
Sinclair internal quality firmness after cold storage	0.66	<.0001
Soft fruits percentage after cold storage	-0.56	<.0001
Calyx colour (hue angle) after cold storage	0.28	<.0001
Fruit colour (hue angle) after cold storage	0.88	<.0001
Blemishes percentage after cold storage	-0.48	<.0001

Table 9: Correlation of ‘Triumph persimmon fruit colour at harvest and fruit quality parameters (fruit firmness, soft fruit percentage, TSS, TA, fruit diameter, fruit weight, blemished fruit percentage and the percentage of green calyx) after shelf-life.

Quality attribute	Correlation coefficient	Pr<F
TSS after shelf-life	-0.54	<.0001
TA after shelf-life	-0.24	0.007
Percentage of green calyx after shelf-life	0.26	0.0004
Fruit diameter after shelf-life	-0.19	0.0078
Fruit weight after shelf-life	-0.18	0.0140
Fruit flesh firmness after shelf-life	0.80	<.0001
Sinclair internal quality firmness after shelf-life	0.70	<.0001
Soft fruits percentage after shelf-life	-0.51	<.0001
Calyx colour (hue angle) after shelf-life	0.36	<.0001
Fruit colour (hue angle) after shelf-life	0.86	<.0001
Blemishes percentage after shelf-life	-0.37	<.0001

Figure 1: Persimmon colour chart (Plant Protection and Inspection Services (PPIS), Bet-Dagan, Israel). In South Africa, ‘Triumph’ persimmon fruit are normally harvested at colour chart values 4 to 5.

PAPER 2

THE EFFECTS OF ORCHARD ON POST-HARVEST QUALITY OF 'TRIUMPH' PERSIMMONS

ABSTRACT

'Triumph' persimmon fruit harvested in the Western Cape, South Africa has variable post-harvest storage potential. Harvesting the fruit at Plant Protection and Inspection Services (PPIS) persimmon colour chart value 5-6 was found to achieve a balance between fruit storability and fruit colour on the shelf. The aim of this study was to determine whether orchards in one production area and in close proximity differ in the storage potential of fruit harvested at the recommended stage of maturity. Fruit were harvested from four early maturing orchards treated with paclobutrazol (PBZ), four non-treated early maturing orchards and four non-treated late maturing orchards in the 2012 season. In the 2013 season, fruit were harvested in five orchards on two adjacent farms in an early region. Fruit quality was assessed at harvest, after 6 weeks and 3 days of storage at -0.5 °C and after ripening for 4 days at 20 °C. Orchard differences in storage potential of fruit harvested at the recommended maturity stage in the same region were observed. A difference in the rate of firmness loss during storage and ripening between orchards that were harvested at the same firmness in the same area was prevalent in both seasons. Firmness differences of about 2 kg were recorded on orchards that had no significant firmness differences at harvest. Furthermore, fruit at the same fruit colour proved to have significantly different flesh firmness and total soluble solids (TSS) depending on the orchard of origin. Fruit firmness differences of 1.5 kg and TSS differences above 1 °Brix between orchards were recorded on fruit that had the same colour. Overally, the data shows that orchard of origin plays a major role in storability of persimmon fruit. The varying storage potential was found for orchards in close proximity, which rules out a climatic reason for the differences observed. We have to assume that orchard factors and practices play a significant role in the storability of 'Triumph' persimmon fruit. Thus, although harvesting fruit according to the PPIS color chart values 5-6 can improve the general quality of fruit on the shelf, significant variation is likely to occur. We would consequently advise persimmon growers and grower groups in South Africa to investigate and address the factors that result in poor storability of fruit from some orchards.

Keywords: *Diospyros kaki*, Colour, Soft fruit, Firmness, Harvest maturity, Storability, Shelf-life

INTRODUCTION

South African 'Triumph' persimmon production is export oriented (Bill, 2012), and the focus is on meeting quality specification demanded by the market. However, South African 'Triumph' persimmons produced in the same production region has variable post-harvest fruit quality (Bill, 2012). This problem was also reported in other persimmon producing countries. In the New Zealand persimmon industry, Mowat and Chee (2011) reported that orchard management had a greater effect on 'Fuyu' fruit quality than the district in which the fruit was grown. In Japan, Kitagawa and Glucina (1984) reported that it is fairly difficult to obtain uniform persimmon fruit after storage.

In early studies, Kader (2002) attributed fruit predisposition to post-harvest disorders to microclimatic factors such as fruit position on the tree, characteristics of the fruiting site, crop load, mineral and carbohydrate nutrition of the developing fruit, water relations and the response to temperature. Mowat (1992) reported that important persimmon quality parameters such as fruit weight, soluble solids and soluble tannins, have a series of climatic and orchard conditions that should be met during the growing season in order to obtain a high quality fruit. In 'Fuyu', orchard practices such as moderate to hard winter pruning, an open canopy and moderate to hard fruit thinning were found to be associated with higher fruit quality (Mowat, 1992).

In the Western Cape persimmon production area in South Africa, 'Triumph' persimmon is produced in two meso-climatic regions classified according to the time 'Triumph' persimmon mature, as early (Simondium area, 33°3' S, 19°9' E) and late (Grabouw area, 34°59' S, 18°00' E). In the early region, some orchards are treated with maturity advancing chemicals such as paclobutrazol so that the fruit can be harvested and send to the export market before it is flooded with persimmon fruits and hence sell at premium price (Bill, 2012). Persimmon fruit that mature at different times generally present a difference in fruit quality after storage and shelf-life (Salvador et al., 2005).

Harvesting fruit at the correct stage of maturity was found to reduce post-harvest persimmon quality variation (Testoni, 2002). Although, the preliminary results of this study (Paper 1) proved that harvesting South African 'Triumph' persimmons that mature at different times at Plant Protection and Inspection Services (PPIS) persimmon colour chart (PPIS, Bet-Dagan, Israel) values 5-6 reduces post-harvest quality loss, it is important to establish whether this recommendation ensures storage potential and quality for all orchards within an area. This study was therefore carried out to investigate the effect of orchards on post-harvest quality of 'Triumph' persimmon harvested at the recommended stage of maturity (PPIS persimmon colour chart values 5-6).

MATERIALS AND METHODS

Trial site

In the 2012 season, the trial was conducted in the early (Simondium - 33°3'S, 19°9'E) and the late (Grabouw - 34°59'S, 18°00'E) persimmon production regions in the Western Cape province of South Africa. Fruit were harvested from four early orchards treated with paclobutrazol (PBZ) (Cultar®: 250 g·L^{-1} active paclobutrazol (triazole); Syngenta SA (Pty) Ltd. Halfway House, South

Africa) (refer to paper 1 for the method of application), four non-treated early orchards and four non-treated late orchards (Table 1). In the 2013 season, fruit were harvested in three orchards on Allee Bleue farm (33°51'S, 18°'E) and two orchards in Solms Delta farm in the early persimmon production region (Table 1). Allee Bleue and Solms Delta are adjacent persimmon producing farms in the Simondium area.

Fruit sampling and treatment

In 2012 season, harvesting was done from 19-24 April on PBZ treated orchards, 1-7 May on early orchards and 17-23 May on late orchards (Table 1). In the 2013 season, harvesting was done in a sequential order from 09 April for orchard 1 to 15 April for orchard 5 (Table 1). In each orchard, fruit were harvested in the whole orchard trying to harvest only fruit that had attained fruit colour stage of the PPIS persimmon colour chart (PPIS, Bet-Dagan, Israel) (Fig. 1, Paper 1) values 5-6. To ensure that fruit of the correct maturity stage were collected, the fruit were brought to a central area where they were colour sorted using the PPIS persimmon colour chart and 4 replicates of 30 fruits each were collected from each orchard. One third of the fruit were evaluated at harvest whilst the remainder were de-astringified with 90% carbon dioxide for 24 h in a hermetically sealed metal box whilst being treated with 500 ppb 1-Methylcyloprene (1-MCP) (Smartfresh™, Agro Fresh, Pennsylvania, USA) and then stored for 6 weeks and 3 days at -0.5 °C. After cold storage, one half of the stored fruit were evaluated whilst the remainder was stored for additional four days at 20 °C simulating shelf-life and evaluated thereafter.

Physicochemical measurements

At each evaluation, fruit colour, flesh firmness, soft fruit percentage, total soluble solids (TSS) and damaged fruit percentage were determined. Fruit colour was determined using a PPIS persimmon colour chart with colour values 1 to 8 where 1 is the most orange and 8 yellowish green (Figure 1, Paper 1). A chromameter (Chromameter CR-400, Minolta Co., Ltd, Osaka, Japan) was also used to determine fruit colour as hue angle by directing the scan on the peel of the fruit on the two equatorial regions (most coloured and least coloured sides) and at the stylar end of the fruit. An average hue angle was calculated for each fruit. Flesh firmness, expressed as the load in kilograms needed to break the flesh up to a fixed depth, was measured with an 11.1 mm plunger on a fruit texture analyser (FTA) (Güss Manufacturing (Pty) Ltd, Strand, South Africa) on three peeled (1 mm deep) fruit sites (opposite sides equatorially and the stylar end of the fruit). The average firmness was calculated for each fruit. Soft fruit percentage was determined subjectively by slightly pressing the equatorial region of each fruit between fingers and the ratio of soft fruit to sound fruit expressed as a percentage for each replicate. A disc was cut at the mid-point of each fruit, pooled per replicate and juiced. The juice was used for TSS measurement. A drop of juice from each replicate was placed on the prism plate of a temperature controlled digital refractometer (PR 32, Atago Co, Ltd. Tokyo, Japan) measuring TSS in °Brix. Damaged fruit percentage was determined by expressing the number of blemished, cracked, bruised and marked fruit as a percentage of the total fruit per replicate.

Statistical procedures

Data were analysed as a randomised complete design using General Linear Models (GLM) procedures in the Statistical Analysis System (SAS) computer program (SAS Enterprise Guide 4.0; SAS Institute, 2006, Cary, NC 27513, USA). Means were separated by least significant difference (LSD) at 5% level. Normality of data was tested in the Statistical Analysis System (SAS) program (SAS Enterprise Guide 4.0; SAS Institute, 2006, Cary, NC 27513, USA). Data obtained after storage and shelf-life in the 2013 season was used in producing principal component analysis (PCA) plots using statistica (Statistica version 11, StatSoft, Inc 200, Tulsa, USA). Only maturity parameters presented in the ANOVA tables were discussed for the PCA loadings plot (Fig. 1 and 2).

RESULTS

2012 season

PBZ treated orchards

At harvest: There was a significant orchard difference in fruit flesh firmness, hue angle, fruit colour (colour chart index), and damaged fruit percentage of fruit harvested from trees treated with PBZ (Table 2). Orchards 2 and 4 (Boesmanrug farm) fruit were significantly firmer than orchards 1 and 3 fruit (Allee Bleue farm). Orchard 3 fruit had significantly more developed orange fruit colour (hue angle) compared to orchards 2 and 4 but not orchard 1. Moreover, there were no significant hue angle differences between orchards 1, 2 and 4. Assessed using colour chart, orchard 3 fruit had significantly more developed orange fruit colour compared to orchards 1 and 4 fruit but not orchard 2 fruit. Furthermore, as with hue angle there was no significant colour chart index differences between orchards 1, 2 and 4 fruit. Orchard 2 fruit had significantly high damaged fruit percentage compared to orchards 3 and 4 fruit. However, there was no significant damaged fruit percentage differences between fruits harvested in orchards 1, 3 and 4. There were no significant orchard differences on soft fruit percentage and total soluble solids

After storage: There were significant orchard differences in fruit flesh firmness, hue angle, fruit colour (colour chart index), total soluble solids, and damaged fruit percentage of the fruit harvested from different orchards that were treated with PBZ (Table 3). Orchard 3 fruit were significantly less firm compared to orchards 2 and 4 fruit but not orchard 1 fruit. Furthermore, there were no significant flesh firmness differences for fruit harvested in orchards 1, 2 and 3. Fruit harvested on orchard 3 were significantly more orange (lower hue angle value) compared to orchards 1, 2 and 4. Moreover fruit harvested from orchards 1, 2 and 4 had no significant fruit colour differences (hue angle). However, when assessed using PPIS colour chart, only orchard 4 fruit has shown to have a significantly less developed orange fruit colour. Orchard 1 fruit had significantly higher TSS compared to orchards 2, 3 and 4 fruit and there were no significant TSS differences for the fruit harvested in orchards 2, 3 and 4. Orchard 1 fruit also had a significantly higher damaged fruit percentage compared to orchards 2, 3 and 4 fruit and the damaged fruit percentage for orchards 2, 3 and 4 was not significantly different. There were no significant orchard differences on soft fruit percentage.

After shelf-life: There were significant orchard differences in fruit flesh firmness, hue angle, fruit colour (colour chart) and total soluble solids of the fruit harvested from trees that were treated with PBZ (Table 4). Fruit harvested from orchards 2 and 4 were not significantly different in their firmness and they were firmer than fruit harvested from orchards 1 and 3 after shelf-life. Furthermore, orchard 3 fruit were significantly firmer than orchard 1 fruit. Orchard 3 fruit were significantly more orange (hue angle) compared to orchards 2 and 4 fruit but not orchard 1. Furthermore, there were no significant fruit colour (hue angle) differences between orchards 1, 2 and 4 fruit. When assessed using PPIS colour chart, orchards 3 and 4 fruit had significantly more developed fruit colour compared to orchards 1 and 2 fruit. However, there were no significant fruit colour differences between orchards 1 and 2 or between orchards 3 and 4 fruit. Orchard 1 fruit had a significantly higher TSS compared to orchards 2, 3 and 4 fruit and TSS for fruit harvested in orchards 2, 3 and 4 did not differ significantly. There were no significant orchard differences on soft fruit percentage and damaged fruit percentage.

Early orchards fruit

At harvest: There were significant orchard differences in fruit flesh firmness, hue angle, fruit colour (colour chart index) and total soluble solids of the fruit harvested in the early persimmon production region (Table 5). Orchard 4 (Chiltern farm) fruit were significantly firmer than orchard 1, 2 and 3 fruit and orchard 1 (Allee Bleue farm) fruit had significantly less firm fruit compared to orchards 2 and 3 fruit (Allee Bleue and Chiltern farms, respectively). However, there were no significant firmness differences on fruit harvested in orchards 2 and 3. Fruit harvested in orchard 1 had significantly more developed orange fruit colour (hue angle) compared to fruit harvested from orchards 2, 3, and 4. Moreover, there were no significant fruit colour (hue angle) differences for fruit harvested from orchards 2, 3 and 4. Assessed using PPIS colour chart, the fruit colour for orchards 1 and 2 as well as 3 and 4 did not differ significantly. However, fruit colour for fruit harvested from orchards 1 and 2 was significantly different from that of fruit harvested from orchards 3 and 4. Orchard 4 fruit had significantly lower TSS compared to orchards 1 and 2 but not orchard 3. Furthermore, orchard 3 fruit had lower TSS compared to orchard 1 fruit but not orchard 2 fruit. However, there was no significant TSS difference between orchard 1 and orchard 2 fruit. There were no significant orchard differences on soft fruit percentage and damaged fruit percentage.

After storage: There were significant orchard differences in fruit flesh firmness, hue angle and total soluble solids for the fruit harvested from different orchards in the early persimmon production region and evaluated after storage (Table 6). Orchard 1 fruit were significantly less firm compared to orchards 2, 3 and 4 fruit and orchard 4 fruit were significantly firmer than orchard 2 fruit, but not orchard 3 fruit. Furthermore, there was no significant firmness difference between orchard 2 and orchard 3 fruit. Orchard 1 fruit had significantly more developed orange fruit colour (hue angle) compared to orchard 2 and 4 fruit but not orchard 3 fruit. However, there were no significant fruit colour (hue angle) differences for fruit harvested on orchards 2, 3 and 4. Orchards 1 and 2 fruit had significantly higher TSS compared to orchards 3 and 4 fruit and there were no significant TSS differences between orchard 1 and 2 fruit or between orchards 3 and 4 fruit. There were no significant orchard differences on soft fruit percentage, fruit colour (colour chart) and damaged fruit percentage.

After shelf-life: There were significant differences in fruit flesh firmness, hue angle, soft fruit percentage, total soluble solids and damaged fruit percentage on the fruit harvested from different orchards in the early persimmon production area after shelf-life (Table 7). Orchard 4 fruit had significantly firmer fruit compared to orchards 1, 2 and 3 fruit and orchards 1, 2 and 3 fruit did not differ significantly in their flesh firmness. The fruit harvested from orchard 1 had significantly more developed orange fruit colour (hue angle) compared to orchard 2 and 4 fruit but not orchard 3 fruit. However, there was no significant fruit colour (hue angle) difference on fruit harvested from orchards 2, 3 and 4. Fruit harvested from orchard 2 and 3 had significantly higher soft fruit percentage compared to orchards 1 and 4 fruit. However, the soft fruit percentages of orchard 1 and 4 fruit were not significantly different and the soft fruit percentages for orchard 2 and 3 fruit were also not significantly different. Orchards 1 and 2 fruit had significantly higher TSS compared to orchard 3 and 4 fruit and there were no significant TSS differences between orchard 1 and 2 fruit as well as between orchard 3 and 4 fruit. Orchards 3 and 4 fruit had significantly higher damaged fruit percentage compared to orchard 2 fruit but not orchard 1 fruit. However, there were no significant differences in damaged fruit percentage between fruit harvested from orchards 1 and 2 or orchards 3 and 4. There were no significant orchard differences in the fruit colour chart index.

Late orchards fruit

At harvest: There were significant orchard differences in fruit colour (colour chart index), total soluble solids and damaged fruit percentage of the fruit harvested in the late persimmon production area at harvest (Table 8). Orchard 3 (Mardale farm) fruit had significantly more orange fruit colour (colour chart index) compared to orchards 1 (Auldearn farm), 2 (Auldearn farm), and 4 (SES farm) fruit and orchard 2 fruit had significantly more orange fruit colour compared to orchards 1 and 4 fruit. However, there was no significant fruit colour difference (colour chart index) between orchard

1 fruit and orchard 4 fruit. Orchards 2 and 3 fruit had significantly higher TSS compared to orchards 1 and 4 fruit and there were no significant TSS differences between orchards 2 and 3 fruit as well as between orchards 1 and 4 fruit. Orchard 3 fruit had a significantly higher damaged fruit percentage compared to orchards 1, 2 and 4 fruit. However, there were no significant damaged fruit percentage differences on fruit harvested from orchards 1, 2 and 4. There were no significant orchard differences on fruit flesh firmness, fruit colour (hue angle) and soft fruit percentage.

After storage: There were significant orchard differences in fruit flesh firmness, fruit colour (hue angle and colour chart) and total soluble solids for the fruit harvested from different orchards in the late persimmon production area after storage (Table 9). Orchards 1 and 2 fruit were significantly firmer compared to orchard 3 but not orchard 4 fruit, and there were no significant flesh firmness differences for orchards 1, 2 and 4 fruit as well as between orchards 3 and 4 fruit. Orchard 3 fruit had significantly more developed orange fruit colour (hue angle) compared to orchard 4 fruit, but not orchards 1 and 2 fruit. Furthermore, there was no significant fruit colour (hue angle) difference on fruit harvested in orchards 1, 2 and 4. When assessed with PPIS colour chart, orchard 3 fruit had significantly more developed orange fruit colour compared to orchards 1, 2 and 4 fruit and orchard 4 fruit had significantly more orange fruit colour compared to orchards 1 and 2 fruit. However, there was no significant fruit colour difference between fruit harvested from orchards 1 and orchard 2. Orchard 1 and 4 fruit had significantly lower TSS compared to orchard 3 fruit but not orchard 2 fruit. However, there were no significant TSS differences for fruit harvested in orchards 1, 2 and 4. There were no significant orchard differences on soft fruit percentage and damaged fruit percentage.

After shelf-life: There were significant orchard differences in fruit flesh firmness, fruit colour (hue angle and colour chart) and total soluble solids, for the fruit harvested from different orchards in the late persimmon production area and evaluated at shelf-life (Table 10). Orchard 3 had significantly less firm fruit compared to orchards 1, 2 and 4 fruit and there were no significant firmness differences for fruit harvested in orchards 1, 2 and 4. Orchard 3 fruit had a significantly more developed orange fruit colour (hue angle) compared to orchard 4 fruit but not significantly different from orchards 1 and 2 fruit. However, there were no significant fruit colour differences for fruit harvested in orchards 1, 2 and 4. Assessed with PPIS colour chart, orchard 4 fruit had significantly less orange fruit colour compared to orchards 3 and 1 fruit but was not significantly different from orchard 2 fruit. However, there was no significant fruit colour difference between fruit harvested in orchards 3 and 1 as well as orchards 2 and 3. Fruit harvested from orchard 3 had a significantly higher soft fruit percentage compared to orchards 2 and 4 fruit. However, there were no significant soft fruit percentage differences for the fruit harvested in orchards 1, 2 and 4. Orchard 3 fruit had significantly higher TSS compared to orchard 4 fruit and there were no significant TSS differences on fruit harvested from orchards 1, 2 and 4. There were no significant orchard differences for damaged fruit percentage.

2013 season

Fruit quality

At harvest: There were significant orchard differences in fruit flesh firmness, fruit colour (hue angle and colour chart) and total soluble solids for the fruit harvested in different orchards in the adjacent farms in the 2013 season (Table 11). Orchard 4 (Solms Delta farm) fruit had significantly firmer fruit compared to orchards 1 and 3 (Allee Bleue and Solms Delta farms, respectively) fruit but not orchards 2 and 5 (Allee Bleue farm) fruit. However, there were no significant firmness differences between orchards for the fruit harvested in orchards 1, 2, 3 and 5 as well as orchards 2, 4 and 5. Orchards 2 and 5 had significantly less orange fruit colour measured by hue angle compared to orchards 1, 3 and 4 fruit and there were no significant fruit colour (hue angle) differences for the fruit harvested in orchards 1, 3 and 4 as well as orchards 2 and 4. When fruit colour was assessed using PPIS colour chart, orchard 2 fruit had less orange fruit colour compared to orchards 1, 3, and 4 fruit and there were no significant differences in fruit colour for the fruit harvested in orchards 1, 3, 4 and 5 as well as orchard 2 and orchard 5 fruit. Orchard 3 fruit had a significantly higher TSS compared to orchards 1, 2 and 5 fruit but not orchard 4 fruit and orchard 4 fruit had a significantly higher TSS value compared to orchard 5 fruit. However, there were no significant TSS differences for the fruit harvested in orchards 1, 2, and 5 as well as orchards 1, 2 and 4. There were no significant orchard differences on soft fruit percentage and damaged fruit percentage at harvest in 2013.

After storage: There were significant orchard differences in fruit colour (hue angle and colour chart) and total soluble solids for the fruit harvested on adjacent farms in the 2013 season (Table 12). Orchards 1 and 3 fruit had a significantly more developed orange fruit colour (hue angle) compared to orchards 2 and 5 fruit but not orchard 4 fruit. However, there were no significant fruit colour (hue angle) differences for fruit harvested in orchards 1, 3 and 4 as well as orchards 1 and 2. Assessed by PPIS colour chart, fruit harvested from orchard 1 also had significantly more developed orange fruit colour (concurs with hue angle) compared to orchards 2, 3 and 5 fruit but not orchard 4 fruit. However, there were no significant fruit colour differences when measured by colour chart for fruit harvested from orchards 2, 3, 4 and 5. Fruit harvested from orchard 1 had significantly higher soft fruit percentage compared to orchards 2, 3, 4 and 5 fruit and there were no significant soft fruit differences for the fruit harvested in orchards 2, 3, 4 and 5. Orchard 3 fruit had significantly high TSS compared to orchards 1, 2, 3 and 4 fruit but there were no significant TSS differences on fruit harvested in orchards 2, 3, 4, and 5. There were no significant orchards differences on fruit flesh firmness and damaged fruit percentage.

After shelf-life: There were significant orchard differences in fruit flesh firmness, fruit colour (hue angle and colour chart), soft fruit percentage and total soluble solids for the fruit harvested in adjacent farms in the 2013 season (Table 13). Orchards 1, 2 and 5 fruit had significantly high fruit flesh firmness compared to orchards 3 and 4 fruit. However, there were no significant fruit flesh firmness differences for the fruit harvested in orchards 1, 2 and 5 as well as orchards 3 and 4. Orchards 3 and 4 fruit had significantly more developed orange fruit colour (hue angle) compared to orchards 1, 2 and 5 fruit and orchard 1 fruit had significantly more developed orange fruit colour (hue angle) compared to orchards 2 and 5 fruit. However there were no significant fruit colour differences for the fruit harvested in orchards 2 and 5 as well as orchards 3 and 4. Assessed using the PPIS colour chart, orchards 3 and 4 fruit had significantly more developed orange fruit colour compared to orchards 1, 2 and 5 fruit and orchards 1 and 5 fruit had significantly more orange fruit colour compared to orchard 2 fruit. However, there were no significant fruit colour (colour chart) differences for the fruit harvested in orchards 3 and 4 as well as orchards 1 and 5. Fruit harvested from orchard 4 had significantly high soft fruit percentage compared to fruit harvested from orchards 1, 2, 3 and 5 and there were no significant soft fruit percentage differences for the fruit harvested in orchards 1, 2, 3 and 5. Orchard 1 and 5 fruit had significantly lower TSS compared to orchards 2, 3 and 4 fruit. However, there were no significant TSS differences on fruit harvested in orchards 1 and 5 as well as orchards 2, 3 and 4. There were no significant orchard differences on damaged fruit percentage.

Discriminant analysis of orchards

After storage: 2013 season

The principal component analysis plots (Fig. 1) explain 53.8% of the variation in the after storage quality parameters data that was used to discriminate between the orchards. Factor 1 explains 36.5% and factor 2 explains 17.3% of the variation. Orchard 3 and 1 fruit (from Solms Delta and Allee Bleue farms, respectively) differ significantly from orchard 5 fruit (on the Allee Bleue farm) on factor 1. This difference could be attributed to damaged fruit percentage being high in orchard 1 and 3 and soft fruit percentage that was high on orchard 1 fruit compared to orchard 5 fruit. Orchard 5 had large fruit with high hue angles (greener fruit colour) compared to orchards 1 and 3 fruit. There was no clear separation of orchards on factor 2.

After shelf-life: 2013 season

The principal component analysis plots (Fig. 2) explain 78% of the variation in the after shelf-life quality parameters data that was used to discriminate between the orchards. Factor 1 explains 58.6% and factor 2 explains 19.8% of the variation. Orchards 3 and 4 fruit (both from the Solms Delta farm) differ significantly with orchards 2 and 5 fruit (both from the Allee Bleue farm) on factor 1. Orchard 3 and 4 fruit had high soft fruit percentage and TSS compared to orchard 2 and 5 fruit. Orchards 2 and 5 fruit had high hue angle (greener fruit colour) and a higher firmness compared to orchards 3 and 4 fruit. Orchards 1 and 5 separated on factor two. Orchard 5 fruit had a higher damaged fruit percentage compared to orchard 1 fruit.

DISCUSSION

Post-harvest fruit quality variation was observed between orchards treated with PBZ as well as early region and late region fruit harvested at the recommended stage of maturity. In the 2012 PBZ treated early region, orchard 1 and 3 fruit from Allee Bleue had a lower firmness compared to fruit from orchards 2 and 4 from Boesmanrug farm, after harvest and storage and was also significantly less firm after shelf-life. However the rate of firmness decline over time was faster for orchard 1 fruit compared to orchard 3 fruit as they differed significantly with 2 kg in firmness after shelf-life. This indicates a clear orchard difference in the rate of ripening since they were both from Allee Bleue farm and harvested at similar firmness, hue angle and TSS. The colour chart index was different at harvest for orchard 1 and orchard 3 however the orchard with the highest rate in firmness decline is the orchard with the slightly greener colour chart index at harvest.

In the early region, orchard 1 fruit from the Allee Bleue farm which was less firm compared to the other 3 orchards at harvest and storage, had no significant difference in firmness with orchards 2 and 3 fruit from Allee Bleue and Chiltern farms after shelf-life, respectively but only differed to orchard 4 fruit from Chiltern farm. This suggest that fruit firmness for the fruit harvested in orchards 2 and 3 decreased rapidly during shelf-life and firmness of orchard 4 did not decrease at a high rate during shelf-life. This is also evidenced by the high soft fruit percentage that was significantly higher for orchards 2 and 3 (Allee Bleue and Chiltern, respectively) compared to orchards 1 and 4 fruit from Allee Bleue and Chiltern, respectively. However, the hue angle values at harvest for orchard 4 fruit that remained firmest was the same as for orchard 2 and 3 fruit. Judging by the colour chart the firmest orchard 4 fruit after harvest and storage had the same colour chart index compared to orchard 3 at harvest, however differed in firmness after shelf-life. Whereas the colour chart index showed that orchard 2 fruit were greener at harvest compared to orchard 1 (5.5 compared to 3.7, respectively) but the fruit had a similar decline in firmness up to shelf-life. Again this indicates that orchards have clear differences in ripening rates and storage potential and in this case, were orchard specific and not farm related. In the late region, flesh firmness and hue angle were the same for all orchards at harvest even though the colour chart index indicated greener fruit with lower TSS for orchard 1 and 4 fruit and the fruit from orchard 3 having the most orange fruit. Orchard 3 fruit had the lowest firmness and hue angle (not always significantly so) after storage and shelf-life, the lowest colour chart index after storage and similar colour chart index to orchard 1 and 2 after shelf-life, however, the highest soft fruit percentage and TSS. Orchard 4 that was similar in firmness at harvest and storage to orchard 3 did show the same rate of decline in firmness and hue angle or increase in TSS with orchard 3. Therefore orchard factors clearly played a role in the shelf-life quality.

In 2013 season, after shelf-life, orchards 3 and 4 fruit from Solms Delta farm were significantly less firm compared to fruit from orchards 1, 2 and 5 on the Allee Bleue farm. However, these orchards were not significantly different from the other 3 orchards after storage but lost their firmness rapidly after shelf-life. As for orchard 4, its soft fruit percentage was also significantly high after shelf-life confirming this rapid loss of firmness. Orchard 3, though not significantly different, had slightly higher soft fruit compared to orchards 1, 2 and 5. This unique post-harvest behaviour of some orchards within a region could be attributed to deferential application of the orchard practices or orchard specific microclimates during fruit growth and development, since these were two orchards on one farm. However, at harvest, these orchards were similar in firmness to other orchards, but their TSS were slightly higher and hue angle slightly lower than most orchards. These small and in some cases insignificant differences in TSS and hue angle may have been an indication that fruit maturity at harvest may have been slightly advanced (Itoo, 1986) which would have had an influence on the 1-MCP (SmartFresh^{TM}) treatment efficacy. However, orchard 1 had a lower and non-significantly different hue angle to the fruit from orchard 3 and 4 and did not have the same reduction in hue, firmness and increase in TSS after shelf-life and therefore the maturity at harvest could not have affected the 1-MCP treatment efficacy and differences in storage potential are therefore purely due to orchard differences.

Generally, fresh produce quality is influenced by environmental factors that include chiefly harvest maturity and cultivar or variety, but also the climate and soil in which it was grown, chemicals applied to the crop and its water status (Thompson, 2003). Thompson (2003) reported that many of these factors may interact with time such as when fertiliser or irrigation was applied or the weather condition near to the time of harvesting. Kader (2002) pointed out that if poor management decisions are made during crop production, the production environment would be less conducive and the quality of the product which reaches the consumer may be unsatisfactory.

In New Zealand, Mowat (1992) described pre-harvest orchard management and climatic conditions that influence persimmon quality attributes such as fruit size, fruit colour, soluble solids and soluble tannins. Moderate to hard winter prunning, an open canopy and moderate to hard fruit thinning were reported as practices that are associated with high persimmon fruit quality (Mowat 1992). A study to identify orchard practices that promote higher post-harvest fruit quality of the South African ‘Triumph’ persimmon is therefore recommended.

Fruit harvested at the same colour proved to have significantly different flesh firmness and TSS (quality) depending on the orchard from which the fruit was obtained. In PBZ treated fruit, although orchards 1 and 3 fruit were significantly less firm compared to orchards 2 and 4 fruit at harvest, there were no significant fruit colour differences for orchards 1, 2 and 4 fruit. Fruit harvested from the early region, also had no significant fruit colour (hue angle) differences between orchards 2, 3 and 4 at harvest, however, orchard 4 fruit differed significantly from orchards 2 and 3 fruit with regards to firmness. This was also the case with TSS, where orchard 2 fruit had higher TSS compared to orchard 4 fruit but there was no significant fruit colour difference between these orchards at harvest. In early fruit, after storage, although orchard 2 and orchard 4 fruit had significantly different fruit flesh firmness and TSS, their fruit colour was not significantly different. After shelf-life, although orchard 2 and 3 fruit had less firm fruit compared to orchard 4 fruit, their fruit colour was not significantly different from that of orchard 4. On late fruit, at harvest, orchards 1 and 4 fruit had significantly higher TSS compared to orchards 2 and 3 fruit but there were no significant fruit colour differences between orchards. After storage, orchard 3 fruit were less firm compared to orchards 1 and 2 fruit but there was no significant fruit colour difference for these orchards. On TSS, orchard 3 fruit had significantly highTSS compared to orchard 1 but fruit colour for orchards 1 and orchard 3 fruit did not differ significantly. After shelf-life, orchard 3 fruit were less firm compared to orchards 1 and 2 fruit but they all have fruit colour that was not significantly different and this was also so with TSS. In 2013 season, at harvest, orchard 1 and 3 fruit had significantly less firm fruits compared to orchard 4 fruit but orchards 1, 3 and 4 fruit did not differ significantly in their fruit colour. After cold storage, orchard 3 fruit had significantly high TSS compared to orchards 1 and 4 fruit but orchards 1, 3 and 4 fruit had significantly no different fruit colour. Furthermore, orchard 1 fruit had significantly high soft fruit percentage compared to orchards 3 and 4 which have no significant fruit colour difference with orchard 1. This proves that fruit harvested from different orchards at the same fruit colour may vary in fruit flesh firmness and TSS due to orchard factors. Wills et al., 2007 reported that ground colour as judged against colour charts does not always correlate with fruit quality. Since some quality attributes cannot be improved after harvest but only maintained (Bachmann and Earless, 2000), it is important to harvest fruit at proper quality (Wills et al., 1989). Identification and studying of these factors raises the possibility of reducing post-harvest fruit quality variation (Thompson, 2003). Complementing the PPIS colour chart with other quality parameters is therefore advised per orchard to ensure fruit quality in addition to a good and even fruit colour after harvest.

Although orchard factors exert a significant impact in post-harvest fruit quality, harvesting fruit at PPIS colour chart values 5-6 again proved to reduce post-harvest quality variation. For example, in the early region fruit, there were no significant soft fruit and damaged fruit difference between orchards and three orchards out of the sampled four orchards were not significantly different on fruit colour and two orchards out of the sampled four orchards were not significantly different in terms of flesh firmness and TSS at harvest. After cold storage, no significant orchard differences on soft fruit percentage and damaged fruit percentage was recorded, three orchards out of the four sampled orchards were not significantly different on fruit colour and two out of the four sampled orchards were not significantly different on flesh firmness and TSS. After shelf-life, three orchards out of the sampled 4 orchards were not significantly different on flesh firmness, fruit colour and damaged fruit percentage and two orchards out of the sampled four orchards were not significantly different on soft fruit percentage and TSS. The same trend was observed on PBZ treated and late late fruit as well as the 2013 orchards fruit. These results therefore confirm the results of paper 1. These results also affirm the fact that stage of maturity is the most important factor that influences post-harvest quality of fruits (Ferguson et al., 1999). Persimmons harvested at the correct stage of maturity can be stored for longer periods of time without loss of quality (Testoni, 2002).

The quality of 'Triumph' persimmon fruit at harvest determines the fruit quality after storage and shelf-life. On PBZ treated fruits, orchard 3 fruit which were less firm and more orange in fruit colour at harvest remained less firm and more orange compared to orchards 2 and 4 fruit after storage and shelf-life. The damaged fruit percentage for ochard 1 fruit was significantly high compared to that of orchards 3 and 4 fruit at harvest and was also significantly high after storage. On early region fruit after storage, orchard 1 which had significantly less firm fruit at harvest, had also significantly less firm fruit compared to orchards 2, 3 and 4 fruit after storage and orchard 4 fruit that were significantly firm at harvest were aslo significantly firmer than orchard 1 and 2 fruit after storage. Furthermore, orchard 1 fruit which had significantly more orange fruit colour at harvest, also had a significantly more orange fruit colour after storage. In the 2013 season, orchard 2 and 4 fruit had less developed orange colour at harvest and also a significantly less developed orange colour after storage. Furthermore, TSS for orchard 3 was significantly high at harvest and was also significantly higher than that of other orchards after storage. Hewett (2006) reported that post-harvest product quality develops during pre-harvest growth and development stages and is maintained by post-harvest technologies. Kader (2002) pointed out that poor management decision making during crop production adversely affect the texture of the product which reaches the consumer.

Judging persimmon fruit colour via the PPIS colour chart for a range of orchards within one region is difficult. This study attempted harvesting of fruit at the PPIS colour chart values of 5-6 as it was proven to increase storability without compromising TSS and colour commercially. Fruit were harvested as close to 5-6 colour chart as possible and then re-sorted in the orchard. Fruit were then taken to a laboratory for further maturity indexing. Even though fruit were sorted three times to obtain the same colour groups for each orchard, the harvest data shows differences in colour chart index values in many instances. Persimmon fruit flower over a long period of time (Kitagawa and Glucina, 1984) which results in mixed maturities within one tree canopy and commercially, up to 5 harvests are required within one orchard in order to harvest fruit at the correct maturity. Furthermore, the fruit inside the canopy may be physiologically of the same maturity but have a different fruit colour due to source sink relations as well as a lack of sunlight. Keeping the range of colour differences within a canopy and orchard in mind a more subjective tool is needed to harvest colour groups accurately. In this study near infrared spectroscopy (Paper 4) and hue angle on multiple sites of the fruit would perhaps prove to be accurate enough. However, these would be expensive and perhaps impractical for orchard use and robust and high speed orchard measuring tools for colour should be further investigated. High speed and accurate hyperspectral colour sorting is already commercially used in stone and tomato fruit in the pack house and have a similar variability in fruit maturity / colour at harvest. This would aid in reducing this additional variable of colour difference at harvest and therefore in storage potential.

CONCLUSION

The varying storage potential was found between orchards in close proximity, which rules out a climatic reason for the differences observed. We have to assume that orchard factors and practices play a significant role in storage potential of 'Triumph' persimmon fruit. Thus, although harvesting fruit according to the PPIS colour chart can improve the general quality of fruit on the shelf, significant variation is likely to occur. We would consequently advise persimmon growers in South Africa to investigate and address the factors that result in poor storage of fruit from some orchards.

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TABLES AND FIGURES

Table 1: Orchards, farms, production area and harvest dates used in an experiment aimed at determining the effect of orchard harvested at one stage of maturity (PPIS colour values 5-6) on storage and shelf-life of ‘Triumph’ persimmon fruit in 2012 and 2013 seasons. Simondium (33° 3’ S, 19° 9’ E), Vyeboom (34° 02’ S, 19° 02’ E), Grabouw (34 ° 59’ S, 18° 00’ E). Allee Bleue and Solms Delta are adjacent farms in Simondium area.

2012 season				
Treatment	**Orchard Number**	**Farm name**	**Area**	**Harvest date**
PBZ treated	1	Allee Bleue	Simondium	19/04/2012
	2	Boesmansrug	Vyeboom	19/04/2012
	3	Allee Bleue	Simondium	23/04/2012
	4	Boesmansrug	Vyeboom	23/04/2012
Early orchards	1	Allee Bleue	Simondium	02/05/2012
	2	Allee Bleue	Simondium	02/05/2012
	3	Chiltern	Vyeboom	07/05/2012
	4	Chiltern	Vyeboom	07/05/2012
Late orchards	1	Auldearn	Grabouw	17/05/2012
	2	Auldearn	Grabouw	17/05/2012
	3	Mardale	Grabouw	22/05/2012
	4	SES	Grabouw	22/05/2012
2013 season				
	1	Allee Bleue	Simondium	09/04/2013
	2	Allee Bleue	Simondium	09/04/2013
	3	Solms Delta	Simondium	11/04/2013
	4	Solms Delta	Simondium	11/04/2013
	5	Allee Bleue	Simondium	15/04/2013

‘Triumph’ persimmon is grafted on *Diospyrus virginiana* rootstock in all orchards sampled

Table 2: The effect of orchards on fruit flesh firmness, fruit colour (hue angle and colour chart), soft fruit percentage, total soluble solids (TSS) and damaged fruit percentage of 'Triumph' persimmon fruit at harvest for trees treated with paclobutrazol to advance harvest maturity, in Western Cape, South Africa in the 2012 season.

Orchard number	Firmness (kg)	Hue angle (˚)	Colour chart index	Soft fruit (%)	TSS (%)	Damaged fruit (%)
1	8.6b*	76.7ab	4.1a	0.0	18.7	35.0ab
2	10.3a	79.4a	3.7ab	2.5	19.0	50.0a
3	8.9b	73.4b	2.8b	0.0	20.1	7.5b
4	11.4a	80.2a	4.2a	0.0	18.4	12.5b
Pr< F	0.0001	0.0087	0.0153	0.4262	0.0749	0.0039

* Means followed by the same letter in the same column do not differ significantly at $P < 0.05$

Table 3: The effect of orchards on fruit flesh firmness, fruit colour (hue angle and colour chart), soft fruit percentage, total soluble solids (TSS) and damaged fruit percentage of 'Triumph' persimmon fruit, assessed after storage from the fruit harvested from the trees treated with paclobutrazol to advance harvest maturity, in Western Cape, South Africa in the 2012 season.

Orchard number	Firmness (kg)	Hue angle (˚)	Colour chart index	Soft fruit (%)	TSS (%)	Damaged fruit (%)
1	6.9ab*	75.3a	3.5b	10.0	17.1a	50.0a
2	8.8a	76.0a	3.7b	7.5	15.9b	15.0b
3	5.9b	70.7b	4.0b	0.0	15.9b	2.5b
4	8.6a	79.0a	5.8a	2.5	15.1b	5.0b
Pr< F	0.0110	0.0005	<.0001	0.4051	0.0005	0.0006

* Means followed by the same letter in the same column do not differ significantly at $P < 0.05$

Table 4: The effect of orchards on fruit flesh firmness, fruit colour (hue angle and colour chart), soft fruit percentage, total soluble solids (TSS) and damaged fruit percentage of 'Triumph' persimmon fruit, assessed after shelf-life from the fruit harvested from the trees that were treated with paclobutrazol to advance harvest maturity, in Western Cape, South Africa in the 2012 season.

Orchard number	**Firmness (kg)**	**Hue angle (˚)**	**Colour chart index**	**Soft fruit (%)**	**TSS (%)**	**Damaged fruit (%)**
1	4.2c*	70.8ab	3.8a	20.0	18.6a	32.5
2	8.3a	72.6a	4.1a	2.5	16.0b	57.5
3	6.2b	69.2b	2.3c	5.0	16.6b	30.0
4	8.0a	72.7a	3.2c	5.0	15.9b	40.0
Pr< F	<.0001	0.0002	<.0001	0.1558	<.0001	0.2507

* Means followed by the same letter in the same column do not differ significantly at P < 0.05

Table 5: The effect of orchards on fruit flesh firmness, fruit colour (hue angle and colour chart), soft fruit percentage, total soluble solids (TSS) and damaged fruit percentage of 'Triumph' persimmon fruit assessed at harvest on the fruit harvested in an early persimmon production area in Western Cape, South Africa in the 2012 season.

Orchard number	**Firmness (kg)**	**Hue angle (˚)**	**Colour chart index**	**Soft fruit (%)**	**TSS (%)**	**Damaged fruit (%)**
1	8.0c*	72.5b	5.4a	0.0	20.6a	17.5
2	9.5b	76.1a	5.5a	2.5	20.0ab	25.0
3	8.8b	75.6a	3.7b	0.0	19.2bc	15.0
4	11.4a	76.5a	3.6b	0.0	18.9c	22.5
Pr< F	<.0001	0.0019	<.0001	0.4262	0.0019	0.8872

* Means followed by the same letter in the same column do not differ significantly at P < 0.05

Table 6: The effect of orchards on fruit flesh firmness, fruit colour (hue angle and colour chart), soft fruit percentage, total soluble solids and damaged fruit percentage of 'Triumph' persimmon fruit assessed after storage on the fruit harvested in an early persimmon production area in Western Cape, South Africa in the 2012 season.

Orchard number	Firmness (kg)	Hue angle (˚)	Colour chart index	Soft fruit (%)	TSS (%)	Damaged fruit (%)
1	5.8c*	71.2b	3.0	10.0	17.9a	10.0
2	7.2b	74.1a	3.1	0.0	18.0a	17.5
3	7.6ab	72.9ab	3.2	7.5	15.5b	27.5
4	8.5a	73.5a	3.1	12.5	15.5b	22.5
Pr< F	0.0001	0.0024	0.9638	0.3457	<.0001	0.2732

* Means followed by the same letter in the same column do not differ significantly at P < 0.05

Table 7: The effect of orchards on fruit flesh firmness, fruit colour (hue angle and colour chart), soft fruit percentage, total soluble solids (TSS) and damaged fruit percentage of 'Triumph' persimmon fruit assessed after shelf-life on the fruit harvested in an early persimmon production area in Western Cape, South Africa in the 2012 season.

Orchard number	Firmness (kg)	Hue angle (˚)	Colour chart index	Soft fruit (%)	TSS (%)	Damaged fruit (%)
1	4.3b*	68.4b	2.8	12.5b	17.9a	40.0ab
2	4.4b	72.6a	3.0	40.0a	17.8a	17.5b
3	4.4b	70.3ab	2.9	57.5a	16.2b	57.5a
4	8.5a	72.8a	3.2	7.5b	15.8b	55.0a
Pr< F	<.0001	0.0004	0.3236	<.0001	<.0001	0.0015

* Means followed by the same letter in the same column do not differ significantly at P < 0.05

Table 8: The effect of orchards on fruit flesh firmness, fruit colour (hue angle and colour chart), soft fruit percentage, total soluble solids and damaged fruit percentage of 'Triumph' persimmon fruit assessed at harvest on the fruit harvested in late production area in Western Cape, South Africa in the 2012 season.

Orchard number	Firmness (kg)	Hue angle (˚)	Colour chart index	Soft fruit (%)	Total soluble solids (%)	Damaged fruit (%)
1	10.1	77.0	5.6a*	0.0	17.4b	2.5b
2	10.6	76.5	4.4b	0.0	19.2a	0.0b
3	9.3	74.5	3.5c	0.0	19.4a	27.5a
4	9.7	79.1	5.5a	0.0	17.3b	7.5ab
Pr< F	0.0933	0.0546	<.0001	-	0.0009	0.0048

* Means followed by the same letter in the same column do not differ significantly at P < 0.05

Table 9: The effect of orchards on fruit flesh firmness, fruit colour (hue angle and colour chart), soft fruit percentage, total soluble solids (TSS) and damaged fruit percentage of 'Triumph' persimmon fruit assessed after storage on the fruit harvested in late production area in Western Cape, South Africa in the 2012 season.

Orchard number	Firmness (kg)	Hue angle (˚)	Colour chart index	Soft fruit (%)	TSS (%)	Damaged fruit (%)
1	9.8a*	76.1ab	5.1a	0.0	15.3b	7.5
2	9.7a	74.6ab	4.9a	0.0	16.0ab	2.5
3	8.1b	72.7b	3.2c	15.0	16.4a	25.0
4	9.1ab	76.6a	4.1b	0.0	15.5b	5.0
Pr< F	0.0174	0.0284	<.0001	0.0728	0.0034	0.0611

* Means followed by the same letter in the same column do not differ significantly at P < 0.05

Table 10: The effect of orchards on fruit flesh firmness, fruit colour (hue angle and colour chart), soft fruit percentage, total soluble solids and damaged fruit percentage of 'Triumph' persimmon fruit assessed after shelf-life on the fruit harvested in late production area in Western Cape, South Africa in the 2012 season.

Orchard number	**Firmness (kg)**	**Hue angle (˚)**	**Colour chart index**	**Soft fruit (%)**	**TSS (%)**	**Damaged fruit (%)**
1	8.2a*	73.9ab	2.8c	7.5ab	15.5ab	12.5
2	9.3a	74.1ab	3.9ab	2.5b	15.5ab	45.0
3	5.8b	72.6b	3.0bc	27.5a	16.5a	57.5
4	9.0a	76.7a	4.4a	2.5b	14.7b	42.5
Pr< F	0.0009	0.0093	0.0032	0.0154	0.0013	0.0585

* Means followed by the same letter in the same column do not differ significantly at P < 0.05

Table 11: The effect of orchards on fruit flesh firmness, fruit colour (hue angle and colour chart), soft fruit percentage, total soluble solids (TSS) and damaged fruit percentage of 'Triumph' persimmon fruit assessed at harvest on the fruit harvested in the same area in Simondium, Western Cape, South Africa in the 2013 season.

Orchard number	**Firmness (kg)**	**Hue angle (˚)**	**Colour chart index**	**Soft fruit (%)**	**TSS (%)**	**Damaged fruit (%)**
1	10.6b*	78.9b	4.6b	0.0	21.4bc	7.5
2	11.2ab	84.9a	6.2a	0.0	21.4bc	12.5
3	10.8b	79.1b	4.1b	0.0	23.9a	2.5
4	11.8a	79.5b	4.0b	0.0	22.5ab	2.4
5	11.3ab	84.6a	5.1ab	0.0	20.6c	0.0
Pr< F	0.0034	<.0001	0.0014	-	<.0001	0.0528

* Means followed by the same letter in the same column do not differ significantly at P < 0.05

Table 12: The effect of orchards on fruit flesh firmness, fruit colour (hue angle and colour chart), soft fruit percentage, total soluble solids (TSS) and damaged fruit percentage of 'Triumph' persimmon fruit assessed after storage on the fruit harvested in the same area in Simondium, Western Cape, South Africa in the 2013 season.

Orchard number	**Firmness (kg)**	**Hue angle (˚)**	**Colour chart index**	**Soft fruit (%)**	**TSS (%)**	**Damaged fruit (%)**
1	10.4	77.1c*	3.2b	15.0a	18.5b	17.5
2	10.2	83.8a	4.3a	0.0b	18.2b	10.0
3	9.9	78.5c	4.3a	0.0b	20.3a	17.5
4	10.3	79.7bc	4.1ab	0.0b	19.1b	7.5
5	10.6	81.6ab	4.4a	0.0b	17.9b	7.5
Pr< F	0.5685	<.0001	0.0095	0.0067	<.0001	0.4746

* Means followed by the same letter in the same column do not differ significantly at P < 0.05

Table 13: The effect of orchards on fruit flesh firmness, fruit colour (hue angle and colour chart), soft fruit percentage, total soluble solids (TSS) and damaged fruit percentage of 'Triumph' persimmon fruit assessed after shelf-life on the fruit harvested in the same area in Simondium, Western Cape, South Africa in the 2013 season.

Orchard number	**Firmness (kg)**	**Hue angle (˚)**	**Colour chart index**	**Soft fruit (%)**	**TSS (%)**	**Damaged fruit (%)**
1	9.4a*	76.6b	4.2b	0.0b	18.1b	17.5
2	10.0a	81.5a	5.0a	7.5b	19.6a	27.5
3	2.3b	71.8c	2.5c	25.0b	20.5a	30.0
4	2.1b	72.6c	3.0c	60.0a	19.9a	32.5
5	10.2a	79.7a	3.8b	5.0b	18.1b	40.0
Pr< F	<.0001	<.0001	<.0001	<.0001	<.0001	0.3053

* Means followed by the same letter in the same column do not differ significantly at P < 0.05

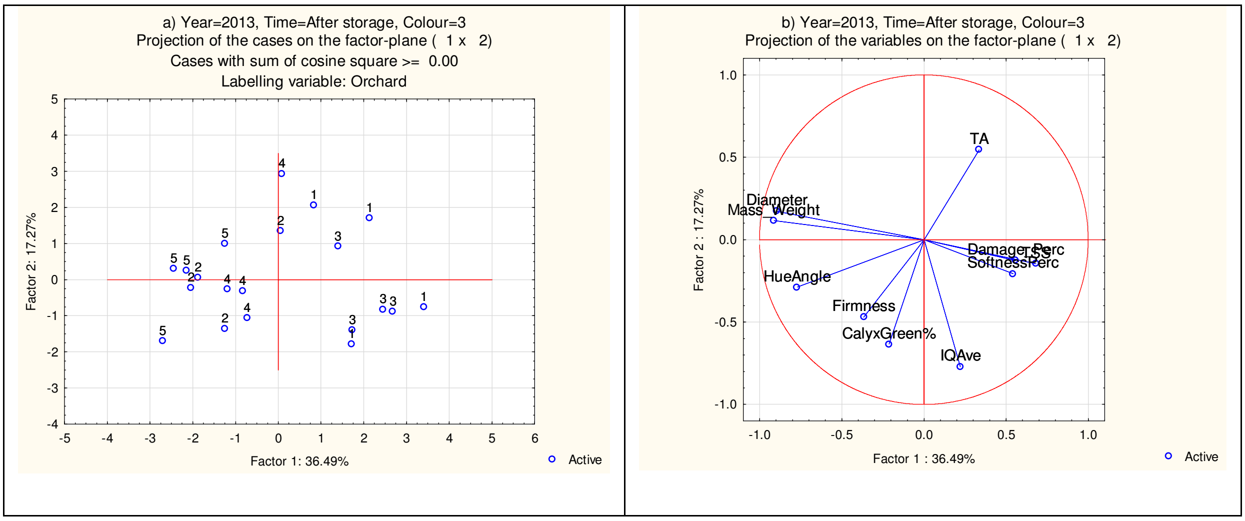

Figure 1: The principal component analysis plotted with the data collected after storage from the fruit harvested in 2013 season, a) Scores plot b) Loadings plots.

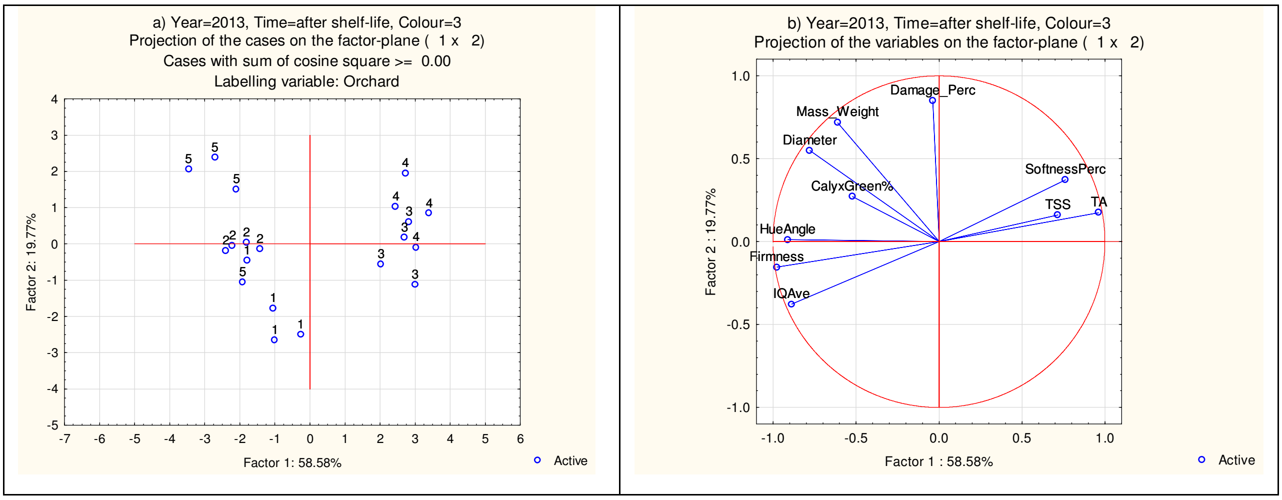

Figure 2: The principal component analysis plotted with the data collected after shelf-life from the fruit harvested in 2013 season, a) Scores plot. b) Loadings plots

PAPER 3

THE EFFECTS OF SIMULATED WIND DAMAGE ON STORABILITY OF 'TRIUMPH' PERSIMMON

ABSTRACT

High wind prevalence results in variable storage potential of 'Triumph' persimmon from Western Cape, South Africa. The aim of this study was to identify post-storage quality defects associated with pre-harvest exposure to wind. The trial was conducted during the 2012 and 2013 seasons on Allee Bleue farm in Simondium, Western Cape. Four treatments simulating wind and a control were randomly applied 10 days prior to harvest. Wind simulating treatments were blowing trees with a mist blower for 10 min and shaking trees for 2 min, while for simulated wind damage, half of the trees were defoliated as well as twisting of the fruit stalks. Fruit were harvested at standard commercial maturity during week 15 in both seasons. Thirty fruit per replicate were collected of which 10 were evaluated at harvest whilst the remainder was de-astringified with 90% carbon dioxide for 24 h whilst being treated with 500 ppb 1-methylcyclopropene (SmartFresh^{TM}) and stored for 6 weeks and 3 days at -0.5 °C. After storage, 10 fruit per replicate were evaluated whilst 10 were stored for four days at 20 °C simulating shelf-life and evaluated thereafter. Wind and wind damage affected post-harvest quality of persimmon fruit at different evaluation stages in the post-harvest life of the fruit in different seasons. Defoliating half the tree and twisting fruit stalks significantly increased soft fruit percentage from 0% at harvest to 28% after cold storage in 2012. Defoliating half the tree and blowing trees significantly decreased titratable acidity compared to the control after shelf-life in 2012 and 2013, and TSS in 2013. Shaking trees for 2 min and twisting fruit stalks significantly delayed fruit colour development after storage in 2013. Although not significantly different from the control, blowing trees with a mist blower increased soft fruit percentage to about 50% after shelf-life in both seasons. In addition, shaking trees induced lower green calyx percentage (27%) in 2012 and higher damaged fruit percentage (72%) in 2013 after shelf-life. Although the effect of wind simulation and damage on storage potential per season varies and should be studied further in more detail, orchard practices that reduce wind speed may have the potential to improve quality of stored 'Triumph' persimmon fruit.

Keywords: *Diospyros kaki,* Simulated wind, Wind damage, Soft fruit, Fruit colour, Twisting fruit stalks, Defoliation

INTRODUCTION

In Western Cape, South Africa, persimmon harvesting time coincides with storms that are associated with high wind speeds and both persimmon plant and fruit are very sensitive to wind (Kitagawa and Glucina, 1984). Breaking of fruit-laden branches, defoliation (Kitagawa and Glucina, 1984), wind rub marks on fruits (Collins et al., 1997) and twisting of fruit stalks are some of the common damages that are associated with high wind speed. Of all the blemishes on persimmon fruit, wind rub marks were found to cause the greatest reduction in marketable fruit in Australia and New Zealand (Collins et al., 1997).

It is reported that wind causes both visible and invisible defects on fresh fruits. Kays (1998) pointed out that high intensity wind result in leaf defoliation, which in fruit crops leads to small fruits, poor fruit colour, and increased surface blemishes such as friction marks on kiwi fruits, wind scab in European prune and wind rub of persimmons. In 'Crimson seedless' grapes, vine defoliation increased berry juice, fruit firmness, total soluble solids (TSS) and decreased acidity (Abd El-Razek et al., 2010). Wind 30-45 days after flowering of 'Dominico harton' plantain increased total sugar content, decreased pulp ash content and increased peel necrotic spotting of the fruit (Parra et al., 2001). In a study on the effects of wind damage on persimmon quality in Korea, fruit weight and TSS decreased significantly with an increase in defoliation rates of 1 fruit per 4, 10 and 20 leaves (Choi et al., 2005). These results indicate that wind affect both external and internal fruit quality.

Visible external marks can be graded and culled after harvest in the orchard or pack houses. However, plants or plant parts experience mechanical perturbation that originates from different sources and is characterized by the absence of direct physical wounding of the tissue (Kays and Paull, 2004). Even though sesimorphogenesis (shaking) and vibromorphogenesis (vibration) were identified as examples of mechanical perturbations, actions such as stroking, bending, flexing and rubbing were also found to exert an influence on plant growth and development (Saltveit and Larson, 1981). The mechanism by which mechanical perturbation induces its effect is not clear, but the reception of the stimulus is known to be quite rapid and recovery gradual taking several days for normal growth to resume (Kays and Paull, 2004). Perturbation increases ethylene synthesis (Kays and Paull, 2004) and effects significant changes in the synthesis of gibberellic acid (Suge, 1978), which both presents sequential responses after initial sensory reception and action (Kays and Paull, 2004). Initial stages of the response to perturbation are assumed to involve a rapid change in membrane permeability and bioelectrical potential (Kays and Paull, 2004). Wind is a natural source of mechanical stress that results in mechanical perturbation at one level and physical damage at another level (Precheur et al., 1978).

Storage potential of Western Cape produced ‘Triumph’ persimmon varies between seasons. It is thought that reduced storage potential in a season could be associated with prevalence of high wind speeds. Although this assumption is based on the above stated theoretical evidence, there is no supportive data to be used in protecting fruit against rapid deterioration as a result of high wind speed occurrences. This study therefore, investigated the effects of wind and or typical wind damage prior to harvest on post-harvest fruit quality of ‘Triumph’ persimmon.

MATERIALS AND METHODS

Trial site

The trial was conducted in two seasons (2012/13) on the same orchard but different trees on Allee Bleue farm in Simondium area (33°3’S, 19°9’E) in Western Cape, South Africa.

Experimental design

The trial was a randomized complete block design (RCBD). The orchard was divided into six blocks (blocks equal to replicates) with the orchard slope as the blocking factor. Two wind simulating treatments, two wind damage simulating treatments and a control were randomly applied to a single tree per treatment in a block. The treatments were applied 10 days before the planned harvesting date (13 April 2012 and 09 April 2013). High wind speed simulated by treatments were blowing trees for 10 minutes with a mist blower (Agriculture mist blower, Yacheng Yili Machinery Co., Ltd, Shandong, China) as well as vigorously shaking trees for 2 minutes by hands. For wind damage simulating treatments, half of the trees were defoliated by removing alternate leaves and twisting fruit stalks of all the fruit per tree. Harvesting maturity was determined according to commercial standard, that is, when 30% of the fruit in an orchard have attained acceptable fruit colour. The acceptable fruit colour is determined according to Plant Protection and Inspection Services (PPIS) persimmon colour chart (PPIS, Bet-Dagan, Israel) as colour chart values 4 to 5 (Fig. 1, Paper 1). Thirty fruit were collected for each replicate (30 fruit x 6 replicates/treatment) and 10 fruit per replicate were evaluated at harvest whilst the remainder was de-astringified with 90% carbon dioxide for 24 h in a hermetically sealed metal box whilst being treated with 500 ppb 1-methylcyclopropene (1-MCP) (Smartfresh™, Agro Fresh, Pennsylvania, USA) and then stored for 6 weeks and 3 days at -0.5 °C. After storage, half of the stored (10 fruit per replicate) fruit was evaluated whilst the remainder was stored for additional four days at 20 °C simulating shelf-life and evaluated thereafter.

Physicochemical measurements

At each evaluation, fruit colour, flesh firmness, TSS, titratable acid (TA), damaged fruit percentage and the percentage of green calyx were determined. Slices were obtained from equatorial regions of fruits, pooled per replicate and juiced. The juice was used for chemical (TSS and TA) analysis. A drop of juice from each replicate was placed on the sensor of a temperature controlled digital refractometer (PR 32, Atago Co, Ltd. Tokyo, Japan) measuring total soluble solids (TSS) in °Brix. The remaining juice per replicate was used for TA analysis. TA was determined using the automatic titrator (719 S Titrino with automatic sample changer model -760, Metrohm South Africa (Pty) Ltd, Private Bag X29, Gallo Manor) which determines malic acid equivalent (%) titrating 10 g aliquot of the juice with 0.1 M NaOH to a pH of 8.2. Soft fruit percentage was determined subjectively on all fruit in a replicate by slightly pressing the equatorial region of the fruit between fingers. The number of soft fruit in each replicate was expressed as a percentage of the total. Flesh firmness (expressed as the load needed to break the flesh) was measured with an 11.1 mm plunger on a fruit texture analyser (FTA) (Güss Manufacturing (Pty) Ltd, Strand, South Africa) on three peeled (1 mm deep) fruit sites (opposite sides equatorially and the apex end of the fruit). The average firmness (kg) was calculated for each fruit including the soft fruits. Fruit colour was determined by the PPIS persimmon colour chart (PPIS, Bet-Dagan, Israel) with colour values 1 to 8 where 1 is the most orange/ red and 8 the pale green stage. External blemishes and marks were visually assessed based on the presence or absence of blemishes and marks. The number of blemished fruit per replicate was expressed as a percentage of the total. Calyx green percentage was visually assessed estimating the percentage of the calyx that remained green.

Statistical procedures

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 least significant difference (LSD) at 5% level.

RESULTS

At harvest:

The effects of simulated wind and wind damage on fruit quality parameters at harvest are shown in Table 1 for the 2012 season and Table 2 for the 2013 season. In the 2012 season, blowing trees with a mist blower, and defoliating half the tree resulted in fruit with advanced orange fruit colour compared to the control, but no significant difference in fruit colour between treatments was found in the 2013 season. Although TSS did not differ significantly between simulation treatments and the control, defoliating half the tree resulted in the lowest TSS in both seasons. Fruit harvested from trees that had half of their leaves removed in the 2012 season had a significantly lower calyx green percentage than fruit harvested from trees that were shaken for 2 min, but there was no significant difference in calyx green percentage between simulation treatments and the control. In the 2013 season, there was no significant calyx green percentage difference; however fruit from the trees that were half defoliated had the lowest calyx green percentage. In general, simulated wind and wind damage had no significant effect on fruit firmness, TSS, TA, soft fruit percentage and damaged fruit percentage at harvest time.

After cold storage:

Table 3 and Table 4 show persimmon quality parameters that were affected by wind and wind damage simulation treatments after cold storage for 2012 and 2013 seasons, respectively. Defoliating half the tree and twisting fruit stalks resulted in fruit with significantly higher soft fruit percentages (28% each) compared to the control (5%) in the 2012 season (Table 3). In contrast, turning fruit stalks in the 2013 season resulted in fruit that had a significantly lower soft fruit percentage after storage compared to the control fruit. Soft fruit percentage of the control did not differ significantly from the other wind and simulated wind damage treatments (Table 4). Although there was no significant firmness difference between wind simulation treatments and the control in the 2013 season, fruit harvested from trees that had half of their leaves removed had significantly less firm fruit than fruit that had their stalks twisted. This difference was not observed in the 2012 season. Although there was no significant fruit colour difference observed in the 2012 season, fruit harvested from shaken trees and fruit that had their stalks twisted had a significantly less developed orange fruit colour than the control fruit in the 2013 season. Blowing trees with a mist blower for 10 min and shaking trees for 2 min resulted in fruit with TA values that were significantly higher than that of fruit that had their stalks twisted in the 2012 season. However, TA values of all the treatments did not differ significantly from that of the control in the 2013 season (data not presented). Generally, there was no significant difference between simulated wind and wind damage treatments and the control for TSS, damaged fruit percentage and green calyx percentage.

After shelf-life:

After shelf-life, fruit quality differs between seasons for the simulated wind and its damage. TA and calyx green percentage were affected in 2012 (Table 5) whereas TSS, firmness, soft fruit percentage, fruit colour (chart value) and damaged fruit percentage were affected in the 2013 season (Table 6). Blowing trees with a mist blower and defoliating half the tree resulted in fruit with significantly lower TSS in the 2013 season. However, this was not observed in the 2012 season. Blowing trees with a mist blower and defoliating half the tree resulted in significantly lower TA compared to the control in the 2012 season. This difference was not observed in the 2013 season. Although not significantly different from the control, fruit harvested from trees that had half of their leaves removed had significantly softer fruit than fruit that had their stalks twisted in the 2013 season. However, this difference was not observed in the 2012 season. Fruit harvested from trees that were blown with a mist blower had the highest soft fruit percentage both in 2012 and 2013 seasons, though not significantly different from the control. In the 2013 season, fruit that had their stalks twisted and fruit harvested from trees that were shaken were less orange in colour compared to the fruit from trees that were blown with a mist blower. However, in the 2013 season, all the treatments were not significantly different from the control and in the 2012 season, there was no significant colour difference observed. Shaking trees resulted in significantly higher damaged fruit percentage compared to the control in the 2013 season and blowing trees resulted in 50% damaged fruit in the 2012 season, but the treatment effect was not significantly different from the control. In the 2012 season, fruit harvested from shaken trees had a lower calyx green percentage than the control but this was not observed in the 2013 season. There was no significant difference between simulated wind and wind damage treatments and the control for fruit firmness, fruit softness percentage and fruit colour in the 2012 season.

DISCUSSION

The results of this study have shown that persimmon fruit exposed to simulated wind damage such as defoliating half the tree and twisting fruit stalks 10 days prior to harvest increased soft fruit percentage after cold storage from 5 to 28% in the 2012 season. However, this increase was not seen when the experiment was repeated in the 2013 season. Simulated wind in the form of mist blowing, although not significantly different from the control, had the highest soft fruit percentage of 50% and 47% after shelf-life in the 2012 and 2013 seasons, respectively. Choi et al. (2005) also reported rapid softening of ‘Fuyu’ fruit harvested from trees defoliated to 100%.

Although TSS for fruit harvested from defoliated trees was not significantly lower than that of the control at harvest, it was the lowest both in 2012 and 2013 seasons. However, TSS for this treatment and also blowing trees with a mist blower were significantly lower than that of the control after shelf-life in 2013 season. In a study of wind damage effects on persimmon quality in Korea, a combination of defoliation and fruit thinning resulted in significant decrease of fruit weight and TSS which were increased by fruit thinning of 60 and 80% without defoliation (Choi et al., 2005). In this study, fruit thinning was not done on defoliated trees; hence the remaining foliage could have failed to supply sufficient photosynthates to the fruit resulting in slightly lower TSS at harvest and significantly lower TSS than the control in 2013 season after shelf-life. Abd El-Razek et al. (2010) also noted a decrease in TSS of defoliated ‘Crimson Seedless’ grapes. Stafne (2012) pointed out that leaf damage on grapevine can cause a reduction in photosynthesis, which negatively impact on fruit quality. Persimmon plants that are not adequately sheltered can be defoliated by strong wind, which leads to poor fruit quality (Kitagawa and Glucina, 1984).

Although there was no significant fruit colour difference among treatments after storage in the 2012 season, fruit colour for fruit that had their stalks twisted were significantly reduced. Testoni (2002) explained that the typical orange colour of persimmons with the formation of high levels of lycopene is obtained only if the fruit are harvested at a correct maturation stage. It is known that if persimmons are harvested too early, the fruit colour is pale orange with yellow discolorations (Testoni, 2002). Poor colour development during storage is a sign of delayed ripening. This may mean that twisting of fruit stalks may have stopped the fruit from obtaining late maturity bio-molecules that are important for post-harvest colour development. Itoo (1986) reported that colour development in persimmon at late stages of maturity is a result of an increase in carotenoids and xanthophylls with the total content of lycopene and other esterified xanthophylls increasing by 30 to 40% and 10 to 20%, respectively at the final stages of maturity. Hodges and Brandle (2006) noted that extreme wind conditions may break stems, which affect translocation of assimilates from one plant part to the other. Persimmon fruit were reported to be very sensitive to wind (Kitagawa and Glucina, 1984). Strong winds break many branches, particularly on trees that are heavily laden with fruit (Kitagawa and Glucina, 1984).

Shaking trees resulted in fruit that had a significantly lower calyx green percentage (26.5%) compared to the control fruit (39.8%) after shelf-life in 2012 season. Persimmon fruit calyx is assumed to help in gaseous exchange as well as in auxin synthesis (Kitagawa and Glucina, 1984) and the more green it remains, the more the fruit is considered fresh by consumers (Jackson and Morley-Burker, 1999).

Commonly known plant damage associated with high wind speeds include leaf stripping, uprooting and breaking of stems and or branches. Wind damage on fruit may be direct surface damage and falling of fruits prematurely (Jackson and Morley-Burker, 1999) or indirectly when fruit quality is affected (Hodges and Brandle, 2006).

CONCLUSION

Apart from wind causing visible blemishes, wind and wind damage such as defoliation of half the tree and twisting fruit stalks influence TSS, TA, colour development and soft fruit percentage during post-harvest storage and ripening. While the effect on fruit colour can be detected at the time of harvest, the effect on fruit softening, TSS, TA, calyx colour and fruit damage may only become evident later after cold storage and or shelf-life. However, great seasonal differences in the response to wind simulations were evident. Apart from actual seasonal differences, this could also be attributed to variations in maturity at harvest as well as differences in orchard practices. Further research over a number of years using improved wind simulation methods is recommended. The effect of strong wind in combination with waterlogged conditions, which typically occur with the onset of winter during the maturation of persimmon fruit in the Western Cape, should also be assessed.

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TABLES AND FIGURES

Table 1: The effect of simulated wind treatments; i.e., BL (blowing trees for 10 min with a mist blower), SK (shaking trees for 2 min), DHL (defoliating half of the tree) and TFS (twisting fruit stalks) on TSS, TA, firmness, soft fruit percentage, fruit colour, damaged fruit percentage and percentage of green calyx of 'Triumph' persimmon at harvest in the 2012 season.

Treatment	TSS (%)	TA (%)	Firmness (kg)	Soft fruit (%)	Fruit colour (chart value)	Damaged fruit (%)	Percentage of green calyx
Control	22.0ns	0.29ns	8.4ns	0.0 ns	3.7a[z]	16.7ns	52.8ab
BL	22.5	0.29	8.3	0.0	3.1b	20.0	52.5ab
SK	22.5	0.30	9.0	0.0	3.4ab	6.7	56.7a
DHL	21.5	0.30	9.1	1.6	3.0b	5.0	45.5b
TFS	21.7	0.31	9.0	0.0	3.7a	21.7	51.8ab
				Pr > F			
Treatment	**0.1289**	**0.4308**	**0.1611**	**0.4711**	**0.0200**	**0.0541**	**0.0185**

ns - not significant.
[z]Means followed by the same letter in the same column do not differ significantly at $P < 0.05$

Table 2: The effect of simulated wind treatments; i.e., BL (blowing trees for 10 min with a mist blower), SK (shaking trees for 2 min), DHL (defoliating half of the tree) and TFS (twisting fruit stalks) on TSS, TA, firmness, soft fruit percentage, fruit colour, damaged fruit percentage and percentage of green calyx of 'Triumph' persimmon at harvest in the 2013 season.

Treatment	TSS (%)	TA (%)	Firmness (kg)	Soft fruit (%)	Fruit colour (chart value)	Damaged fruit (%)	Percentage of green calyx
Control	20.1ns	0.36ns	10.0ns	0 ns	3.2ns	11.7ns	73.3ns
BL	20.3	0.37	10.9	0	3.0	3.3	78.3
SK	20.7	0.35	10.3	0	4.0	5.0	75.0
DHL	19.9	0.35	10.2	0	3.3	11.7	68.3
TFS	20.5	0.37	10.5	0	2.7	1.7	75.0
				Pr > F			
Treatment	**0.2937**	**0.0892**	**0.0814**	**-**	**0.3813**	**0.3679**	**0.3651**

ns - not significant.

Table 3: The effect of simulated wind treatments; i.e., BL (blowing trees for 10 min with a mist blower), SK (shaking trees for 2 min), DHL (defoliating half of the tree) and TFS (twisting fruit stalks) on TSS, TA, firmness, soft fruit percentage, fruit colour, damaged fruit percentage and percentage of green calyx of 'Triumph' persimmon after cold storage in the 2012 season.

Treatment	TSS (%)	TA (%)	Firmness (kg)	Soft fruit (%)	Fruit colour (chart value)	Damaged fruit (%)	Percentage of green calyx
Control	18.5ns	0.17ab[z]	5.0ns	5.0b	3.0ns	16.7ns	43.2ns
BL	19.7	0.18a	4.4	13.3ab	2.9	21.7	43.0
SK	19.6	0.18a	4.8	13.3ab	2.9	6.7	42.8
DHL	19.2	0.17ab	5.0	28.3a	2.8	16.7	41.2
TFS	19.3	0.16b	4.8	28.3a	2.9	21.7	38.7
				Pr > F			
Treatment	**0.1608**	**0.0089**	**0.3481**	**0.0306**	**0.8573**	**0.4766**	**0.6743**

ns - not significant.
[z]Means followed by the same letter in the same column do not differ significantly at $P < 0.05$

Table 4: The effect of simulated wind treatments; i.e., BL (blowing trees for 10 min with a mist blower), SK (shaking trees for 2 min), DHL (defoliating half of the tree) and TFS (twisting fruit stalks) on TSS, firmness, soft fruit percentage, fruit colour, damaged fruit percentage and calyx green percentage of 'Triumph' persimmon after cold storage in the 2013 season.

Treatment	TSS (%)	Firmness (kg)	Soft fruit (%)	Fruit colour (chart value)	Damaged fruit (%)	Percentage of green calyx (%)
Control	17.5ns	7.9ab[z]	33.5a	2.7b	25.0ns	43.5ns
BL	17.2	8.5ab	12.8ab	3.1ab	18.3	44.3
SK	17.4	8.5ab	10.0ab	3.6a	26.7	41.2
DHL	17.3	7.8b	26.4ab	3.3ab	16.7	35.2
TFS	17.1	9.2a	5.4b	3.4a	35.0	38.1
			Pr > F			
Treatment	**0.1212**	**0.0302**	**0.0230**	**0.0105**	**0.2424**	**0.1613**

ns - not significant.
[z]Means followed by the same letter in the same column do not differ significantly at $P < 0.05$

Table 5: The effect of simulated wind treatments; i.e., BL (blowing trees for 10 min with a mist blower), SK (shaking trees for 2 min), DHL (defoliating half of the tree) and TFS (twisting fruit stalks) on TSS, TA, firmness, soft fruit percentage, fruit colour, damaged fruit percentage (DFP) and percentage of green calyx of 'Triumph' persimmon after shelf-life in the 2012 season.

Treatment	TSS (%)	TA (%)	Firmness (kg)	Soft fruit (%)	Fruit colour (chart value)	Damaged fruit (%)	Percentage of green calyx (%)
Control	19.0ns	0.17a^z	3.9ns	41.7ns	2.9ns	28.3ns	39.8a
BL	19.5	0.15b	3.1	50.0	2.9	50.0	30.2ab
SK	18.4	0.18a	4.3	43.0	2.9	28.3	26.5b
DHL	18.8	0.15b	4.0	35.0	3.0	28.3	31.7ab
TFS	19.2	0.16a	3.1	41.0	2.9	20.0	37.3a
				Pr > F			
Treatment	**0.1692**	**0.0046**	**0.3252**	**0.4219**	**0.8076**	**0.0787**	**0.0031**

ns - not significant.
^{z}Means followed by the same letter in the same column do not differ significantly at P < 0.05

Table 6: The effect of simulated wind treatments; i.e., BL (blowing trees for 10 min with a mist blower), SK (shaking trees for 2 min), DHL (defoliating half of the tree) and TFS (twisting fruit stalks) on TSS, TA, firmness, soft fruit percentage, fruit colour, damaged fruit percentage and calyx green percentage of 'Triumph' persimmon after shelf-life in the 2013 season.

Treatment	TSS (%)	TA (%)	Firmness (kg)	Soft fruit (%)	Fruit colour (chart value)	Damaged fruit (%)	Percentage of green calyx (%)
Control	18.0a^z	0.12ns	5.7ab	23.3ab	2.8ab	41.7b	29.9ns
BL	17.0b	0.11	4.6b	46.7a	2.3b	41.7b	35.6
SK	17.9a	0.11	5.6ab	38.3ab	3.2a	71.7a	37.0
DHL	17.0b	0.10	6.0ab	21.7ab	2.7ab	35.0b	29.8
TFS	17.5ab	0.09	7.1a	11.7b	3.1a	40.0b	25.8
				Pr > F			
Treatment	**0.0016**	**0.2179**	**0.0088**	**0.0236**	**0.0036**	**0.0391**	**0.0682**

ns - not significant.
^{z}Means followed by the same letter in the same column do not differ significantly at P < 0.05

PAPER 4

PREDICTION OF POSTHARVEST QUALITY OF 'TRIUMPH' PERSIMMON FRUIT USING NEAR INFRARED (NIR) SPECTROSCOPY

ABSTRACT

This study investigated using Near-infrared spectroscopy (NIRs) as an alternative to the persimmon colour chart to non-destructively assess persimmon fruit quality. Fruit of 4 distinct colour groups were harvested from Allee Bleue farm in the Simondium persimmon growing area (33°3'S, 19°9'E) of the Western Cape province of South Africa. Each colour group had 4 replicates of 15 fruit each, of which 5 were used for analysis at harvest, 5 after 6 weeks and 3 days of storage at -0.5 °C and the remaining 5 after additional 4 days storage at 20 °C simulating shelf-life. Spectra data was obtained by a multi-purpose analyser (MPA) spectrometer from three positions on each fruit, i.e. least coloured equatorial, most coloured equatorial and the stylar end. Reference parameters (flesh firmness, non-destructive internal quality firmness (Sinclair), total soluble solids (TSS), titratable acidity (TA) and fruit colour were determined after spectral measurements. Reference data confirmed that colour chart values alone cannot categorise fruit into precise, distinctive maturity stages at harvest. In both the 2012 and 2013 seasons, all measured parameters had overlapping ranges across maturity stages. NIR calibration and validation models showed that NIRs predicts TSS and fruit colour (hue angle) throughout post-harvest storage and shelf-life of 'Triumph' persimmon fruit. Furthermore, NIRs has shown some potential to predict firmness and TA by scanning certain fruit positions after cold storage and after shelf-life. Further studies should therefore refine the potential of NIRs to non-destructively grade 'Triumph' persimmon fruits into distinctive TSS and fruit colour ranges.

Keywords: *Diospyros kaki,* Non-destructive, Near Infrared spectroscopy, Sinclair, fruit colour, destructive, firmness.

INTRODUCTION

Commercial marketing indices of fruit generally involve some expression of the stage of development and usually require determination of some characteristics known to change as the fruit develops. This may involve taking decision about levels of marketing and consumer acceptability, and generally necessitates making objective and subjective judgements or both (Wills et al., 2007). The objective or subjective assessments may be destructive or non-destructive in nature with the aim of providing the consumer with a uniform, high quality product. The present need in most horticultural industries is for a simple, rapid and readily field or pack-house applicable non-destructive maturity test tool (Magwaza et al., 2012). Non-destructive testing techniques offer the ability to monitor or instantly analyse parameters of fruit in the field, develop strategies for

harvesting as well as for the next stage of handling and packaging at fruit pack-houses where fruit sorting according to certain quality parameters is desirable (Sanchez, 2012). Most commercial quality classification systems for fresh produce are based on external quality aspects because only these attributes can be measured non-destructively at speeds compatible with the typical speed of a commercial sorting line, which may be as high as 10 fruit per second (Nicolai et al., 2005).
In the South African persimmon industry, Plant Protection and Inspection Services (PPIS) colour chart (Bet-Dagan, Israel) is used as maturity indexing tool (Bill, 2012). However, postharvest quality variation of fruit harvested at the same colour chart value is common (Bill, 2012). Even though ground colour as judged against colour charts is a useful index of maturity for fruits such as apple, pears, stone fruits and mango, it is not entirely reliable because it is influenced by factors other than maturity (Wills et al., 2007). Pre-harvest temperature was identified as one of many factors that cause differences between internal flesh quality and colour, where generally high pre-harvest temperature incite rapid maturity of the internal flesh whilst the peel colour is not showing (Kays and Paull, 2004; Wills et al., 2007). Chemical composition analysis such as total soluble solids (TSS) and titratable acidity (TA) as well as some destructive methods of determining firmness such as the use of a penetrometer are laboratory assessments that compliment colour charts. However, these are performed on a sample representing the entire population and hence sample transportation and laboratory analysis have both time and monetary cost implications (Sanchez, 2012). Besides, most current objective methods are destructive and the product is sacrificed with the analyses (Watada, 1989). This impracticality at farm level as well as their destructive nature has prompted the need for a non-destructive sorting tool.

Near-infrared spectroscopy (NIRs) has been suggested to have great potential to non-destructively determine internal attributes of fruits and its maturity (Sanchez, 2012). Near infrared (NIR) is a region of the electromagnetic spectrum that cover the wavelength range from 780 to 2500 nm. In NIRs, the product is irradiated with NIR radiation and when the radiation hits the sample, the incident radiation may be reflected, absorbed or transmitted with the relative contribution of each depending on chemical and physical parameters of the sample (Nicolai et al., 2007). The effect of the interaction of NIR radiation and the chemical and physical attributes of the sample is reflected in the NIR spectra. The shape of the spectra is more related to absorption processes (Nicolai et al., 2007). Louw and Theron (2010) noted that the spectral response is due to changes in a specific chemical component; hence quality is predicted from the correlation between the chemical component and the quality attribute. NIR spectra are dominated by absorption bands associated with CH, OH and NH groups (Sanchez, 2012) and other molecule bonds play a minor role.

Upon generation of the spectral data, the required information is then extracted using advanced multivariate statistics techniques such as partial least squares (PLS) regression (Nicolai et al., 2005). In PLS, information in the original spectra is projected onto a small number of underlying variables called PLS components and the response variables are actively used in estimating the latent variables to ensure that the first components are those that are most relevant for predicting the response variables (Nicolai et al., 2005). Accuracy of the calibration model has to be assessed by validation procedures, which also enable identification of over fitting (Nicolai et al., 2005). Using appropriate statistics to assess the prediction performance is pertinent (Sanchez, 2012). The calibration statistic, squared coefficient of calibration (R^2) was found to reflect the model fitness, but not its performance (Sanchez, 2012). The residual predictive deviation (RPD) is considered the most consensual and useful statistic to compare values of different parameters. Nicolai et al. (2007) presented tables showing research work on use of NIRs in post-harvest quality assessment for attributes such as internal chemical composition, internal defects and physiological disorders as well as external attributes such as fruit colour in tomatoes and dryness in tangerines. However, currently no study on use of NIRs on assessment of persimmon fruit quality has been done.

It was noted that the effectiveness of the technology differs with method, commodity, and the interpretation of data (Watada, 1989). In explaining the effect of commodity as well as method, Nicolai et al. (2005) pointed out that NIR penetration depth is relatively superficial (1-5 mm for a typical reflectance set up) depending on wavelength; hence the applicability to fruit with a thick peel might be limited unless transmission methods with high power illumination are used. Nicolai et al. (2007) pointed out that for each fruit species and cultivar, a new calibration model is required. Kitagawa and Glucina (1984) stated that persimmon peel has many stone cells and consequently is fairly hard although the fruit becomes very soft when overripe. This study therefore evaluates the usefulness of NIRs as an alternative to the persimmon colour chart for assessment of the quality of ‘Triumph’ persimmons at harvest, after cold storage and after shelf-life.

MATERIAL AND METHODS

Plant material

Fruit were harvested on 15 April in the 2012 season and 23 April in the 2013 season from Allee Bleue farm in the Simondium persimmon growing area (33°3’S, 19°9’E) in the Western Cape province of South Africa into four colour groups determined by Plant Protection and Inspection Services (PPIS) persimmon colour chart (Bet-Dagan, Israel) with values 1-8 where 1 = red/ orange and 8 = green. Fruit harvested at colour chart values 1-2 formed colour group 1, fruit harvested at colour chart values 3-4 formed colour group 2, fruit harvested at colour chart values 5-6 formed colour group 3 and colour group 4 was made up of fruit harvested at colour chart values 7-8. In South Africa, ‘Triumph’ persimmons are harvested according to the PPIS colour chart (PPIS, Bet-Dagan, Israel) at values 4 to 5. Each colour group was replicated four times and 15 fruits were collected per each replication. One third of the fruit per replicate was analysed at harvest and the remainder were de-astringified with 90% carbon dioxide in a hermetically sealed metal box whilst being treated with 1-methlycyclopropе (1-MCP) (Smartfresh™, Agro Fresh, Pennsylvania, USA) for 24 h and then stored for 6 weeks and 3 days at -0.5 °C as per commercial procedure. Half of the stored fruit were analysed after cold storage and the remainder was further stored for 4 days at 20 °C simulating shelf-life and evaluated thereafter.

Physicochemical measurements

A multi-purpose analyser (MPA) spectrometer (MPA-0612, Bruker Optics, Ettling, Germany) fitted with a high sensitive, thermo-electrically cooled InGaAs detector solid probe fiber optics module that uses a tungsten lamp as NIR source was used to obtain spectra. Three spectra on each fruit were obtained by directing the solid probe on the fruit peel at opposite equatorial (least coloured equatorial, most coloured equatorial) as well as the fruit stylar end (bottom) positions. Spectra were collected over the wavelength range of 800-2500 nm. For each spectrum, an average of 16 scans with a resolution of 8 nm was used.

After scanning, reference data (flesh firmness, internal quality firmness, TSS, TA and fruit colour) were collected using conventional methods. Flesh firmness measured with an 11.1 mm plunger on a fruit texture analyser (FTA) (Guss Manufacturing (Pty) Ltd, Strand, South Africa), internal quality firmness measured by Sinclair Internal Quality Firmness Tester (Sinclair international Ltd, Norwich, England) and fruit colour measured as hue angle by chromameter (Chromameter CR-400, Minolta Co Ltd, Oska, Japan) were obtained on the same three fruit positions used for NIR scanning. A disc was obtained from the equatorial region of each fruit, and milled in a commercial blender to obtain fruit juice. A drop of the juice from each fruit was placed on the prism plate of a temperature controlled digital refractometer (PR 32, Atago Co., Ltd. Tokyo, Japan) measuring TSS in °Brix. The remainder of the juice was used to measure TA using an automatic titrator (719 S, Metrohm South Africa (Pty) Ltd, Private Bag X 29, Gallo Manor, South Africa), determining malic acid equivalent (%) titrating 10 g aliquot of the juice with 0.1 M NaOH to a pH of 8.2. TSS and TA values obtained from each fruit were assigned to three NIR spectra for that fruit.

Statistical procedures

The Partial least squares (PLS) regression technique in the Opus computer chemometrics software (OPUS version 6.1, Bruker Optics, Ettlingen, Germany) was used to establish mathematical relationships between quality parameter variation in the NIR spectra of samples with the sample variation in quality parameters measured by conventional tools (Nicolai., 2007). Spectra parameters were selected using the optimization function in the "Quant 2 methods" function of the software that checks common wavelength frequency regions in combination with several data pre-processing methods (Louw and Theron, 2010). The data were split into two equal subsets, viz. a calibration and validation set. The calibration model was constructed using the calibration set and prediction residuals were calculated by applying the calibration set to the validation set. The calibration model was assessed in terms of coefficient of determination (R^2), root mean square error of estimation (RMSEE) and RPD, which is defined as the ratio of standard deviation of the response variable to the RMSEE. The performance of the model was described by the coefficient of calibration (R^2), which gives the variation in the reference (true) values that is reproduced in the prediction and has a maximum value of 1.0 for a perfect prediction (Liew and Lau, 2012). In addition, the root mean square error of prediction (RMSEP) which indicates the prediction error or the validation variance and the RPD which is the ratio of the standard deviation of the response variable to the RMSEP were used. An RPD between 1.5 and 2 means that the model can discriminate low from high values of the response variable, a value between 2 and 2.5 indicates that coarse quantitative predictions are possible and a value between 2.5 and 3 or above corresponds to good and excellent prediction accuracy, respectively (Nicolai, 2007). Bias, which shows the average differences between actual value and NIR predicted value (Liew and Lau, 2012), was also used to assess the performance of the model. Reference data were analysed using Statistical Analysis System (SAS) computer program (SAS Enterprise Guide 4.0; SAS Institute, 2006, Cary, NC, USA). For each fruit quality parameter, mean and standard deviation for each colour group (stage of maturity at harvest) was determined.

RESULTS

At harvest

Actual (true) measurements for all quality parameters assessed showed overlapping ranges over stages of maturity at harvest (colour groups) in both 2012 and 2013 seasons (Table 1). The calibration and validation models for the measured parameters at harvest are shown on Table 2 for the 2012 season and Table 3 for the 2013 season. NIRs showed a statistical predictive ability for TSS and fruit colour. R^2 and RPD values in the validation model using all spectra (least coloured equatorial, most coloured equatorial and the stylar end) of 79.88 and 2.26 for TSS and 70.02 and 1.83 for fruit colour in the 2012 season (Table 2) and 74.2 and 1.99 for TSS and 76.46 and 2.06 for fruit colour in the 2013 season (Table 3) were recorded. However, the predictive statistic for scanned fruit position did not show a consistent pattern over seasons for these parameters. In the 2012 season, least coloured side scans had a better TSS prediction (R^2 = 71.34) than most coloured (R^2 = 67.41) and stylar end scans (R^2 = 64.78) whereas the most coloured side scans had a better fruit colour prediction (R^2 = 76.18) than the other fruit position scans (Table 2) in the validation models. In the 2013 season, the stylar scans had a better TSS (R^2 = 69.07) and fruit colour (R^2 = 80.04) predictions than all the other position scans (Table 3) in the validation models. Combined scans (of all positions) gave a better prediction compared to single position scans for TSS at harvest in both the 2012 and 2013 seasons in the validation models. For fruit colour, combined scans had the least predictive (R^2) value compared to the single position scans in the 2012 season and the stylar end scans had the highest R^2 value in 2013 season in the validation models. There was no predictive relationship by NIR spectroscopy for flesh firmness, TA and internal quality firmness using all spectra in both the 2012 and 2013 seasons in the validation models.

After cold storage

The calibration and validation models for the measured parameters after cold storage are shown in Table 4 for the 2012 season and Table 5 for the 2013 season. NIRs showed a statistical predictive ability for TSS and fruit colour with R^2 value of 62.78 and RPD value of 1.64 for TSS and an R^2 value of 72.17 and a RPD value of 1.9 for fruit colour in the 2012 season (Table 4) for all scans in the validation model. In the 2013 season, R^2 value was 83.18 and RPD value 2.45 for TSS while the R^2 value was 68.4 and the RPD value 1.82 for fruit colour in the validation models for all scans (Table 5). In the 2012 season, the most coloured and least coloured side scans had the best TSS prediction (Table 4) whereas in the 2013 season, pooled (all) scans had the best TSS prediction (Table 5) in the validation models. The prediction (R^2) of TSS with single position scans was much lower in 2013 after storage compared to the 2012 season as well as compared to measurements at harvest in the validation models. In the 2012 season, the least coloured side scans had the best fruit colour prediction (Table 4) whereas in the 2013 season, pooled (all) scans had the best fruit colour prediction (Table 5) in the validation models. Even though firmness could not be predicted where all spectra were used, R^2 values of 52.4 in the 2012 season and 54.65 in the 2013 season were obtained for the most coloured equatorial spectra, and R^2 values of 56.21 in the 2012 season and 55.18 in the 2013 season for the stylar end spectra in the validation models. TA had R^2 values of 54.46, 52.06 and 51.95 for least coloured equatorial, stylar end and all sides combined scans, respectively in the validation models in the 2012 season. However, the validation model for the 2013 season did not show predictability of TA. There was no predictive relationship by NIR spectroscopy for internal quality firmness using all spectra in both the 2012 and 2013 seasons in the validation models.

After shelf-life

The calibration and validation models for the measured parameters after shelf-life are shown in Table 6 and Table 7 for the 2012 and 2013 seasons, respectively. NIRs showed a statistical predictive ability for TSS and fruit colour with an R^2 value of 60.97 and RPD value of 1.61 for TSS and an R^2 value of 56.9 and RPD value of 1.53 for fruit colour in the 2012 season in the validation model using all scans. In the 2013 season, an R^2 value of 94.71 and RPD value of 4.42 for TSS and an R^2 value of 68.6 and RPD value of 1.85 for fruit colour in the validation models using all scans were observed. The TSS prediction of 2013 after shelf-life was the best of all evaluations (R^2 = 94.55 in the validation model for all scans). Least coloured side scans had the best TSS prediction both in 2012 and 2013, but fruit colour was best predicted with the stylar end scans in the 2012 season and least coloured side scans in the 2013 season. Even though TA did not seem to be predicted when all spectra were used, R^2 values of 71.35, 54.28 and 61.89 were obtained for least coloured equatorial, most coloured equatorial and the stylar end sides, respectively in the 2013 season in the validation models. Flesh firmness was predicted with R^2 values of 61.52 for the stylar end spectra and 52.28 for the pooled (all) spectra in 2012 season, and an R^2 value of 50.56

for most coloured equatorial spectra in the 2013 season in the validation models. In the 2013 season the R^2 value of internal quality firmness for the styler end was 67.09 and had a RPD value of 1.75 in the validation models. For the remaining spectra in both 2012 and 2013 seasons there was no predictive relationship by NIR spectroscopy for internal quality firmness in the validation models.

DISCUSSION

The results confirm that NIRs can predict TSS (Fig. 1) of 'Triumph' persimmon fruit as for for other fruits. This study also found NIRs to predict fruit colour (Fig. 2) of 'Triumph' persimmon, which agrees with data on tomato (Kusumiyati et al., 2008) and apple (McDlone et al., 2002). However, colour can also be assessed using other non-destructive and readily available and accurate colour sorters such as the chromameter.

In this study, NIRs failed to predict TA of 'Triumph' persimmon fruit. Nicolai et al. (2007) pointed out that the concentration of acids in most fruit and vegetables is smaller than that of sugars and possibly too small to affect the NIR spectrum significantly. Apart from sugars, the dominance of water absorption bands in fresh produce also makes minor constituents difficult to measure (Nicolai et al., 2007). Sanchez (2012) noted that even though TA is difficult to predict using NIRs due to relatively low levels of organic acids, several authors have reported various levels of success in predicting TA of diverse fruits.

Although reasonable results have been obtained for texture attributes that are believed to be related to the scattering properties of tissues and hence firmness (Nicolai et al., 2007), the results of this study showed that NIRs could not significantly predict firmness of 'Triumph' persimmon fruit where all spectra were used. However, R^2 values above 50.00 were obtained, though inconsistently, when different scanned positions were considered. Nicolai et al. (2005) noted that stiffness index which is measured by NIRs is related to, but certainly not equivalent with the traditional Magness-Taylor firmness. Where reasonable results were found, multi- and hyper-spectral techniques with more mechanistic light transport models have been used to address the scattering effect (Nicolai et al., 2007).

Fruit parameters such as firmness, colour, soluble solids, acidity and cell adhesion may change during storage and so does the spectral information (Nicolai et al., 2005). During persimmon storage, the colour of the fruit gradually intensifies, flesh firmness decreases slightly (Kitagawa and Glucina, 1984), TSS increases and TA decreases (Ben Arie and Zutkhi, 1997). In this study, fruit were stored after astringency removal. Persimmon astringency is known to be removed by two processes, viz. dilution and coagulation (Kitagawa and Glucina, 1984). An increase of fruit water during softening and a decrease in chemical bonding (Foss, 2005) are known to interfere with NIR absorption (Nicolai et al., 2007). All these changes may cause changes in NIR absorption and therefore changing prediction ability after storage and shelf-life. The results of this study showed that changes that took place in storage and shelf-life did not affect the predictability of TSS and fruit colour by NIRs. However, NIR spectroscopy has shown some potential to predict firmness and TA by scanning certain fruit positions after cold storage and after shelf-life. The non-destructive internal quality firmness measured by the Sinclair Internal Quality Firmness Tester (SIQFT) is not related or consistently related to the changes in NIRs spectra and cannot be predicted via NIRs. This also indicates that there is a clear difference between Magness-Taylor firmness measurements of force needed to penetrate the peeled fruit compared to using a piezoelectric sensor providing a voltage signal proportional to the impact on the surface (García-Ramos et al., 2005). Persimmon fruit have a tough peel that may change elasticity during storage and ripening, which may be unrelated to changes in flesh firmness measured by the penetrometer.

Overlapping of quality ranges of distinct maturity grades classified using the PPIS colour chart suggest that PPIS colour chart alone fails to group fruit into separate categories according to quality parameters such as TSS, firmness, TA and hue angle.

CONCLUSION

NIRs predicts TSS and fruit colour (hue angle) of ‘Triumph’ persimmon fruit throughout post-harvest. NIRs can be an alternative non-destructive TSS assessment tool on ‘Triumph’ persimmon fruit. Since fruit graded into different maturity stages using the PPIS persimmon colour chart had overlapping quality parameter ranges, NIRs may therefore, be used to compliment PPIS colour chart to further grade ‘Triumph’ persimmon fruits non-destructively into fruits of similar TSS ranges. This may be able to further reduce the variability in quality after storage and enabling a better separation between fruit that should be marketed immediately and the ones that are ideal for storage. However, further research focusing on building a multi-variate quality grading model that includes all important persimmon quality attributes is recommended.

Even though NIRs have shown to have potential to predict TA and flesh firmness, consistency in predicting these parameters was lacking. However, further study with multi- and hyper-spectral techniques with more mechanistic light transport models, is recommended.

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TABLES AND FIGURES

Table 1: Characteristics of the actual quality parameter(firmness, Sinclair Internal quality firmness (IQF), total soluble solids (TSS), titratable acidity(TA) and hue angle) data of 'Triumph' persimmon at different stages of maturity at harvest (colours groups 1- 4) measured at harvest in 2012/2013 seasons.

		Firmness (kg)	**Sinclair (IQ) value**	**TSS (%)**	**TA (%)**	**Hue angle (°)**
Colour group		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
2012 season						
1	True	6.7^{b} ± 2.4	32.7^{ns} ± 5.2	20.7^{a} ± 0.3	0.30^{ns} ± 0.02	65.8^{b} ± 4.2
2	True	8.2^{ab} ± 1.7	35.0 ± 6.2	19.9^{b} ± 0.5	0.30 ± 0.01	69.0^{b} ± 5.0
3	True	9.1^{ab} ± 1.9	37.1 ± 4.8	19.4^{b} ± 0.2	0.31 ± 0.01	80.0^{a} ± 5.8
4	True	10.3^{a} ± 1.0	40.7 ± 5.7	18.8^{b} ± 0.4	0.32 ± 0.01	83.2^{a} ± 5.8
2013 season						
1	True	7.7^{b} ± 0.2	33.9^{ns} ± 6.0	20.8^{a} ± 0.3	0.25^{b} ± 0.04	71.0^{c} ± 3.8
2	True	8.9^{b} ± 1.3	34.7 ± 6.2	19.9^{ab} ± 0.6	0.29^{ab} ± 0.02	73.9^{bc} ± 4.6
3	True	11.6^{a} ± 1.3	37.5 ± 5.5	19.4^{b} ± 0.2	0.30^{ab} ± 0.02	84.0^{b} ± 5.9
4	True	11.6^{a} ± 1.0	38.6 ± 5.8	18.7^{c} ± 0.4	0.32^{a} ± 0.02	94.1^{a} ± 4.5

Abbreviations: ns - Not significant, SD - standard deviation.
Means followed by the same letter in the same column in the same season are not significantly different from each other.

Table 2: The predictive relationship/models (calibration and validation) of NIR spectroscopy and fruit quality parameters: flesh firmness, internal quality firmness (IQF), total soluble solids (TSS), titratable acidity (TA) and fruit colour of 'Triumph' persimmon at harvest by scanned fruit position (least coloured equatorial (GE), most coloured equatorial (YE) and the stylar end (BE) and for all scans combined) in 2012 season.

Quality parameter	Fruit position scanned	Interactive NIR region	Data pre-processing method	Calibration			Validation			
				R^2	RMSEP	RPD	R^2	RMSEP	RPD	Bias
Firmness	GE	1480.2-1310, 970.4-800.2	Constant offset elimination	21.89	2.160	1.13	29.44	2.360	1.36	0.557
	YE	2330.2-1480, 1140.3-800.2	Min-max normalisation	66.31	1.540	1.72	61.01	1.280	1.68	0.384
	BE	2330.2-2160, 1990.3-970.1	Multiplicative scattering	37.42	1.630	1.26	37.47	1.580	1.26	-0.031
	All*	1820.3-1650.2,1480.2-1140.1	Straight line subtraction	40.71	1.590	1.30	29.47	1.870	1.19	-0.006
IQF	GE	2500.1-2160, 1820.3-1480	Min-max normalisation	41.57	3.910	1.31	44.01	3.650	1.34	-0.407
	YE	2330.2-1480, 1140.3-800.2	Min-max normalisation	65.11	3.270	1.69	46.23	3.140	1.36	-0.071
	BE	2500.1-800.2	Straight line subtraction	5.176	7.330	1.03	9.822	5.710	1.06	0.805
	All	1820.3-1650.2, 1480.2-1310	Second derivative	31.81	4.410	1.21	23.57	5.450	1.15	0.294
TSS	GE	2500.1-2160,1990.3-1480	Constant offset elimination	83.94	0.352	2.50	71.34	0.423	1.97	0.136
	YE	2330.2-1480, 1140.3-800.2	Min-max normalisation	72.36	0.455	1.90	67.41	0.453	1.80	0.107
	BE	2330.2-2160, 1990.3-1310	Multiplicative scattering	74.08	0.403	1.96	64.78	0.504	1.69	-0.054
	All	1480.2-1310, 970.4-800.2	Constant offset elimination	76.53	0.403	2.05	79.88	0.357	2.26	-0.059
TA	GE	1820.3-1650.2, 1140.3-970.1	Vector normalisation	94.71	0.003	4.35	40.52	0.010	1.30	-0.001
	YE	2330.2-1480, 1140.3-800.2	Min-max normalisation	14.72	0.011	1.08	24.45	0.011	1.17	-0.002
	BE	1990.3-1820.1, 1650.2-1480	Vector normalisation	34.20	0.010	1.23	25.96	0.010	1.18	-0.002
	All	1820.3-1310	Second derivative	49.04	0.001	1.40	40.00	0.009	1.29	-0.000
Fruit colour	GE	1820.3-1650.2, 1140.3-970.1	First derivative	84.42	3.590	2.53	74.63	3.880	2.00	-0.459
	YE	2330.2-1480, 1140.3-800.2	Min-max normalisation	72.36	0.455	1.90	76.18	3.830	2.05	-0.053
	BE	2160.2-1820.1, 1650.2-970.1	Constant offset elimination	75.60	3.990	2.02	74.14	3.750	1.97	-0.111
	All	1650.2-1480,1310.3-800.2	Constant offset elimination	76.89	4.360	2.08	70.02	4.860	1.83	0.0391

*All - combined spectra for green equatorial, yellow equatorial and the bottom end.

Table 3: The predictive relationship/models (calibration and validation) of NIR spectroscopy and fruit quality parameters: flesh firmness, internal quality firmness (IQF), total soluble solids (TSS), titratable acidity (TA) and fruit colour of 'Triumph' persimmon at harvest by scanned fruit position (green equatorial (GE), yellow equatorial (YE) and the bottom end (BE) and for all scans combined) in 2013 season.

Quality parameter	**Fruit position scanned**	**Interactive NIR region**	**Data pre-processing method**	**Calibration**			**Validation**			
				R^2	RMSEP	RPD	R^2	RMSEP	RPD	Bias
Firmness	GE	2330.4-2160.2	No spectra data pre-processing	57.65	1.580	1.54	53.92	1.360	1.52	-0.14
	YE	1820.3-1310.3, 970.9-800.7	Constant offset elimination	48.98	1.760	1.4	49.39	1.450	1.43	0.285
	BE	1140.6-970.6	Constant offset elimination	54.81	1.400	1.49	64.07	1.270	1.67	-0.065
	All*	1650.6 1480.5, 970.9-800.7	No spectra data pre-processing	56.15	1.450	1.51	48.82	1.600	1.40	-0.03
IQF	GE	2330.4-2160.2, 1820.3-800.7	Constant offset elimination	32.15	5.040	1.21	37.87	4.020	1.27	-0.005
	YE	1820.3-1310.3,970.9-800.7	Second derivative	44.92	4.970	1.35	18.87	5.610	1.12	0.572
	BE	2500.1-2160.2	Vector normalisation	7.31	6.090	1.04	2.033	7.350	1.01	0.261
	All	1140.6-800.7	Multiplicative scattering correction	11.62	5.510	1.06	14.18	5.580	1.08	-0.029
TSS	GE	2330.4-2160.2	No spectra data pre-processing	78.04	0.402	2.13	66.01	0.462	1.76	-0.099
	YE	2330.4-1990, 1820.3-800.7	Constant offset elimination	88.60	0.313	2.96	68.26	0.417	1.79	0.054
	BE	1310.8-800.7	Multiplicative scattering correction	61.27	0.532	1.61	69.07	0.440	1.80	0.031
	All	1820.3-1650.2, 1310.8-970.4	Straight line subtraction	74.71	0.395	1.99	74.20	0.421	1.99	0.065
TA	GE	2330.4-1820.6, 1650.6-800.7	No spectra data pre-processing	53.69	0.032	1.47	50.49	0.027	1.42	-0.000
	YE	1820.3-1650.2, 1310.8-970.4	First derivative	34.65	0.038	1.24	33.46	0.031	1.24	-0.004
	BE	1310.8-1140.6, 970.9-800.7	Vector normalisation	59.17	0.028	1.56	41.52	0.031	1.31	0.002
	All	1820.3-1650.2	First derivative	42.95	0.030	1.32	3.714	3.260	1.02	-0.091
Fruit colour	GE	2330-2160.2, 1650.6-1480.5	Multiplicative scattering correction	83.01	4.670	2.43	79.55	4.430	2.24	0.649
	YE	2500.1-1820.3, 1650.6-800.7	Multiplicative scattering correction	74.40	5.560	1.98	67.06	5.050	1.89	-1.97
	BE	1140.6-800.7	Min-max normalisation	72.98	5.470	1.92	80.04	4.580	2.25	0.363
	All	2330.4-1990, 1820.3-1480.5	No spectra data pre-processing	72.59	5.330	1.91	76.46	5.530	2.06	0.093

*All - combined spectra for green equatorial, yellow equatorial and the bottom end.

Table 4: The predictive relationship/models (calibration and validation) of NIR spectroscopy and fruit quality parameters: flesh firmness, internal quality firmness (IQF), total soluble solids (TSS), titratable acidity (TA) and fruit colour of 'Triumph' persimmon after cold storage by scanned fruit position (green equatorial (GE), yellow equatorial (YE) and the bottom end (BE) and for all scans combined) in 2012 season.

Quality parameter	Fruit position scanned	Interactive NIR region	Data pre-processing method	Calibration			Validation			
				R^2	RMSEP	RPD	R^2	RMSEP	RPD	Bias
Firmness	GE	1820.3-1650.1,1310.3-970.1	Second derivative	78.65	1.660	2.16	47.83	2.600	1.41	-0.457
	YE	1820.3-1650.1	Second derivative	57.46	2.480	1.53	52.11	2.510	1.45	-0.583
	BE	1480.2-1140.1	Second derivative	65.53	2.330	1.7	56.21	2.570	1.36	0.091
	All*	1820.3-1650.2	Min- max normalisation	59.45	2.440	1.57	46.83	2.640	1.37	0.017
IQF	GE	1820.3-1650.1	Second derivative	55.01	4.280	1.46	37.37	4.870	1.27	-0.316
	YE	1820.3-1650.1,1140.3-970.1	First derivative	57.46	2.480	1.53	35.07	4.480	1.25	-0.578
	BE	2500.1-1820.1, 1650.1-800.2	Straight line subtraction	8.668	7.460	1.05	18.03	5.520	1.13	-1.260
	All	1820.3-1310, 1140.3-970.1	No spectral data pre-processing	59.06	4.290	1.56	27.56	5.680	1.18	-0.561
TSS	GE	1820.3-1479.9	Straight line subtraction	89.81	0.279	3.13	69.45	0.487	1.85	-0.096
	YE	1820.3-1650.2,1480.2-1310	Second derivative	78.84	0.402	2.17	69.74	0.454	1.82	0.038
	BE	1820.3-1310	Vector normalisation (SVN)	85.13	0.365	2.59	68.5	0.451	1.79	-0.039
	All	1820.3-1479.9,1310.3-970.1	Min- max normalisation	76.59	0.982	2.07	62.78	1.230	1.64	0.075
TA	GE	1820.3-1650.1,1480.2-970.1	Min- max normalisation	82.4	0.009	2.38	54.46	0.013	1.48	0.001
	YE	1480.2-1310	Min- max normalisation	67.43	0.012	1.75	46.44	0.014	1.37	-7.470
	BE	1480.2-1310	Vector normalisation (SVN)	76.66	0.010	2.07	52.06	0.014	1.44	1.930
	All	1650.1-1140.1	Vector normalisation (SVN)	70.55	0.011	1.84	51.95	0.014	1.45	-0.001
Fruit colour	GE	1480.2-1310	Constant offset elimination	89.25	2.680	3.05	78.34	3.280	2.15	-0.041
	YE	1820.3-1650.1	Second derivative	76.95	4.040	2.08	71.46	4.060	1.88	-0.272
	BE	1480.2-1310.	Vector normalisation (SVN)	86.69	3.260	2.74	67.81	4.350	1.78	0.646
	All	1820.3-970.1	Vector normalisation (SVN)	75.26	4.870	2.01	72.17	5.100	1.9	0.0577

*All - combined spectra for green equatorial, yellow equatorial and the bottom end.

Table 5: The predictive relationship/models (calibration and validation) of NIR spectroscopy and fruit quality parameters: flesh firmness, internal quality firmness (IQF), total soluble solids (TSS), titratable acidity (TA) and fruit colour of 'Triumph' persimmon after cold storage by scanned fruit position (green equatorial (GE), yellow equatorial (YE) and the bottom end (BE) and for all scans combined) in 2013 season.

Quality parameter	Fruit position scanned	Interactive NIR region	Data pre-processing method	Calibration			Validation			
				R^2	RMSEP	RPD	R^2	RMSEP	RPD	Bias
Firmness	GE	2160.5-1989.9, 1820.3-1310.1	No spectral data pre-processing	50.50	2.700	1.42	40.72	2.820	1.30	-0.098
	YE	1650.3-1140.1	Vector normalisation (SVN)	39.43	3.300	1.28	54.65	2.370	1.49	0.138
	BE	1650.3-1480.2,1310.6-800.4	Min- max normalisation	60.24	2.640	1.59	55.18	2.340	1.50	-0.256
	All*	1820.3-1140.1	First derivative	50.92	2.690	1.43	45.92	2.660	1.36	-0.116
IQF	GE	1820.3-1310.1,1140.6-970	Second derivative	60.04	2.850	1.58	9.711	3.550	1.05	0.151
	YE	1310.6-970	Min- max normalisation	81.39	2.050	2.32	35.58	3.090	1.25	0.036
	BE	1140.6-800.4	Min- max normalisation	3.287	4.310	1.02	8.111	3.910	1.05	0.553
	All	1820.3-1140.1	First derivative	28.68	3.560	1.18	23.38	3.590	1.14	0.148
TSS	GE	1650.1-1310.1,1140.6-800.4	Multiplicative scattering correction	83.69	0.893	2.48	67.00	0.497	1.75	-0.055
	YE	2160.5-1989.9,1820.3-970	Multiplicative scattering correction	52.72	1.430	1.45	57.60	1.320	1.54	0.007
	BE	2330.5-2160, 1990.4-1480.2	No spectral data pre-processing	54.23	1.560	1.48	57.05	1.230	1.53	0.010
	All	1820.3-1140.1	First derivative	82.45	0.858	2.39	83.18	0.835	2.44	-0.019
TA	GE	2330.5-1989.9,1650.3-1480.2	Min- max normalisation	18.28	0.024	1.11	29.36	0.022	1.20	-0.002
	YE	2160.5-1989.9,1820.3-1310.4	Multiplicative scattering correction	36.59	0.019	1.26	11.01	0.027	1.09	0.006
	BE	1820.3-1650.3, 1310.6-970	First derivative	75.79	0.013	2.03	23.60	0.0237	1.15	0.003
	All	1820.3-1140.1	First derivative	38.08	0.021	1.27	40.93	0.020	1.30	-0.001
Fruit colour	GE	2330.5-2160, 1990.4-1310.1.	Multiplicative scattering correction	55.15	5.370	1.49	61.32	4.420	1.61	-0.359
	YE	2160.5-1989.9,1820.3-800.4	Straight line subtraction	56.5	6.060	1.52	64.01	4.390	1.77	-1.450
	BE	2330.5-2160, 1650.3-1480.2.	Constant offset elimination	54.69	5.840	1.49	56.14	5.170	1.55	1.120
	All	1820.3-1140.1	First derivative	63.53	5.430	1.66	68.40	4.480	1.82	0.944

*All-combined spectra for green equatorial, yellow equatorial and the bottom end.

Table 6: The predictive relationship/models (calibration and validation) of NIR spectroscopy and fruit quality parameters: flesh firmness, internal quality firmness (IQF), total soluble solids (TSS), titratable acidity (TA) and fruit colour of 'Triumph' persimmon after shelf-life by scanned fruit position (green equatorial (GE), yellow equatorial (YE) and the bottom end (BE) and for all scans combined) in 2012 season.

Quality parameter	**Fruit position scanned**	**Interactive NIR region**	**Data pre-processing method**	**Calibration**			**Validation**			
				R^2	RMSEP	RPD	R^2	RMSEP	RPD	Bias
Firmness	GE	1310.3-1140.1	Vector normalisation (SNV)	31.94	2.890	1.21	34.96	2.62	1.24	0.075
	YE	2160.2-1310, 1140.3-800.2	No spectra data pre-processing	63.09	2.290	1.65	40.81	2.30	1.3	-0.008
	BE	970.4-800.2	No spectral data pre-processing	61.04	2.300	1.6	61.52	2.34	1.62	-0.285
	All*	1820.3-1650.1, 1140.3-970.1	Vector normalisation (SNV)	54.49	2.360	1.48	52.28	2.39	1.45	0.185
IQF	GE	2160.2-1990, 1820.3-1310	No spectra data pre-processing	82.06	2.810	2.36	36.89	3.87	1.26	0.225
	YE	1820- 1650.1	First derivative	71.07	3.140	1.86	48.08	3.52	1.39	-0.235
	BE	2500.1-2160, 1990.3-1820.1	Straight line subtraction	16.55	6.490	1.09	33.94	4.78	1.24	-0.572
	All	1820.3-1650.1,1140.3-800.2	Vector normalisation (SNV)	43.22	4.420	1.33	34.79	4.88	1.25	-0.081
TSS	GE	2160.2-1990, 1820.3-1310	No spectra data pre-processing	60.13	0.801	1.58	73.22	0.58	1.93	-0.030
	YE	2330.2-2160, 1990.3-1479.9	No spectra data pre-processing	87.04	0.457	2.78	61.18	0.70	1.61	-0.044
	BE	1820.3-1479.9, 1140.3-800.2	No spectra data pre-processing	70.39	0.672	1.84	59.85	0.71	1.6	0.124
	All	2330.2-1990, 1650.1-1310	Straight line subtraction	73.73	0.618	1.95	60.97	0.71	1.61	0.053
TA	GE	1310.3-970.1	Vector normalisation (SNV)	31.73	0.021	1.21	23.53	0.02	1.17	-0.002
	YE	2330.2-1310	Straight line subtraction	41.08	0.020	1.3	32.47	0.02	1.23	0.002
	BE	2330.2-2160, 1650.1-1479.9	Straight line subtraction	32.94	0.023	1.22	37.05	0.02	1.28	-0.003
	All	1820.3-1650.1	First derivative	35.5	0.020	1.25	26.82	0.02	1.18	-0.002
Fruit colour	GE	1820.3-1650.1	Min-max normalisation	63.58	5.290	1.66	54.08	5.67	1.48	0.076
	YE	2330.2-1479,9, 1310.3-970.1	No spectra data pre-processing	75.84	4.120	2.03	51.69	5.16	1.44	0.453
	BE	2330.2-1260,1820.3-1650.1	Constant offset elimination	73.77	4.480	1.95	62.75	4.51	1.61	-0.64
	All	1820.3-1650.1, 1140.3-970.1	Vector normalisation (SNV)	59.95	5.630	1.58	56.9	5.59	1.53	-0.423

*All - combined spectra for green equatorial, yellow equatorial and the bottom end.

Table 7: The predictive relationship/models (calibration and validation) of NIR spectroscopy and fruit quality parameters: flesh firmness, internal quality firmness (IQF), total soluble solids (TSS), titratable acidity (TA) and fruit colour of 'Triumph' persimmon after shelf-life by scanned fruit position (green equatorial (GE), yellow equatorial (YE) and the bottom end (BE) and for all scans combined) in 2013 season.

Quality parameter	Fruit position scanned	Interactive NIR region	Data pre-processing method	calibration			Validation			
				R^2	RMSEP	RPD	R^2	RMSEP	RPD	Bias
Firmness	GE	1650.3-1480.2	First derivative	49.72	2.530	1.41	41.21	2.370	1.37	-0.717
	YE	1820.3-1650.3, 1480.7-970	Constant offset elimination	63.61	2.260	1.66	50.56	2.160	1.42	-0.003
	BE	2500.1-2330, 2160.5-800.4	Multiplicative scattering correction	70.31	2.270	1.84	40.28	2.500	1.31	-0.425
	All*	2330.5-2160, 1650.3-1480.2	Min-max normalisation	49.24	2.590	1.40	49.81	2.450	1.41	0.165
IQF	GE	2330.5-1989.9, 1820.3-1650.3	Vector normalisation (SNV)	41.20	3.980	1.30	44.00	3.450	1.37	-0.800
	YE	2500.1-1989, 1480.7-1310.1	No spectra data pre-processing	58.59	3.630	1.55	45.30	3.320	1.35	0.156
	BE	1310.6-1140.1, 970.5-800.4	First derivative	51.88	3.440	1.54	67.09	2.290	1.75	0.124
	All	1820.3-1650.2, 1310.6-1140.1	First derivative	45.09	3.750	1.35	38.38	3.770	1.27	-0.072
TSS	GE	2330.5-1989.9, 1820.3-1650.5	Vector normalisation (SNV)	96.33	0.485	5.22	96.48	0.473	5.39	0.0724
	YE	1650.3-1140.1	Constant offset elimination	96.39	0.501	5.26	94.55	0.594	4.52	-0.189
	BE	1820.3-1650.3,1310.6-970	First derivative	94.61	0.591	4.31	95.98	0.473	5.05	-0.070
	All	1820.3-1310.1, 1140.6-800.4	Straight line subtraction	94.10	0.601	4.12	94.71	0.558	4.42	-0.103
TA	GE	2330.5-2160,1990.4-1819.8,	Vector normalisation (SNV)	71.24	0.033	1.86	71.35	0.031	1.87	0.001
	YE	1820.3-1650.3,1310.6-970	Min-max normalisation	41.99	0.050	1.31	54.28	0.037	1.48	0.002
	BE	2330.5-1989.9, 1820.3-1310.1	No spectra data pre-processing	77.04	0.031	2.09	61.89	0.036	1.65	0.007
	All	1820.3-1650.3	First derivative	65.47	0.035	1.70	48.06	0.042	1.39	0.001
Fruit colour	GE	2330.5-1989.9, 970.5-800.4	Vector normalisation (SNV)	80.50	4.110	2.26	82.40	3.370	2.61	-1.380
	YE	1820.3-970	Vector normalisation (SNV)	77.79	4.500	2.12	79.10	3.840	2.19	-0.186
	BE	2330.5-1480.2, 1310.6-1140.1	Min-max normalisation	79.67	4.350	2.22	76.83	4.250	2.10	0.594
	All	2330.5-2160, 1820.3-1140.1	Min-max normalisation	70.14	5.410	1.83	68.60	5.280	1.85	1.340

*All - combined spectra for green equatorial, yellow equatorial and the bottom end.

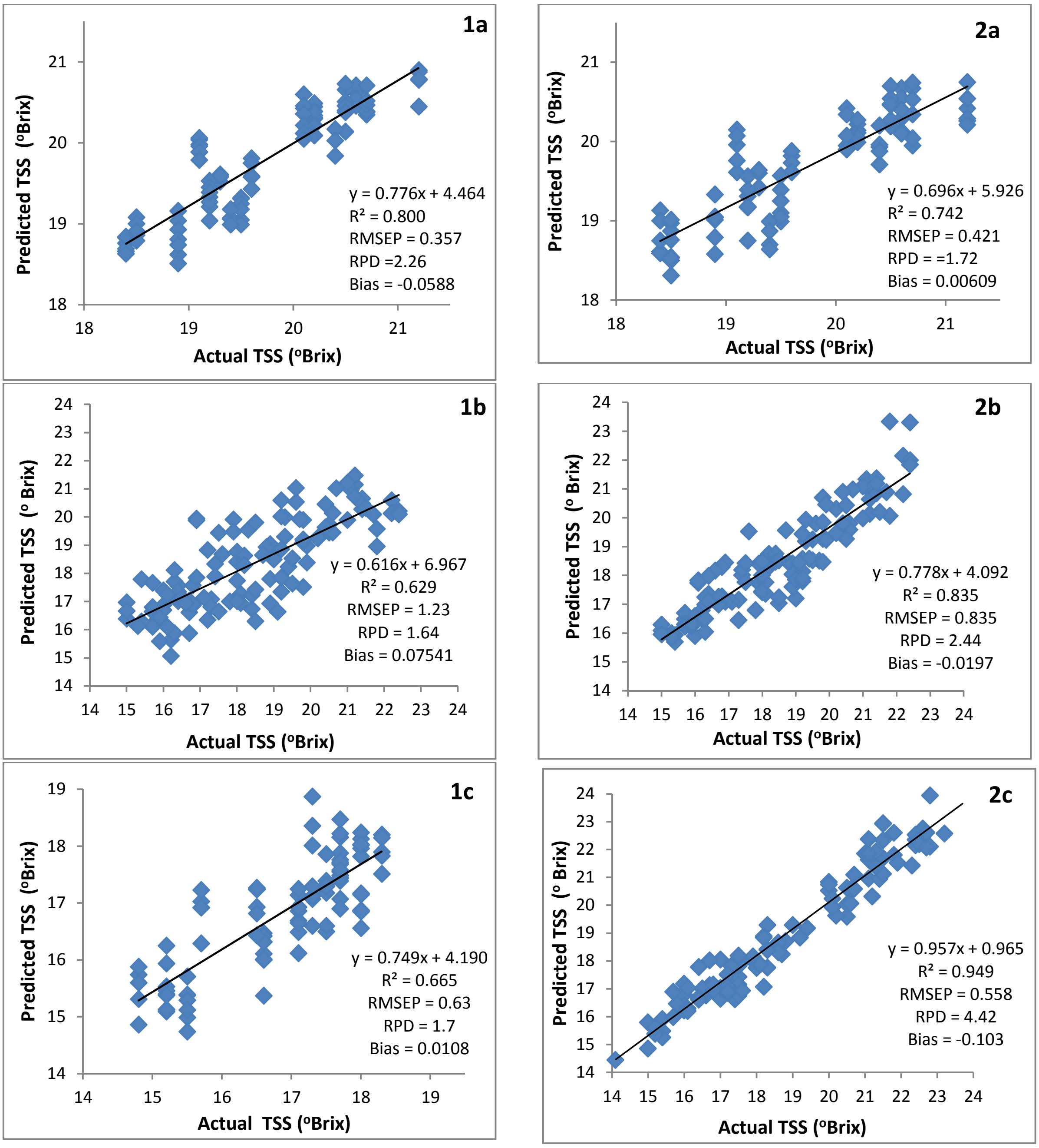

Figure 1: The prediction model of NIR spectroscopy on persimmon fruit for total soluble solids (TSS) scanned at harvest (a), after cold storage (b) and after shelf-life (c) in 2012 (1) and 2013 (2) seasons using all scans.

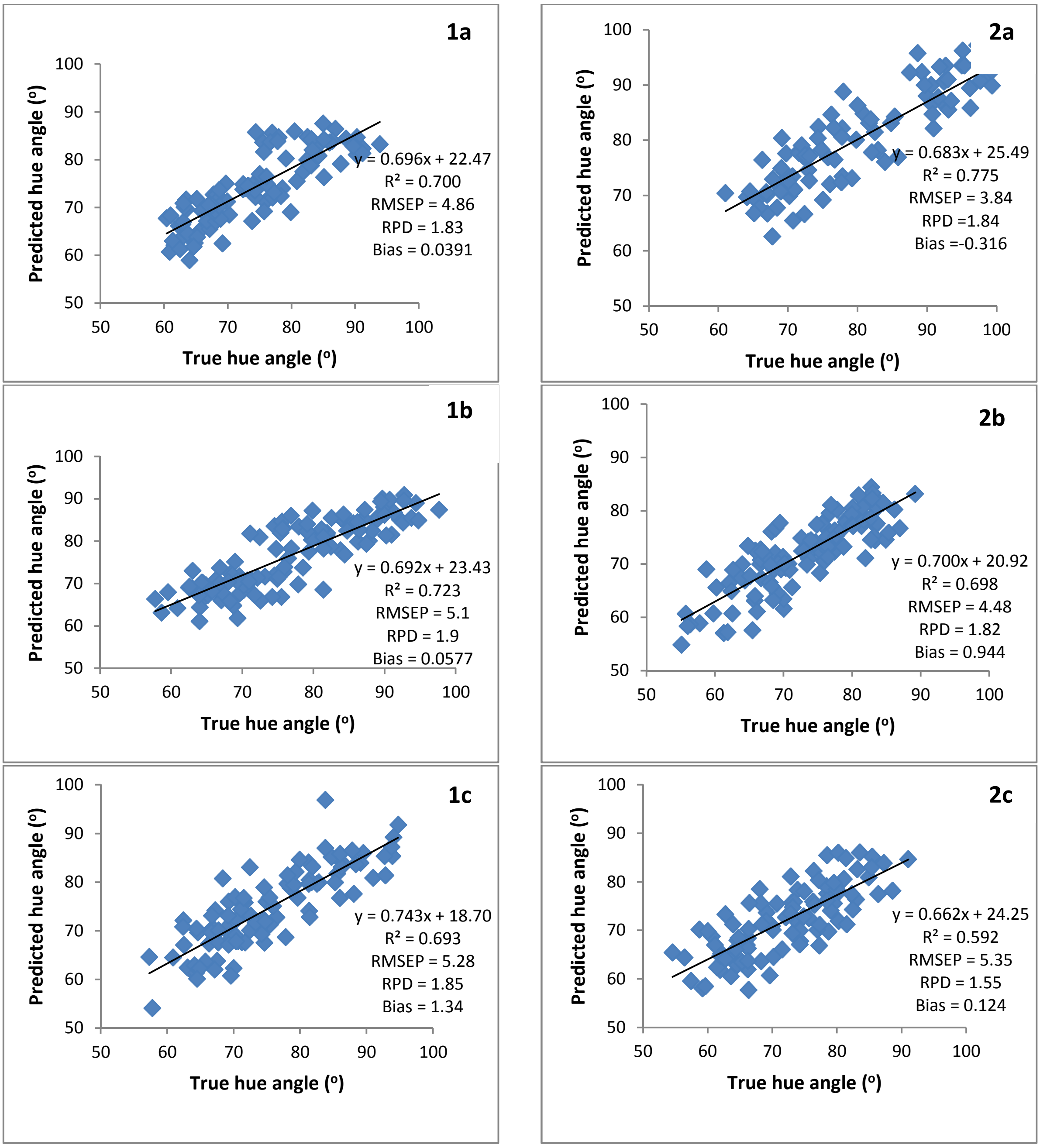

Figure 2: The prediction model of NIR spectroscopy on persimmon fruit for fruit colour (hue angle) scanned at harvest (a), after cold storage (b) and after shelf-life (c) in 2012 (1) and 2013 (2) seasons using all scans.

GENERAL DISCUSSION AND CONCLUSION

In an effort to improve post-harvest fruit quality of South African ‘Triumph’ persimmon, a literature study on pre-harvest factors that affect fruit quality with a special reference to persimmon fruit was conducted. This study was prompted by the knowledge that, post-harvest product quality develops during pre-harvest growth and development stages and is maintained by post-harvest technologies (Hewett, 2006). Ferguson et al. (1999) reported that development of disorders during post-harvest storage and ripening of fruits depends on a range of pre-harvest factors and identification of these pre-harvest factors raises the probability of producing fruits with a lower predisposition to post-harvest disorders. Some of these factors; time of maturity influenced by region and paclobutrazol treatment, stage of maturity at harvest, differences in orchards and orchard management practices and strong wind that coincides with harvesting time were found to be prevalent in the South African persimmon production area, hence their effect on post-harvest quality of ‘Triumph’ persimmon were investigated by experimental studies.

In a study to investigate the effects of time of maturity and stage of maturity at harvest on post-harvest quality of ‘Triumph’ persimmon, the interaction of time of maturity and stage of maturity at harvest on firmness, soft fruit percentage and green calyx percentage was found to be non-significant at harvest. However, the interaction of time of maturity and stage of maturity at harvest on these parameters was found to be significant after cold storage and after shelf-life. Apart from these parameters, time of maturity proved to interact with stage of maturity at harvest on total soluble solids (TSS) and fruit colour of ‘Triumph’ persimmon throughout post-harvest life of the fruit. On titratable acid (TA) and percentage of damaged fruit, the interaction of time of maturity and stage of maturity at harvest was significant at harvest and after cold storage but not significant after shelf-life. TSS, soft fruit percentage, fruit flesh firmness and calyx green percentage after shelf-life showed that late fruit harvested at colour groups 2 and 3 (Plant Protection and Inspection Services (PPIS) colour chart values 3-6) presents fruit that keep quality much better followed by fruit from an early region treated with paclobutrazol (PBZ) and fruit from untreated early orchards had the lowest quality. Early fruit harvested at colour group 3, did not differ statistically to late fruit harvested at colour group 2 after shelf-life with regards to TSS, flesh firmness, soft fruit percentage and fruit colour. In a study to investigate the effects of harvest date on chilling injury development of ‘Rojo Brillante’ persimmon, Salvador et al. (2005) found late harvested fruit to be firmer than early harvested fruit after storage.

Apart from the interaction of time of maturity and stage of maturity at harvest, effects of stage of maturity at harvest were eminent. Fruit harvested at colour group 1 (PPIS colour chart values 1-2), were less firm with high percentage of soft fruit and high percentage of damaged fruit throughout the post-harvest life of the fruit. Fruit harvested at colour group 4 (PPIS colour chart values 7-8) had firmer, less developed fruit colour and low total soluble solids throughout post-harvest life. Fruit harvested at colour group 2 (PPIS colour chart value 3-4), even though they had well developed varietal fruit colour, had high soft fruit percentage after cold storage and shelf-life. Fruit harvested at colour group 3 (PPIS colour chart values 5-6), had firmer fruit, low soft fruit percentage and even though not the best, better fruit colour after storage and shelf-life. Loss of firmness (fruit softening) is known to be the major post-harvest quality problem of persimmon fruit (Woolf et al., 1997), hence harvesting the South African 'Triumph' persimmon for all maturity times at colour group 3 is therefore recommended.

The stage at which the fruit is harvested was reported as the most important post-harvest quality determinant factor (Wills et al., 1989). Bachmann and Earless (2000) pointed out that, since quality is mantained after harvest, it is important to harvest fruit at the proper stages and size and at peak quality. Immature fruit might not ripen and shrivel during storage even though fruit harvested in this stage will be hard and are excellent for handling and storage (Kader, 2002). Overmature produce may not last long in storage (Bachmann and Earless, 2000). Testoni (2002) noted that research done in Italy on persimmon fruit have shown that, fruit picked at the correct ripening stage could be stored for 60 days without loss of quality or decay and skin browning which is a sign of cold damage related to too early harvesting at a ripening stage before the fruit colour has reached the turning stage.

In a study to investigate whether orchards play a role in storage and shelf-life quality of persimmon fruit, it was found that orchard factors and practices play a significant role in the storage potential of 'Triumph' persimmon fruit even if the fruit is harvested at the correct stage of maturity from the same area/region. Orchard differences in storage potential of fruit harvested at the recommended maturity stage in the same region were observed. Differences in the rate of firmness loss during storage and ripening between orchards that was harvested at the same firmness or at the same colour group within one area was prevalent in all seasons. For example persimmon flesh firmness for orchard 1 and 3 fruit in the early PBZ treated region in 2012 was not significantly different at harvest and after storage but there was a 2kg difference in firmness between fruit from these orchards after shelf-life. Such variation was assumed to be the effect of different application of pre-harvest orchard management practices on post-harvest storage of the fruit. Orchard practices such as fruit thinning, prunning, irrigation, fertilisation and fruit tree training modifies pre-harvest environment and hence such operations influence fruit response to post-harvest conditions. Mowat (1992) studied pre-harvest orchard management and climatic conditions that influence 'Fuyu' persimmon fruit quality attributes and moderate to hard winter prunning, an open canopy and moderate to hard fruit thinning were found to be associated with high persimmon fruit quality.

In a study to investigate the influence of wind and wind damage on post-harvest quality of persimmon fruit, the effects of wind and wind damage manifested on different quality attributes at different stages in the post-harvest life of the fruit. Persimmon fruit exposed to simulated wind damage such as defoliating half of the tree and twisting fruit stalks 10 days prior to harvest increased soft fruit percentage from 5 to 28% after cold storage, decreased TSS and TA after shelf-life and delayed fruit colour development after cold storage and after shelf-life. Simulated wind in the form of mist blowing, increased soft fruit percentage to around 47% after shelf-life, and in the form of shaking, induced lower green calyx percentage (27%) and higher damaged fruit percentage (72%) after shelf-life. Mechanical perturbment which is caused by wind is known to increase ethylene synthesis (Kays and Paull, 2004) as well as to effect significant changes in the synthesis of gibberellic acid (Suge, 1978) which both presents sequential responses after initial sensory reception and action (Kays and Paull, 2004).

Apart from the above experimental studies that were carried out to investigate the effects of pre-harvest factors on postharvest quality of 'Triumph' persimmon fruit, a study was conducted to investigate the possibility of using Near-infrared spectroscopy (NIRs) as an alternative or complimentary tool to the PPIS persimmon colour chart. This was prompted by the increasing knowledge that ground colour as judged against colour charts is not entirely reliable because it is influenced by factors other than maturity (Wills et al, 2007; Kays and Paull, 2004; Steyn, 2012) whereas NIRs is successfully used as a non-destructive tool in assessment of internal quality of many fruits (Nicolai et al., 2007; Louw and Theron, 2010; Magwaza et al., 2012). The reference data (data collected using conventional tools and related to NIRs) in this study confirmed that colour chart alone cannot categorise 'Triumph' persimmon fruits into precise distinctive maturity stages at harvest. In both 2012 and 2013 seasons, all measured parameters have shown overlapping ranges across maturity stages. NIR calibration and validation models have shown that NIRs predicts TSS and fruit colour (hue angle) throughout the post-harvest period of 'Triumph' persimmon fruit. The results of this study suggest that NIRs could be used as a non-destructive tool in sorting 'Triumph' persimmon fruit into distinctive total soluble solids and fruit colour classes or grades.

In conclusion, this study found that harvesting South African 'Triumph' persimmon at PPIS colour chart values 5-6, orchard management for post-harvest quality, reducing wind damage and using NIRs as a complimentary maturity indexing tool may improve storage potential of the South African 'Triumph' persimmon fruit.

Future studies should focus on combining fruit colour with other harvesting indices in maturity indexing as well as fruit sorting. Accurate maturity indexing at harvest and storage of uniform fruit may translate into quality maintenance hence better post-harvest fruit quality. Studies to identify orchard practices that promote higher post-harvest fruit quality of the South African 'Triumph' persimmon is also recommended. The effect of strong wind in combination with waterlogged conditions, which typically occur with the onset of winter during the maturation of persimmon fruit in the Western Cape, should also be assessed over a number of years using improved wind simulation methods.

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