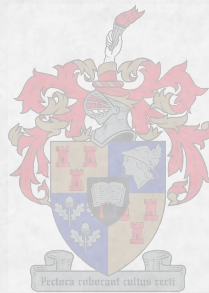


**YIELD AND FRUIT QUALITY OF CITRUS SPECIES  
RELATIVE TO FOLIAR SPRAYS OF  
MACRONUTRIENTS**

**BY**

**MUDAU N. FHATUWANI**



Declaration

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**BY**

**MUDAU N. FHATUWANI**

Thesis presented in partial fulfillment of the requirements for the degree Masters of Science in Agriculture in the Department of Horticultural Science, University of Stellenbosch, Stellenbosch.

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April, 2001

## **Declaration**

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and has not previously, in its entirety or in part, been submitted at any university for a degree.

## SUMMARY

### *Yield and fruit quality of Citrus species relative to foliar sprays of macronutrients*

Marginal fruit colour and poor internal quality have been primary problems in the production of early-maturing mandarins in the Western Cape region (34 °S 19°E). This leads to a reduction in the percentage of exportable fruit, a delay in the picking and consequent reduction in internal quality due to over-maturity. Therefore, a well-developed rind colour and internal quality of citrus are quality parameters of major importance in the fruit market.

The effect of soil-applied limestone ammonium nitrate (LAN) and foliar low-biuret on fruit colour, yield and internal fruit quality of 'Mihowase' Satsuma on 'Troyer' citrange rootstock were evaluated. A significant reduction in leaf N levels was recorded where soil N has been reduced from 168 kg N/ha per annum to 126 kg N/ha per annum. Nitrogen applications influenced internal quality, although differences between treatments were too small to be of commercial importance. Despite tree appearance being more yellow in some years where N was predominantly applied as foliar spray, no consistent reduction in fruit size or yield was found. There were no clear significant differences in fruit colour, probably due to the fact that leaf N-levels were still within or below the norms suggested for Satsuma.

The effect of Seniphos<sup>®</sup>, a mineral mixture of 310g/L P<sub>2</sub>O<sub>5</sub>, 56g/L CaO and 30g/L total N, and mono-potassium phosphate (MKP) [52% P<sub>2</sub>O<sub>5</sub> and 34% K<sub>2</sub>O] on fruit colour, yield and internal fruit quality of mandarins, viz., 'Mihowase' Satsuma and 'Nules' Clementine on 'Troyer' citrange rootstock were evaluated. Seniphos<sup>®</sup> and MKP applied during autumn colour break also did not influence fruit colour, yield and internal fruit quality, viz., juice content (%), total soluble solids (TSS), titratable acid (TA) and TSS:TA ratio of 'Nules' Clementine and 'Mihowase' Satsuma.

In the Citrusdal region of South Africa (Western Cape Province), rind roughness is a general problem which often limits the percentage of exportable fruits. The effect of foliar mono-potassium phosphate (MKP) applied at 3% or 5% and urea ammonium phosphate (UAP) at 2% at 4 or 6 weeks, respectively, after full bloom (AFB) on yield, internal and external fruit quality (rind texture) of *Citrus* spp on rough lemon rootstock were evaluated. MKP and UAP had no consistent effect on yield, juice content (%), TSS, TA and TSS:TA ratio of 'Nouvelle' tangor, 'Valencia' orange, 'Shamouti' midseason and 'Oroval' Clementine. MKP and UAP sprays significantly, but inconsistently improved rind texture of 'Nouvelle' tangor, 'Shamouti' midseason and 'Valencia' orange. However, no positive effect was found on rind texture of 'Oroval' Clementine and 'Eureka' lemon. Inconsistent effects of MKP and UAP sprays were also found on % leaf N, P and K.

## OPSOMMING

### *Opbrengs en vrugkwaliteit van sitrus spesies relatief tot blaar toedienings van makroelemente*

Marginale vrugkleur en swak interne kwaliteit is die primêre produksieprobleme in vroeë seisoen mandaryne in die Wes-Kaap (34 °S 19°E). Die gevolg is 'n lae persentasie uitvoerbare vrugte omdat die oesdatum uitgestel word wat 'n afname in interne kwaliteit veroorsaak weens oorrypheid. Goed ontwikkelde skilkleur en interne kwaliteit is dus van groot belang vir bemerking van die vrugte.

Grond-toegediende kalksteen-ammonium-nitraat (KAN) en lae biuret ureum se effek op vrugkleur, oesgrootte en interne vrugkwaliteit van 'Mihowase' Satsuma op 'Troyer citrange' onderstamme is ge-evalueer. 'n Betekenisvolle afname van die N vlakke in die blare is gevind nadat grond-toediening van N vanaf 168 kg N/ha/jaar na 126 kg N/ha/jaar verminder is. N toedienings het interne kwaliteit beïnvloed, maar die verskille tussen die behandelings was nie van kommersiële waarde nie. Al was die boomvoorkoms geler in sommige jare waarin N hoofsaaklik as blaarvoedings toegedien is, was daar nie konstante afnames in vrug-of oesgrootte nie. Daar was geen betekenisvolle verskille in vrugkleur nie, waarskynlik omdat die blaarvlakke van N steeds binne die norme daarvoor in Satsumas was.

Die effek van Seniphos ('n minerale mengsel van 310g/L  $P_2O_5$ , 56g/L  $CaO$  en 30g/L totaal N en monokaliumfosfaat (MKP) [52%  $P_2O_5$  en 34%  $K_2O$ ] op vrugkleur, oesgrootte en interne vrugkwaliteit van 'Mihowase' Satsumas en 'Nules' Clementine op Troyer citrange onderstamme is geëvalueer. Seniphos en MKP, toegedien tydens kleurbreek in die herfs, het ook nie skilkleur of interne vrugkwaliteit (sappersentasie, totale oplosbare vaste stowwe (TOV), suurheid (TS) en TOV:TS) betekenisvol beïnvloed nie.

In die Citrusdal-omgewing in die Wes-Kaap Provinsie (Suid-Afrika) is skilgrofheid 'n algemene probleem wat die hoeveelheid uitvoerbare vrugte beperk. Die effek van blaartoegediende MKP teen 3 en 5% en ureum-ammonium-fosfaat (UAP) teen 2%, op onderskeidelik 4 of 6 weke na volblom, is geëvalueer ten opsigte van oesgrootte, interne en ekstenne (skil grofheid) vrug kwaliteit in *Citrus spp* op growweskijsuurlemoen onderstam. Nie MKP of UAP het konsekwente verskille getoon t.o.v. oesgrootte, sappersentasie, TOV, TS, of TOV:TS in 'Nouvelle' tangor, 'Valencia' orange, 'Shamouti' midseison of 'Oroval' Clementine nie. Skiltekstuur is egter betekenisvol, hoewel inkonsekwent, verbeter in laasgenoemde drie. Skiltekstuur van 'Oroval' Clementine en 'Eureka' suurlemoen is nie beïnvloed nie. Blaarpersentasies van N, P en K is ook inkonsekwent deur MKP en UAP beïnvloed.

Dedicated to all young South Africans



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# 1. LITERATURE REVIEW: FACTORS AFFECTING INTERNAL AND EXTERNAL FRUIT QUALITY IN CITRUS

## 1.1. INTRODUCTION

Marginal exportable quality and fruit colour has been the primary problems in the production of the early-maturing 'Mihowase' Satsuma. Therefore, these led to a reduction in the percentage of fruit exported a delay in picking and consequent reduction in internal quality due to over maturity.

Small fruit size is a serious problem, reducing grower's return for oranges, grapefruits and tangerines. In mandarins types such as 'Nules' Clementine and 'Mihowase' Satsuma, smaller fruits and internal fruit quality are major the problems.

In the Citrusdal region of South Africa (Western Cape Province), skin roughness is a general problem which often limits the percentage of fruits which can be exported. The soil type is sandy (<10 % clay content), and often deficient in calcium and sulphur (pers. comm<sup>1</sup>). A reduced set of larger fruits with rougher skin is ascribed to sandy soil conditions (pers.obs.). This is clearly seen in 'Shamouti' midseason, 'Valencia' orange, 'Eureka' lemon, 'Oroval' Clementine and 'Nouvelle' tangor. Vigorous rootstocks such as rough lemon gives rise to scion fruits having a rougher peel texture than fruits developing on scions grown on 'Troyer' citrange rootstock (Rabe & Von Broembsen, 1991).

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<sup>1</sup> Personal communication A. van Merwe from ALG Boerdery in October 1999

Consumer demand places an emphasis on internal quality (TSS; (total soluble solids), TA (titratable acidity) and the TSS:TA ratio (total soluble solids to acid ratio)) and external quality (rind colour and texture). Citrus growers must therefore consider the internal and external quality as major determinant factors of sales and export.

A better understanding of foliar nutrition on yield, internal and external quality of citrus trees is of importance, in order to derive reliable exportable quality products through macroelements.

Internal quality is primarily an assessment of TSS (total soluble solids) level, TA (titratable acidity), juice content (%) and (TSS:TA ratio) total soluble solids to acid ratio (Davies & Albrigo, 1994, Gilfillan, 1996). External quality viz., fruit colour is rated using Capespan colour charts (ratings 1 to 8, with 1 rated yellow or orange yellow and 8 rated dark green) and rind texture is rated using the Capespan texture charts (ratings 1 to 8, 1 rated smooth rind and 8 rated rough rind).

This review will cover internal quality parameters, which determine the taste and palatability of citrus, i.e. the TSS, TA and TSS:TA ratio and external quality, mainly rind colour (yellow or orange-yellow, rind texture (smooth rind) and fruit size. The ratio of TSS (measured by a refractometer or hydrometer) and the percent TA (measured as a citric acid by titration) are the most important parameter of internal quality in the citrus industry. The TSS:TA ratio is used to determine optimum maturity for harvesting of fruit.

Therefore, the objective of this review is to address factors that affect internal and external quality through foliar sprays of macronutrients, foliar absorption of nutrients

and nitrogen and carbohydrate fluctuations in citrus. Cultural practices that affect internal, external fruit quality and fruit size will also be included for the sake of completeness.

## **1.2. INTERNAL FRUIT QUALITY**

### **1.2.1 COMPONENTS OF INTERNAL QUALITY**

#### **1.2.1.1. TOTAL SOLUBLE SOLIDS (TSS)**

Total soluble solids (TSS), includes carbohydrates, account for 70-80% of the TSS in the fruit (Ting & Deszyck, 1961). The major carbohydrates in citrus fruits include monosacharides (glucose, fructose), oligosaccharides (sucrose) and polysaccharides (cellulose, starch, hemicellulose, pectins) (Deszyck & Ting, 1960). Sucrose is the primary non-reducing sugar and is the major translatable carbohydrate (Tzur *et al.*, 1992). Closer to maturity, the level of reducing sugars decrease in relation to TSS but the level of sucrose increases rapidly (Tzur *et al.*, 1992). Sucrose synthase primarily functions in sucrose degradation rather than sucrose synthesis especially in tissue in or near the zone of phloem unloading (Kadyi & Tanaka, 1972; Lowell *et al.*, 1989). The sucrose concentration continued to increase through subsequent tissue expansion during fruit growth (Phase II) (Lowell *et al.*, 1989). TSS levels increase as fruit size increases, becoming nearly constant during Phase III (Lowell *et al.*, 1989). In grapefruit, Lowell *et al.* (1989) found that during fruit growth Phase III of development, sucrose levels in juice sacs were less than those in the albedo (the non-pigmented portion of the peel) and the vascular bundle/segment epidermis fraction. The activity of soluble sugar significantly increased throughout fruit development (Iwagaki *et al.*, 1981; Tzur *et al.*, 1992) and more specifically in Phase II, in the transport tissue (Lowell *et al.*, 1989) and the flavedo (Tzur *et al.*, 1992). The enzymatic breakdown of sucrose involves the

invertase and sucrose synthase enzymes (Echeverria & Burns, 1989). Photosynthetic activity in leaves behind the fruiting terminal has been thought to influence levels of TSS in fruit (Kriedemann, 1969; 1970; Koch, 1984a), possibly by “downhill” concentration gradient from leaves to points where sugar is ‘unloaded’ from the vascular tissues in the fruits. Koch (1984b) reported that photosynthates from single leaves near fruit are translocated into the fruit. Furthermore, investigation of individual juice segments has shown that most of the photosynthates from a single leaf move into only one or two of the segments (Lowell *et al.*, 1989).

#### **1.2.1.2. TITRATABLE ACIDITY (TA)**

Total acidity (TA) of citrus juices determines juice quality and time of fruit harvest (Davies & Albrigo, 1994). Citric acid is the primary organic acid (70-90 % of total) followed by malic and oxalic acids with lesser amounts of succinic, malonic, quinic, lactic and tartaric (Ting & Attaway, 1971; Koch, 1984a; Davis & Albrigo, 1994). Acid invertase activity is present in sink tissues and decrease with the onset of maturation (Lowell *et al.*, 1989). The hydrolytic activity of acid and alkaline invertase increases and decreases, as the total and reducing sugar levels increased with the development of ‘Mihowase’ Satsuma mandarins (Kato & Kubota, 1978) and ‘Marsh’ grapefruit (Lowell *et al.*, 1989). The accumulation of citric acid in juice vesicles of citrus fruit directly affects the quality and palatability of the juice (Ting & Attaway, 1971). The juice vesicle produces organic acids (including citric acid) through the glycolytic pathway by which carbohydrates are oxidized and enter the Krebs cycle (Ting & Attaway, 1971; Koch, 1988). PEP carboxylase, the enzyme involved in the organic acid synthesis is present in peel tissue and juice vesicles (Koch, 1988). The rate of citric acid utilization



could ultimately affect levels of this acid which accumulate, and the enzyme aconitase is primarily responsible for its direct breakdown in most tissues (Koch, 1988).

### **1.2.1.3. TOTAL SOLUBLE SOLID TO ACID RATIO (TSS:TA RATIO)**

The ratio of TSS:TA increases during maturation and is a good indicator of palatability (Davies & Albrigo, 1994). Fruit having high TSS:TA ratios and high TSS taste sweet, whereas those with low ratios and TSS are tart (Davies & Albrigo, 1994).

## **1.3. FACTORS AFFECTING INTERNAL QUALITY**

### **1.3.1. ENVIRONMENTAL FACTORS**

#### **1.3.1.1 CLIMATE**

Climate has a dominant effect on fruit quality which varies with the developmental stage of the fruit (Koch, 1988). In tropical climates, TSS levels were lowest in mandarins, grapefruit, tangelos, and tangor (Chandler, 1978; Haury *et al.*, 1978). Gilfillan (1990) reported that hot weather during the normal packing period (NPP), particularly hot dry weather resulted in a lower juice percentage and a more rapid drop in acid levels. The acid levels show little change under cool overcast conditions (Gilfillan, 1996). The highest sugar levels and lower acidity as found in humid areas with warmer nights (Reuther, 1973; Koch, 1988; Davies & Albrigo, 1994).

#### **1.3.1.2. RAINFALL**

Gilfillan (1990) reported that excessive rain or irrigation causes a dilution effect and a subsequent decrease in TSS and the TA before harvest. Sanchez *et al.* (1978) reported that heavy rainfall two months prior to harvest significantly reduced TSS and TA levels

in 'Nules' Clementine. In arid areas with cool nights and low rainfall, fruits are usually well coloured with high sugar, low acid levels and thick rinds (Chandler, 1978).

### **1.3.2. CULTURAL PRACTICES**

#### **1.3.2.1. ROOTSTOCK**

The rootstock has an effect on internal fruit quality as well as influencing harvesting date of the crop. According to Wutscher (1988), 4-year averages of juice content from a large rootstock trial in South Carolina varied 88 % between fruit on Citrumelo F80-18 and on rough lemon. The differences in TSS were 2-3 % and in total acids 0.5% (Wutscher, 1988). Vigorous rough lemon rootstock produces fruit with lower TSS and TA while the TSS and TA are significantly increased on trifoliolate orange hybrids (Gilfillan, 1987; Georgiou & Gregoriou, 1999). 'Palmer' navel orange on 'Troyer' citrange have higher TSS and higher acid contents than fruit on rough lemon (Gilfillan, 1990). This may allow significantly earlier picking because the required TSS:TA ratio is achieved earlier, although restrictions on maximum acid may delay the picking date.

#### **1.3.2.2. MINERAL NUTRITION**

Increasing rates of N application level has the effect of small fruit and a subsequently increase in juice content (Jones & Parker, 1949; Jones & Embleton, 1959; Lynch *et al.*, 1953; Mungomery *et al.*, 1978). High N fertilisation tend to decrease TSS (Reuther & Smith, 1952; Smith, 1967; Calvert, 1969; Mungomery *et al.*, 1978; Hirobe, 1981; Goepfert *et al.*, 1987; Bielorai *et al.*, 1993; Carranca *et al.*, 1993; Orphasnos *et al.*, 1993; Nath & Mohan, 1995) and slightly increase TA (Jones & Embleton, 1958; Reitz & Koo, 1960; Reuther, 1973; Chapman, 1986; Lee & Chapman, 1988; Okada *et al.*, 1992).

High rates of K application resulted in lower juice content (Reuther & Smith, 1952; Koo & Reitz, 1959; Smith, 1966; Calvert, 1970; Cicala & Catara, 1992, Storey & Treeby, 2000). It also increases TA (Reuther & Smith, 1952; Jones & Parker, 1949; Calvert, 1970; Berger *et al.*, 1996) and reduce the TSS:TA ratio (Berger *et al.*, 1996). However, K deficiency lowers the TSS (Sites & Reitz, 1952; Ting, 1969; Reese & Koo, 1974; Koo, 1988). The TSS:TA ratio was decreased by the increase in K rate as a result of increased TA content in Ellendale mandarins (Sites & Deszyck, 1952; Embleton *et al.*, 1956; Reese & Koo, 1974; Lee & Chapman, 1988; Cicala & Catara, 1992; Loupassaki *et al.*, 1992; Lavon *et al.*, 1996). Berger *et al.* (1996) reported that K sources such as  $\text{KNO}_3$ ,  $\text{K}_2\text{SO}_4$  and  $\text{K-MgSO}_4$  increased the TA of fruit at harvest.

High P levels reduce the TSS level of juice (Smith *et al.*, 1952; Smith *et al.*, 1963) and TA (Bouma, 1956; Smith *et al.*, 1963; Anderson, 1966) and increases percentage juice (Jones & Parker, 1949; De Villiers 1969). With mandarins, the TSS levels increased and then decreased with increased P fertilisation (Kefford & Chandler, 1970; Ting & Attaway, 1971). However, it is therefore clear that P give inconsistent results and further research work still need to be done.

### **1.3.2.3. IRRIGATION**

Peng & Rabe (1996) reported that deficit irrigation treatments (soil water tension of  $-60\text{kPa}$ ) significantly increased total TSS content in 'Mihowase' Satsuma fruit over fruit from trees under a normal irrigation regime. Peng & Rabe (1998) also reported that deficit irrigation, to a soil water tension of  $-60\text{kPa}$  at 60 cm depth, initiated at, 0-2 weeks APFD ("after physiological fruit drop") in sandy-loam soil and 0-4 weeks APFD in clay-loam soil, significantly increased TSS level and TSS:TA ratios compared with

the normal irrigation level, where soil water tension reached a maximum of  $-30\text{kPa}$  at 60 cm depth. The sugar content in the rind of severely water-stressed fruits was lower than in those under moderate stress (Mukai *et al.*, 1994). Frequent irrigation has a negative effect on most fruit quality characteristics (Koch, 1988) and rain or frequent irrigation specifically have a dilution effect on TSS (Reitz & Embleton, 1986; Koch, 1988). Koch (1988) also reported that the juice of water-stressed Satsuma mandarin fruits had a higher glucose and fructose level but sucrose levels of stressed fruit were lower than that of the control. According to a report by Levy *et al.* (1978), summer water stress caused high TA levels in 'Marsh' grapefruit and in the winter period. Acidity was correlated with high day temperatures, but neither affected TSS levels (Levy *et al.*, 1978).

#### **1.3.2.4. PRUNING**

High light levels increase sprouting, formation of floral buds and improve inflorescence quality ("greener" blossoms) (Iwagaki *et al.*, 1981). They also showed a positive relationship between light intensity and fruit size, fruit colour and internal quality (high sugar content) and reduce fruit to fruit variability within trees (Iwagaki *et al.*, 1981). Kretchman & Juntras (1963) found that the more severe pruning of 'Duncan', 'Excelsior', 'Walters' and 'Marsh' grapefruit, the larger the fruit size with subsequently lower TSS levels.

#### **1.3.2.5. POSITION IN THE TREE**

Sites & Reitz (1952) reported that 'Duncan' grapefruit borne in the outer canopy averaged 11.1% TSS with a TSS: TA ratio of 12.6 compared to 8.7% with a 10.4 ratio for fruit inside the tree. They also indicated that fruit on the southern and western

position of trees had a higher level of TSS than the northern shady position of the tree (Northern Hemisphere). Fruits from the outer canopy as well as the sunny (north, Southern Hemisphere) side of the tree results in fruits with higher solids content (Reitz & Embleton, 1986). Fruits from the top of the tree also have a higher TSS (Koch, 1988). TA was higher in the northern position but there was no relationship between the fruit position and juice content of the fruit (Sites & Reitz, 1949; Looney *et al.*, 1992). Gilfillan (1990) reported that the differences between the outside northern fruit and the inside southern fruit is often 1-2% TSS units and 0.1-0.2% acid units on large healthy trees while there is little difference on young trees, which have better light conditions because of a less dense canopy. The amount of light intercepted by the leaves determines the photosynthetic potential (Yamanishi & Hasegawa, 1985; Gilfillan, 1990).

#### **1.3.2.6. TREE AGE**

Gilfillan (1990) reported that young trees (less than 5 years for orange and about 3 years for grapefruit) have larger fruit with coarser and thicker rinds. He also reported that fruit from young trees have a lower juice, TSS and acid content than fruit from older trees. As fruit from young trees do not achieve exportable standards, it is advisable to remove the fruit from young trees so as to encourage additional vegetative growth (Gilfillan, 1990).

#### **1.3.2.7. CROP LOAD**

The application of synthetic auxins such as 2, 4-DP (2,4-dichlorophenoxy propionic acid), 3,5,6-TPA (3,5,6-trichloro-2-pyridyl-oxyacetic acid) and ethychlozate during Phase I (cell division phase) and Phase II (cell enlargement) (Iwahori *et al.*, 1986;

Guardiola & Lazaro, 1987; Agusti *et al.*, 1995; Rabe *et al.*, 1995; Koch *et al.*, 1996; Guardiola & García-Luis, 2000), have been widely reported to improve fruit with larger fruit size.

Tominago & Daito (1981) reported that 200 ppm of ethychlozate towards the Phase I and II have been found to produce large fruits with better colour and increase on TSS of 'Mihowase' Satsuma. No significant difference on internal quality viz., juice content, TSS, TA and TSS:TA ratio was found on 'Fina' Clementine after 3,5,6-trichloro-2-pyridyloxyacetic acid spray (Agusti *et al.*, 1995). Hutton (1992) reported that 400mg/L of ethephon tended to decrease TA and increase TSS and TSS:TA ratio of 'Late' Valencia orange. No differences on juice content, TSS, TA, TSS:TA ratio were obtained eight weeks after full bloom on 'Nules' Clementine after 2,4-DP spray (Koch, 1995).

#### **1.3.2.8. CALCIUM ARSENATE SPRAYS**

Calcium arsenate sprays have been used for many years to reduce acidity in 'Valencia' oranges, 'Minneola' tangelos, 'Ellendale' mandarins and 'Marsh' grapefruit (Deszyck & Ting, 1960; Gilfillan, 1992). They reported that the calcium arsenate spray reduces the acid concentration in the juice without affecting the TSS levels. The TSS: TA ratio is thus raised, making the fruit palatable at an earlier stage. Calcium sprays seemingly can also reduce the acid level in the juice from 1.3 % down to 1.0 % two months after fruit set, enabling picking to start 1-3 weeks earlier than untreated trees (Ting, 1969). The arsenate in calcium arsenate reduces the acid level in the juice by partly substituting for phosphate in the ATP-ADP energy transfer system (Gilfillan, 1992). Arsenate is a phosphate competitor resulting in phosphorylation uncoupling of the portion of the

Krebs cycle, which leads to citric acid accumulation (Ting & Attaway, 1971). Arsinilic acid (PROGEN) has been used extensively on 'Marsh' grapefruit, 'Hamlin' and 'Valencia' orange, but the results were not consistent (Wilson & Obreza, 1988).

## **1.4. EXTERNAL FRUIT QUALITY**

### **1.4.1. COLOUR**

#### **1.4.2. FACTORS AFFECTING EXTERNAL QUALITY**

##### **1.4.2.1. LIGHT**

Colour changes in the flavedo results from changes in the level of chlorophylls (Sala *et al.*, 1992), carotenoids (El-Zeftawi & Garret, 1978), anthocyanins (Looney *et al.*, 1992; Treptow, 1994) and lycopene (Davies & Albrigo, 1994). Shaded fruit are less coloured than fruit exposed to light because light stimulates carotenoid synthesis (Reuther, 1988). Fruit trees in hedge rows are therefore likely to develop poor coloured fruits towards the interior of the tree (Davies & Albrigo, 1994). A light level of about 25-30 % of full sunlight is needed to sustain net photosynthesis (Reuther, 1988; Goldschmidt & Koch, 1996). Shading reduces sugar content (TSS) of fruit by reducing net photosynthesis and dark respiration of these shaded leaves (Reuther, 1988; Yamanishi & Hasegawa, 1995)

##### **1.4.2.2. TEMPERATURE**

There are some striking effects of the seasonal temperature regimes on rind colour development especially in oranges and mandarins. In cooler night temperatures, Wardowski *et al.* (1973) suggested that the onset of chilly nights in subtropical climates caused the beginning of yellow or orange coloration of the peel (colour break). It was found that chilling injury caused increased ethylene production associated with the stimulation of chlorophyll breakdown and synthesis of carotenoid in commercial citrus

varieties. Hot climates tended to increase the lycopene concentration in the flesh of grapefruit and pummelos (pink or red fleshed fruits) (Wardowski, 1988).

#### **1.4.2.3. TREE VIGOUR**

Vigorous growing trees have high concentrations of growth promoting hormones such as gibberellins and in such trees fruit colour development is retarded (Krajewski, 1996). Exogenous gibberellin application has been proved to prevent rind colouration (Gilfillan, 1992). Scion/rootstock combinations, which are inherently vigorous, tend to produce fruit with poor colour development. Thus, fast-growing rootstocks such as rough lemon and Volckameriana tend to produce fruit with poorer colour than the slower growing rootstocks such as trifoliata and its hybrids (Davies & Albrigo, 1994; Gilfillan, 1996; Georgiou & Gregoriou, 2000), possibly due to heavy vegetative flushes late in the season (Gilfillan, 1996).

#### **1.4.2.4. MINERAL NUTRITION**

An increase in leaf N from 2.3 to 2.5 % was reported on fruit that received the highest soil N treatments in 'Valencia' orange and 'Marsh' grapefruit (Reuther & Smith, 1952; Jones & Embleton, 1959; Reitz & Koo, 1960) that resulted in delay in fruit colour break. According to Sala *et al.* (1992), trees irrigated with an ammonium-nitrate containing solution (5meq) were less green or more orange-yellow than fruits from trees irrigated with a pure nitrate-containing nutritional solution (5meq).

Heavy K fertilisation (associated with 1.7 % K in the leaf behind the fruiting terminal) tended to produce a high proportion of late maturing, poorly coloured large fruit in Valencia orange (Reuther & Smith, 1952). It was also reported that a low rate of K



fertilisation (associated with 0.8 % K in the leaf behind the fruiting terminal) produced a high proportion of early maturing well-coloured fruit. According to Smith *et al.* (1963), a delay in colour break and subsequent delays in the development of full orange colour becomes noticeable in fruits grown in the presence of high phosphorus applications.

#### **1.4.2.5. SELECTIVE PICKING AND COLOUR SORTING**

The most obvious way for producers to improve the colour of fruit which passes over their grading table is to selectively pick their best-coloured fruit, starting as soon as 10-20% of the fruit has reached full colour (Gilfillan, 1995). Selective picking is the best method in cultivars with a long picking window, such as 'Nules' Clementine to ensure that fruits of the same colour range are degreened or packed. It should be viewed as the cornerstone of fruit colour improvement, even where ethylene hastens fruit colour development (Krajewski, 1996). Fruit that have not broken colour should not be picked, e.g. colour chart T7 and 8 of Capespan's colour chart No. 34. This is due to a risk of more oleocellosis damage as well as the difficulty to grade-out the blemishes in the packhouse, although treated greenish fruit (T7) will respond to ethylene gas for degreening (Gilfillan, 1995).

Colour sorting after picking in the orchard or prior to degreening in the packhouse ensures the best results as it eliminates excess degreening of better coloured fruit and extended degreening of poorly coloured fruit (Krajewski, 1996).

#### **1.4.2.6. CHEMICAL TREATMENTS**

The application of 200 mg.l<sup>-1</sup> of Ethephon (2-Chloro-ethylphosphonic acid) to adult trees of 'Oroval' and 'Marisol' mandarins, both Clementine selections (*Citrus reticulata*

Blanco), enhances fruit colour development (Pons *et al.*, 1992). Ethephon is a commercially available ethylene-releasing compound that is also used to enhance anthocyanin development through ethylene action in apples (Larrigaudiere *et al.*, 1996). Fruit colour development was faster in fruit treated with ethrel, 'Mihowase' Satsuma (Le Roux *et al.*, 1997), 'SRA 63', 'Oroval' and 'Nules' Clementine (Protopapadakis & Manseka, 1992). Ethephon evolves gaseous ethylene at  $\text{pH} \geq 4.1$  (Fishler & Monselise, 1971), thus readily evolved in living cells, which have a cytoplasm pH between 7.0 and 7.5 (Salisbury & Ross, 1992).

The last step in ethylene synthesis occurs in the tonoplast of the vacuole (Salisbury & Ross, 1992). The non-climacteric nature of citrus fruits allows a concentration-dependent response to exogenously-applied ethylene, inducing endogenous ethylene production at a very low level (Protopapadakis & Manseka, 1992; El-Otmani *et al.*, 1996). The exact mode of action of ethylene in rind degreening has to be determined. It is generally accepted that in natural on-tree degreening when night temperatures are sufficiently low, the chilling effect causes mild injury to the rind (Krajewski, 1996), thus stimulating the production of stress-related wound ethylene (Cooper *et al.*, 1969; Petracek & Montalvo, 1997), as well as endogenous ethylene (Cooper *et al.*, 1969). The ethylene causes morphological changes in the exocarp and ultrastructural changes in plastids, leading to chloroplast breakdown and carotenoid synthesis and unmasking of the green colour (Tomás *et al.*, 1993).

Seniphos<sup>®</sup> is a phosphorus-calcium mixture that is believed to improve fruit colour in various red apple cultivars. There is no published work in *Citrus* on the effect of Seniphos<sup>®</sup> on fruit colour development. The mode of action remains unclear, whilst

Larrigaudiere *et al.* (1996) suggested that the treatment improves mineral uptake by apple fruit. Thus, colour improvement may be due to changes in mineral composition of the fruit. In 'Starking Delicious' apple the use of Seniphos<sup>®</sup> stimulates anthocyanin accumulation without activation of ethylene production and subsequent ripening (Gómez-Cordovés *et al.*, 1996; Larrigaudiere *et al.*, 1996). They also reported that Seniphos<sup>®</sup> increased the activity of phenylalanine ammonia-lyase (PAL) enzyme, which appears to be the determining factor for colour enhancement in red apples but the mode of action remains unclear in citrus.

## **1.5. RIND TEXTURE**

### **1.5.1. MINERAL NUTRITION**

Mono-potassium phosphate ( $\text{KH}_2\text{PO}_4$  or MKP) is used as fertiliser, and has shown to be beneficial when applied as foliar spray (Ankorion, 1996; Lavon *et al.*, 1996).

High N application rates have been associated with increased peel thickness (Hirobe, 1981; Goepfert *et al.*, 1987; Carranca *et al.*, 1993; Orphanos *et al.*, 1993; Nath & Mohan, 1995). P application has been found to increase tree yield as well as fruit weight, fruit diameter and reduce fruit peel thickness (Goepfert *et al.*, 1987; Loupassaki *et al.*, 1992; Orphanos *et al.*, 1993).

K application has been observed to increase peel thickness (Goepfert *et al.*, 1987; Ebrahim *et al.*, 1993). Lavon *et al.* (1996) sprayed 'Star Ruby' grapefruit and 'Shamouti' midseason trees with MKP with the objective of improving fruit quality viz., TSS, TA and external quality (rind texture). He reported that beneficial effects

attributed to MKP application include decrease in TA, peel thickness, and rind roughness, increased in fruit size, juice content, TSS and TSS:TA ratio.

When a high level of K fertilisation was used in conjunction with high levels of N, high yield was obtained, but a high proportion of the fruit were undesirably large in size, late maturing and poorly-coloured in 'Valencia' orange (Reuther & Smith, 1952). However, when low or moderate levels of K fertilisation was used in conjunction with high N level, high yield and fruit with a smooth textured rind was obtained in 'Valencia' orange (Reuther & Smith, 1952). Heavy K fertilisation (associated with 1.6 to 1.9 % K in dry matter) tended to produce a high proportion of late maturing poorly coloured large fruit with a thick coarse-textured rind in pineapple orange (Smith *et al.*, 1963). They reported that a low rate of K fertilisation (associated with 0.7 to 1.0 % K in leaves) produced a high proportion of early-maturing small fruit with a thin, smooth-textured rind.

## **1.6. MORPHOLOGY OF CITRUS FRUIT GROWTH**

Citrus fruit (hesperidium-type berry) follows sigmoidal pattern (Guardiola & Garcia-Luis, 2000) identified in three growth phases e.g. 'Valencia' orange fruit, Phase I, 60 days, from full-bloom to mid-November (S.H); Phase II approx. 29 weeks, from mid-November to mid-June; Phase III, the maturation period from mid-June to harvest.

Phase 1 is the cell division phase which extends from mid-November (S.H) (Bain, 1958). Increase in fruit size is mainly due to increase in the thickness of pericarp as a results of cell division (Guardiola & Carcía-Luis, 2000). These cells differentiate into the flavedo and albedo, oil glands, pulp segments and juice sacs (Bain, 1958). The

length of cell division is critical as longer period ensures larger fruit with fresh and dry mass (Bain, 1958).

Phase II is elongation phase which characterised by the vasculisation of the juice sacs, the marked increase in size of the locules and a significant reduction in the peel thickness (Guardiola & García-Luis, 2000). The rate of dry matter accumulation increases initially with fruitlet age to reach maximum value at the beginning of the cell elongation phase to remain nearly constant until maturation (Guardiola & García-Luis, 2000).

Phase III is the maturation phase (from Mid-June to harvest ) in Southern Hemisphere. It is marked by ripening of the fruit with decrease growth rates, flavedo colour changes, a slight increase in TSS and decrease TA (Bain, 1958; Davies & Albrigo, 1994). Increases in fruit size with increases in the pulp and central axis (Bain, 1958).

## **1.7. FRUIT SIZE**

The production of citrus fruit of marketable size is of critical economic importance especially in smaller mandarins 'Tomango' midseason and 'Valencia' orange. In these cultivars a significant percentage of the crop cannot be marketed at economic prices as fresh fruit due to small fruit sizes. These have to be used in local markets, and juice factories where the returns are not lucrative. Therefore, fruit size is one of the main parameters determining citrus fruit quality. There are numerous factors that determine the final fruit size. These can be categorized in two groups, i.e. non-controllable factors such as climate (viz. temperatures, light intensity, sunshine, rainfall, irrigation and wind), rootstock and scion and tree age (Gilfillan, 1987). Controllable factors include

mineral nutrition (Jones & Embleton, 1958; Lavon *et al.*, 1996), crop load, diseases and pests (Gilfillan, 1987) as well as pruning (Krajewski, 1996).

### **1.7.1. FACTORS AFFECTING FRUIT SIZE**

#### **1.7.2. NON-CONTROLLABLE FACTORS**

##### **1.7.2.1. CLIMATE**

The components of climate that have been found important are ambient temperature, rainfall, solar radiation, wind (Reuther, 1973; Du Plessis, 1980; Gilfillan, 1987). In South Africa, citrus growing areas have been classified into, “smaller” fruited areas, comprising the largest part of the citrus producing areas and “large” fruited, representing the hotter regions, e.g. Malelane, Komatipoort, Hoedspruit, Nkwaleni, Tshipise and Citrusdal. The cooler “smaller” fruit producing areas are Letsitele, Nelspruit, Zebediela, Sundays River Valley, Gamtoos, etc.

**Temperature:** Du Plessis & Smart (1982) reported that temperature during pre-bloom periods is the major determining factors of fruit size. Apart from photochemical reactions, enzymatic reactions are affected by temperature. Fruit size can be divided into different phases (Guardiola & García-Luis, 2000).

Phase I: The rate of cell division and enlargement is dependent on the minimum and maximum temperature, hence maximum temperature during flowering and stage I periods improve fruit growth when temperature does not exceeds 30 °C. There is a rapid increase in fruit growth between 26 °C and 30 °C (Gilfillan, 1990).

Phase II: This is the cell elongation phase. Fruit size is rarely limited by temperature that are too low during this stage, but temperatures that becomes too high restricts growth (Gilfillan, 1990). Hilgeman *et al.* (1967) reported that temperatures greater than 38 °C decreased fruit growth in mid and late summer (December to March in South Africa).

Phase III is the maturation phase. No climatic effects on fruit size have been reported during this stage (mid June to harvest of 'Valencia' orange) (Gilfillan 1987). Gilfillan (1990) reported that fruit size continues to increase at a lower pace.

It is reported that the average maximum temperatures in October and November were the main determinants of fruit size in 'Valencia' orange in the Nelspruit area with lower temperatures resulting in smaller fruit sizes (Gilfillan, 1990). The cold stress induces dormancy, which permits the build up of nutrient reserves, and carbohydrates for the subsequent flowering and fruit set (Du Plessis, 1996). The average daily air temperature for Citrusdal during June, July and August is approximately 13 °C while it is approximately 15 °C over the same time period at Nelspruit. Therefore, with lower average air temperatures and a more intense cold being experienced at Citrusdal, the citrus tree should enter a more pronounced rest period and accumulate reserves. However, the same climatic factors, i.e., daily average air temperature below 13 °C during the winter until September appears to be responsible for causing late flowering at Citrusdal (Du Plessis, 1996). Hilgeman *et al.* (1967) reported that periods of extreme heat of approximately 40 °C might cause injuries. During excessively hot days, roots never meet the strong evaporative demand of the leaves, this high demand is caused by high transpiration and high air vapour pressure deficit and is enhanced under windy conditions (Gilfillan, 1987).

**Irrigation and rainfall:** Adequate rainfall and irrigation during Phase II (cell enlargement) significantly improves fruit size and juice content (Davies & Albrigo, 1994), although Gilfillan (1990) reported that ample water supply during all fruit growth stages is of importance.

**Solar radiation:** Although citrus can tolerate partial shade, full sun is of importance in order to obtain high production throughout the phases of plant growth and development (Reuther, 1973). The higher the sunshine hours, the higher the photosynthates that tend to produce fruit with larger size (Davies & Albrigo, 1994). However, sunshine is also very important during Phase 1 of the growth cycle by causing fruit abscission and consequently increase the final fruit size (Gilfillan, 1990; Du Plessis, 1996). When comparing fruit size of two different areas in South Africa i.e. Nelspruit ('small fruit') and Citrusdal ('large fruit'), sunshine differs between these two regions (Du Plessis, 1996). He reported that between October and March, Citrusdal had more sunshine due to less cloud cover in summer with the difference increasing from 1.3 hours/day in October to 3.9 hours/day in January. The higher the sunshine hours the higher the photosynthates that tend to produce fruit with larger size (Davies & Albrigo, 1994).

**Wind:** Wind conditions and soil temperatures are secondary factors that influence fruit set period (Gilfillan, 1987). This can also be severe particularly when the wind is dry (Gilfillan, 1987). During excessively hot days, roots never meet the strong evaporative demand of the leaves, this high demand is caused by high transpiration and high air vapour pressure deficit and is enhanced under windy conditions (Gilfillan, 1987). Monthly wind run for Citrusdal are larger for all month compared with Nelspruit (Du Plessis, 1996). Cool air carried in from the Benguela ocean current in Citrusdal has a



cooling effect on leaves that is hypothesized that citrus leaf temperature in Citrusdal is lower than Nelspruit, that is assumed that fruit tend to have enough water that results in an increase of fruit size due to lower transpiration rate (Du Plessis, 1996).

#### **1.7.2.2. TREE AGE**

Many factors contribute to low average yields, e.g. declining trees due to age. Stanton (1982) reported that young trees produce larger because high concentrations of growth promoting hormone e.g. auxin, lower percentage of fruit per leaf area which often limit intersink competition on fruit growth and increases the sink strength of the fruitlets.

#### **1.7.2.3. SCION SELECTION**

Various clonal selections give better fruit size than others. The 'Delta' and 'Midnight' selections of 'Valencia' give better fruit size than 'Olinda' and 'Frost Nucellar' (Gilfillan, 1987). The problem of small fruit size is particularly acute with 'Hamlin' on sour orange and sweet orange rootstocks (Reese & Koo, 1974).

#### **1.7.2.4. ROOTSTOCK**

Trees on Rough lemon (*Citrus jambhiri* Lush) and Rangpur lime (*Citrus limonia* Osbeck) rootstock produce good fruit size (Gilfillan, 1987). It was reported that less vigorous rootstocks such as the 'Troyer' and 'Carrizo' citrange, sweet orange and Rubidoux (small flower) trifoliolate give intermediate sized fruit while 'Cleopatra' mandarin, 'Pomeroy' trifoliolate and 'Morton' citrange are associated with smaller fruit sizes (Gilfillan, 1987). According to Fallahi *et al.* (1989), fruits of 'Redblush' grapefruit on 'Carrizo' and 'Troyer' citrange were significantly larger than fruit on 'Volckameriana' lemon. However, there is no universal rootstock that can be

recommended for all conditions. Many aspects have to be considered besides fruit size such as, rind thickness, juice content, TSS and TA that cannot be compromised (Georgiou & Gregoriou, 1999).

### **1.7.2.5. TRISTEZA AND GREENING DISEASES**

Gilfillan (1987) reported that tristeza-infected trees produce smaller fruit. Root systems of severely-affected trees show an almost complete lack of feeder roots and larger roots are often found rotting. Decaying roots and even the trunks up to the bud union are almost devoid of starch. Less severely-affected trees, and trees that have staged a limited recovery, have little leaf flush and a large crop of small fruit (Gilfillan, 1987). Martinez & Wallace (1969) reported that fruits from trees affected with greening were abnormally small, underdeveloped, lopsided, strongly acidic in taste and hardened during stage III. Maclean *et al.* (1969) also suggested that these effects are caused by impaired translocation of photosynthates within the tree, and fruits borne on infected branches are of poor quality remaining small and dropping prematurely.

### **1.7.3. CONTROLLABLE FACTORS**

#### **1.7.3.1. MINERAL NUTRITION**

Potassium nitrate have generally been quite successful in increasing fruit size (Page *et al.*, 1963, Bredell & Rusk, 1969; Calvert, 1969; Reese & Koo, 1974; Androulakis *et al.*, 1992). The concentration of K in the soil solution is dependent on the amount of adsorbed K on the soil colloids, the cation exchange capacity and type of clay mineral (Gilfillan, 1987). Other studies show that soil applications of K are of doubtful value on soil that “fix” large amounts of K. The only mineral nutrient that is reported to increase fruit size is K (Reuther & Smith, 1952; Sites & Deszyck, 1952; Koo & Reitz, 1959; De

Villiers, 1969; Calvert, 1970; Fourche *et al.*, 1977; Goepfert *et al.*, 1987; Orphasnos *et al.*, 1993; Lavon *et al.*, 1996). In 'Valencia' orange, leaf K levels less than 0.9 % (on a 7-month leaf behind the fruiting terminal) resulted in reduced fruit size (Okada *et al.*, 1992). Du Plessis (1982) reported that 4% KNO<sub>3</sub> sprays applied in November and December give better fruit size. It is reported that little attention has been given to the physiological functions of K in the citrus tree and fruit.

### 1.7.3.2. GIRDLING

Girdling prevent translocation of photosynthates from the source to sink located below the girdle (Fishler *et al.*, 1983). It has an indirect effect of reducing sink size thereby increasing the amount of photosynthates available to the fruits and other meristems above the girdled regions (Krezdorn & Brown, 1970; Van der Poll *et al.*, 1991). However, citrus productivity and tree responses to girdling depend on many factors such as girdling date, procedures and technique such as girdling width and climatic conditions (Cohen, 1981).

Spring girdling increases fruit set (Monselise *et al.*, 1972) and autumn girdling reduces fruit size. Although spring girdling has little effect, summer girdling increase fruit size of Marsh seedless grapefruit (Cohen, 1984). By contrast, Peng & Rabe (1996) reported that summer trunk girdling after physiological fruit drop yielded significantly small fruit size of 'Mihowase' Satsuma. Monselise *et al.* (1972) reported that girdling at the beginning of bloom, increase yield of oranges by increasing fruit number but not fruit size. In fruit trees girdling can be used to increase fruit set, improve as fruit size (Hochberg *et al.*, 1977; Cohen, 1981). Girdling also increases gibberellin activity in the

part above the girdle and has an effect on flower formation and fruit setting (Monselise *et al.*, 1972).

### 1.7.3.3. PLANT GROWTH REGULATORS

Guardiola (1988) reported the direct effects resulting from the application of synthetic auxins to the developing citrus fruits and their influence on fruitlet growth and abscission due to an increase in sink strength of the developing fruitlets which may increase intersink competition of water and nutrients.

The use of NAA as a fruit growth enhancer in 'Mihowase' Satsuma was reported by Ortola *et al.* (1991). When applied shortly after the physiological drop period, NAA increased the growth rate of 'Mihowase' Satsuma resulting in bigger fruit size at harvest without an undesirable reduction in yields (Ortola *et al.*, 1991; Koch *et al.*, 1997).

Hutton (1992) reported an increase in fruit size of 'Late Valencia' orange by ethephon, due to thinning in a heavy set year, when applied at 8-9 weeks post bloom, when fruitlets were 10-15 mm in diameter. Greenberg *et al.* (1992) reported that 2,4-D applied to 'Star Ruby' grapefruit at the end of the physiological fruit drop period, improved final fruit size. A significant thinning effect was observed at early application at high concentrations ( $100 \text{ mg.l}^{-1}$ ). It was also found that  $50 \text{ mg.l}^{-1}$  was most effective in fruit size improvement when 2,4-D was applied just before the end of the physiological fruit drop period. The increase in fruit size of Clementine ('SRA 63') by 2,4-DP depended on the time of application and the concentration (Rabe *et al.*, 1995; Koch *et al.*, 1996). The effect differed over time with large fruits resulting from the earliest sprays (5 Dec), when average fruit size was 5 mm. The higher spray

concentrations (150 mg/l) resulted in significant fruit size increases, during early sprays, but the accompanying yield reduction indicated that there were severe thinning effects (Rabe *et al.*, 1995; Koch *et al.*, 1996).

## **1.8. FOLIAR APPLICATION OF NUTRIENTS**

### **1.8.1. STRUCTURE OF CITRUS LEAF**

Leaves consist of an epidermis, mesophyll and ground tissue (Esau, 1977; James, 1988; Fahn, 1990). The epidermis is covered by a cuticle, which consists of two layers (Swietlik & Faust, 1980). The outerlayer consists entirely of cutin covered by a waxy surface of (epicuticular) waxes (Esau, 1977). The inner layer is comprised of cellulose (Swietlik & Faust, 1980; James, 1988; Fahn, 1990) and pectic substances encrusted with cutin (Fahn, 1990). The cutin consists of polyesterified hydroxy fatty acids (Martin & Juniper, 1970), pectinaceous substances (Franke, 1967) and proteins (Swietlik & Faust, 1980). The leaves contain more stomata on the abaxial (lower) side than adaxial (upper) surface (Esau, 1977; Swietlik & Faust, 1980; Fahn, 1990); such leaves are called hypostomatous. The ground tissue is mesophyll (Esau, 1977; James, 1988) and is differentiated into palissade and spongy parenchyma.

#### **1.8.1.1. UPTAKE THROUGH THE CUTICLE**

The cuticle is the first limiting barrier of nutrients (Swietlik & Faust, 1980). The epicuticular waxes are the most hydrophobic components of the leaf surface (Franke, 1967). The cutin consists of polyesterified hydroxy fatty acids (Swietlik & Faust, 1980), which are both hydrophylic (-OH and -COOH), due to the presence of polar groups attracting water through hydrogen bonds (Van Overbeek, 1956), and lipophylic due to the hydrophobic groups (-CH<sub>2</sub> and -CH<sub>3</sub>) (Franke, 1967). The pectinaceous

substances (Franke, 1967) and proteins (Swietlik & Faust, 1980) are the other components of the cuticle (Fahn, 1990) and they have the ability to absorb water that may serve as a polar pathway of water and solutes.

In 'McIntosh' apples, pectinaceous substances form a continuum across the cuticle that serves as a polar transport (Roberts *et al.*, 1948). In citrus, Schonherr (1976) reported the existence of transcuticular canals lined with carboxyl groups in the leaf cuticle. Swietlik & Faust (1980) reported that, depending upon dissociation and hydration of carboxyl groups, the canals may swell or shrink, thus facilitating the passage of water and solutes.

#### **1.8.1.2. UPTAKE THROUGH THE STOMATA**

Besides penetration through the outer leaf cuticle, ions may enter a leaf through stomatal pores (Swietlik & Faust, 1980). This route does not bypass the cuticular barriers since stomatal openings are cuticular invaginations and not cuticular perforations (Yamada *et al.*, 1965; Norris & Bukovac, 1968) because the cuticle covering the stomatal cavity is hydrated and wax-free (Norris & Bukovac, 1968). The guard and subsidiary cells often have a greater frequency of ectodesmata or techoids (Yamada *et al.*, 1965), which allow diffusion of ions through the stomatal openings thus allowing penetration through the leaf into the substomatal cavity. The ectodesmata are found on the edge of stomata around guard cells (Franke, 1967) and are wax free (Esau, 1977; Fahn 1990), thus facilitating movement of ions.

### 1.8.1.3. UPTAKE THROUGH TRICHOMES

This is the uptake mechanism that cannot be elucidated in citrus due to the outerlayer, which is consisted of cutin covered by a waxy surface of (epicuticular) waxes. Trichomes may serve as a portal of entry for foliar-applied nutrients in pome fruits (Swietlik & Faust, 1980). The importance of this pathway through leaf absorption depends on the localization of trichome cutinization, which is associated with maturity and also plant species. The mechanism of this pathway is poorly understood. It is hypothesized that trichomes abscise from the upper leaf surface at a fairly early stage, apparently due to the change of pectic acid in the middle lamella to soluble pectin (Franke, 1967). However, trichome walls of the lower leaf surface become increasingly impregmented with polyesterified hydroxy fatty acid material, which polymerizes to form cutin (Van Overbeek, 1956). The trichomal wall has the ability to absorb water because of its hydrophylic nature and it may serve as a polar pathway for water, ions and solutes (Franke, 1967).

### 1.8.1.4. MOVEMENT OF IONS INSIDE THE LEAF

The movement of ions inside the leaf occurs via passive and active transport (Weatherly, 1963). The passive transport involves ion movement with water without metabolic involvement (Gardner *et al.*, 1985). The ions in high concentration tend to move rapidly in the free space (apoplasm) (Weatherly, 1963), finally passing the cuticle, facilitated by ectodesmata in the outer wall of epidermal cells (Yamada *et al.*, 1965).

Active transport involves the movement of ions across the plasmalemma into the leaf cells (Franke, 1967; Gardner *et al.*, 1985; Serano, 1989), transported within the cytoplasm of the leaf cells via plasmodesmata to the phloem (Franke, 1967). The

mechanism by which ions are transported across the plasmalemma into the leaf cells is poorly understood. Serano (1989) reported that during formation of the energy-rich state (ATP), the ATPase changes its shape, combines with an ion and opens the hole in itself, through which the ion can protrude out of the membrane into the aqueous cytoplasm where it reacts with ATP and water. Furthermore, the mechanism occurs only when ATP is being hydrolysed and ATPase combines with ions to move across the plasmalemma (Serano, 1989).

### **1.9. INFLUENCE OF WETTING AGENTS ON FOLIAR UPTAKE**

Surfactants are widely used as wetting, emulsifying and dispersing agents in the formulation of agrochemicals (Knoche & Noga, 1991). It improves wetting of the leaf by lowering the surface tension and consequently reduces the contact angle between the liquid and leaf surface (Swietlik & Faust, 1980). They also reported that the complete wetting angle is determined when the contact angle is zero. However, the liquid surface tension at which the contact angle is zero is known as the critical surface tension (Schonherr & Bukovac, 1972). By contrast, Beauchamp & Lean (1973) reported that surface solution may not be a useful characteristic in determining surfactant effectiveness in promoting leaf absorption. Surfactants such as Aerosol OT, Triton X100 and Monflor 51 may damage cellular membranes while FC128 and Aerosol OT may precipitate and form inorganic salts (Beauchamp & Lean, 1973). However the hydrophile/lipophile balance (HLB) is a useful measure of surfactant effectiveness, although predicting surfactant effect on leaf absorption with certainty is difficult due to the type of chemical compound applied along with the surfactant (Swietlik & Faust, 1980). Leaf surface properties interact with a surfactant and influence its effectiveness (Swietlik & Faust, 1980). More research still needs to be done to determine which



surfactant can influence rapid uptake of foliar nutrients. Normally no wetting agent is applied with foliar nutrient sprays in citrus.

### 1.10. pH OF THE SOLUTION

The absorption of certain mineral nutrients by leaves and fruits have been found to be pH dependent (Swietlik & Faust, 1980). Absorption of urea by apple leaves was highest at pH 5.4 and 6.6, intermediate at pH 8.0 and lowest at pH 7.3 (Cook & Boynton, 1952; Schonheer, 1976; Bernard *et al.*, 1996). In beans, Swietlik & Faust (1980) reported a 30 % reduction in absorption of  $\text{Ca}^{2+}$ , when the pH of the solution was lowered from 5 to 4, but increasing the pH from 5 to 6 did not affect  $\text{Ca}^{2+}$  absorption. In sweet cherry fruit, Lidster *et al.* (1979) reported that optimum pH for calcium absorption was 7. In cut flowers such as chrysanthemum leaves, Reed & Tukey (1978) reported that absorption of phosphorus occur at pH 2. In Citrus there is little reported work on the influence of pH of the solution in facilitating foliar absorption of the nutrients.

### 1.11. FACTORS AFFECTING THE EFFECTIVENESS OF SOIL-APPLIED MACRO ELEMENTS

**Nitrogen (N):** Inorganic N is present in the soil solution as primary N, nitrate ( $\text{NO}_3^-$ ) or ammonium ( $\text{NH}_4^+$ ) and are being taken up by citrus trees, although  $\text{NH}_4^+$  and  $\text{NO}_3^-$  absorption is greater at high and low pH, respectively (Kato, 1986). However,  $\text{NO}_3^-$  is highly mobile in the soil solution and may be leached from the root zone by excessive rainfall or irrigation (Embleton & Jones, 1974). Moreover, both forms of N may be denitrified by bacteria to  $\text{N}_2\text{O}$  and  $\text{N}_2$ , which diffuse to the atmosphere (Davies & Albrigo, 1994). Nitrate is taken up through the transpiration stream and translocated to

the canopy in ionic form.  $\text{NH}_4^+$  is converted into amino acids, primarily glutamate in the roots after which it moves to the canopy through the transpiration stream (Kato, 1986). However, it has been suggested that foliar application might reduce  $\text{NO}_3^-$  accumulation in soil and minimize leaching (Embleton & Jones, 1974; Sud & Bhutani, 1988), thus reduce the potential for nitrate pollution of the groundwater (Ali & Lovatt, 1992; Lovatt, 1998; Southwick *et al.*, 1999).

**Phosphorus (P):** The edaphic factors, which influence or modify P uptake act through the influence of absorption and concentration on P at the root zone (Black, 1969). The most common over-all effect on P availability is pH dependent (Hageman, 1969). At low pH (<5 in water), phosphate is mainly bound as iron and aluminium phosphate or to the surface of the oxides and hydrates of these two elements (Black, 1969). An increase in pH, by which the hydroxyl-ion concentration is increased, leads to a release of P through ligand exchange, so that there is an increase in the phosphate concentration in the soil solution (Hageman, 1969). When a soil with a high pH (>7 in water) is acidified, the solubility of phosphate also increases if such soil contains calcium phosphates (Black, 1969).

**Potassium (K):** The movement of soil-applied K into the root zone of the trees depends on the mineralogical influence as well as the chemical composition of the soil (Humbert, 1969). Soil high in clay fixes K and is not readily available to the trees, and under such conditions, if leaf analysis indicates deficiency for K, foliar application is the best method to correct deficiencies (Embleton & Jones, 1969, Humbert, 1969). They also reported that in soils where the clay minerals are largely montmorillonitic, which does not fix K, the exchange capacity needs to be satisfied for K movement. Massive

applications in the soil have been effective but dosage must avoid a build-up of salinity as massive doses may induce salinity problems and hence nullify the availability of K in the soil (Hageman, 1969).

## <sup>10</sup> 1.12. NITROGEN AND CARBOHYDRATE FLUCTUATIONS IN CITRUS.

Young leaves and developing organs such as fruits and seeds with strong sink demands may draw heavily on N in the older leaves (Gardner *et al.*, 1985). The results of such redistribution when N uptake is limited is firing (yellowing and senescence) of lower leaves (Gardner *et al.*, 1985). This is the critical stage where foliar-applied fertiliser is necessary to supplement the soil-applied fertiliser to enhance vegetative growth. Such firing of leaves causes deficiency of N that finally reduces the vegetative growth (Monselise & Goldschmidt, 1982). The highest concentration of carbohydrates is usually found in root tissue (Monselise & Goldschmidt, 1982). Starch is the major storage carbohydrate in citrus tree organs (roots and leaves) during the “off” year of alternate bearing in mandarins (Goldschmidt & Golomb, 1982). The stored carbohydrates were highest in roots, lower in trunks and intermediate in leaves and branches (Goldschmidt & Golomb, 1982). The build-up of reserves in the absence of competition of vegetative or reproductive sinks (flowers) in citrus helps the spring flush, floral development, anthesis and fruit set (Goldschmidt & Golomb, 1982).

The large amounts of carbohydrate build-up during the previous year are of primary importance for early spring flush (Shimuzi *et al.*, 1978; Tromp, 1983). The decline in carbohydrate levels throughout the flowering and fruit set period (Jones & Steinacker, 1951; Hilgeman *et al.*, 1967; González-Ferrer *et al.*, 1984; Garcia-Luis, 1988) is

accentuated by heavy flowering (Garcia-Luis *et al.*, 1988). Reserve carbohydrates are also utilised to sustain early stages of reproductive development in citrus (Shimuzi *et al.*, 1978, Goldschmidt & Golomb, 1982; Harpaz *et al.*, 1990; Goldschmidt & Koch, 1996).

The general commercial practice of applying N to the soil during the middle to late winter is thus of limited immediate benefit to the tree, especially since roots start to absorb N only after soil temperatures reach 14 °C and is limited even up to 22 °C (Bevington & Castle, 1985).

The annual growth and fruit yield of citrus trees contain only a small proportion of the N fertiliser applied during the growth period (Dasberg, 1987). More than 80% of the N in the new growth is drawn from the tree reserves in the permanent tree parts trunks, branches and roots in citrus (Kato, 1986; Dasberg, 1987; Mooney & Richardson, 1992). This explains why lack of N application does not always result in yield decrease and why trees are able to grow vigorously in the spring when N uptake is still very low.

The usual N fertilisation practice in Southern Africa is to apply soil N during late winter or early spring at the sign of bud break (Rabe, 1994). N utilised during the spring growth flush and fruit set period is derived from storage nitrogen reserve (Kato, 1986; Dasberg, 1987; Mooney & Richardson, 1992). However, the timing of the normal soil-applied N is such that it does not contribute significantly to the N requirement for the emerging flower and vegetative flush.

Application of urea through the foliage as a substitute or supplement to soil nitrogen dressing have proved to be efficient means of improving fruit set, size and yield of

apples (Blasberg, 1953; Shim *et al.*, 1973; Fallahi *et al.*, 1989; Fallahi *et al.*, 1997). In stone fruits such as plum, cherry and 'French' prune trees, foliar urea has been reported to increase yield (Bullock *et al.*, 1952; Walker & Fisher, 1955; Sud & Bhutani, 1988; Southwick *et al.*, 1999). Foliar-applied urea sprayed until run-off (i.e. a full cover spray) increased yield compared to the control in 'Washington' navel orange (Androulakis *et al.*, 1992; Ali & Lovatt, 1992; 1994; Lovatt *et al.*, 1992; Rabe, 1993; 1994; Lovatt, 1998). Similar results were obtained in 'Shamouti' midseason with pre-blossom urea sprays (Dasberg *et al.*, 1983; Rabe & Van der Walt, 1992; Rabe, 1994).

Increases in fruit set following autumn urea sprays indicated a high effectiveness of foliar sprays for building N reserves which is critical for tree development in early spring (Swietlik & Faust, 1980). High reserves were shown to have beneficial effects on flower bud development, increasing longevity of ovules and enhancing the degree of self-fertilisation in citrus (Lovatt, 1999).

In general, low-biuret urea (46% N) applied during the period from flower initiation through fruit set significantly increased yield without reducing fruit size. Applications made at the end of the cell division stage of fruit development significantly increased fruit size without affecting yield (Lovatt, 1998).

Lovatt (1999) found that foliar application of low-biuret urea at full bloom in 'Washington' navel orange significantly increased fruit size, concentrations of ammonia, arginine and polyamines, thus increasing cell division and fruit growth. Winter and spring foliar urea applications likely increased fruit set and yield because of limited availability of nutrient essential for flowering and fruit set. This is due to

reduced transpiration or nutrient acquisition by roots, when the air temperatures are low (Lovatt, 1999). However, there was no consistent relationship between tree N status and yield in 'Washington' navel (Lovatt, 1999).

## CONCLUSIONS

Internal and external quality is an important issue in marketing of citrus. Fruit with poor colour and coarse rind results in a reduction in exportable fruit, negative financial impact on both producer and exporter and customer dissatisfaction. To preclude this situation it is essential that fruit meet specific export standards for good colour, rind texture and size.

Factors that affect internal quality are categorized as environmental factors such as climate and rainfall and cultural factors such as rootstock, mineral nutrition, irrigation, pruning, position of the fruit in the tree, tree age and crop load.

External fruit quality is divided into two components, i.e. fruit colour and rind texture. Factors that affect fruit colour are light, temperature, tree vigour, mineral nutrition, selective picking and colour sorting and chemical treatments such as ethephon. Nutritional elements such phosphorus and potassium, in turn affects rind texture.

Factors that affect fruit size are also subdivided in two groups i.e. non-controllable pre-planting factors such as climate, post-planting factors such as tree age, scion selection, rootstock and viruses and other related diseases. Controllable factors

influencing fruit size, include mineral nutrition, irrigation practices, crop load and plant growth regulators.

Surfactants are widely used as wetting, emulsifying and dispersing agents in the formulation of agrochemicals. Predicting surfactant effect on leaf absorption with certainty with foliar sprays is difficult due to the type of chemical compound applied along with the surfactant. More research still needs to be done to determine which surfactant can influence rapid uptake of foliar nutrients.

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## 2. PAPER 1. EFFECT OF FOLIAR NITROGEN APPLICATIONS ON FRUIT COLOUR DEVELOPMENT, YIELD, FRUIT SIZE AND INTERNAL QUALITY OF 'MIHOWASE' SATSUMA (*Citrus unshiu* Marc).

**Abstract.** Marginal fruit colour and poor quality has been primary problems in the production of early-maturing 'Mihowase' Satsuma. The effect of different combinations of soil-applied limestone ammonium nitrate (LAN) and foliar low-biuret urea (1%) on fruit colour, yield, and internal quality of 'Mihowase' Satsuma on 'Troyer' citrange rootstock was evaluated. The trial was carried out over four consecutive seasons in Stellenbosch, South Africa (34°S 19°E). The effect of soil-applied N and foliar-applied leaf N on fruit colour, fruit size and yield were inconsistent. Tree appearance tended to be more yellow where soil-applied LAN was substituted with multiple foliar N. N applications influenced internal quality, although differences between treatments were too small to be of commercial importance. A significant reduction in leaf N levels was recorded where soil N had been reduced from 168 kg N/ha per annum to 126 kg N/ha per annum. Despite tree appearance being more yellow in some years with the foliar N spray treatment, no consistent reduction in fruit size or yields was found and no enhancement in fruit colour was recorded, probably due to the fact that leaf N-levels were still within or below the norms suggested for Satsumas.

## INTRODUCTION

Adequate rind colour is an important characteristic in attaining consumer appeal and acceptance, therefore, a well-developed rind colour of citrus fruit is an external quality parameter of major importance in the fruit markets. In the Western Cape region of South Africa, marginal exportable quality and fruit colour has been primary problems in the production of early-maturing 'Mihowase' Satsuma. This leads to a reduction in the percentage of exportable fruits, a delay in picking and a consequent reduction in internal quality due to over maturity.

Cultural practices such as girdling (Peng & Rabe, 1996), water stress management (Peng & Rabe, 1998; Yakushiji *et al.*, 1998) and nitrogenous fertiliser application (Embleton & Jones, 1974; Dasberg, 1987; Sud & Bhutani, 1988; Sala *et al.*, 1992; Fallahi *et al.*, 1997; Rosecrance *et al.*, 1998) have been widely used to enhance internal and external fruit quality. 'Mihowase' Satsuma matures early while night temperatures are still high, which delays rind colour development (Davies & Albrigo, 1994). Lowering temperatures cause mild injury to the rind and consequently enhance the release of naturally-produced ethylene which initiate changes in the rind pigment (Cooper *et al.*, 1969; Petracek & Montalvo, 1997).

Foliar application of urea as a supplement to soil N uptake has been shown to be an efficient means of improving fruit set, fruit size and yield in apples (Blasberg, 1953), apricot (Sud & Bhutani, 1988), 'Shamouti' midseason citrus (Rabe, 1993) and in 'French' prune trees (Southwick *et al.*, 1999). Yields were increased, but there was no concurrent

decrease in fruit size when 'Shamouti' midseason citrus, 'Ellendale' tangor and 'Minneola' tangelo were treated with pre-blossom urea sprays (Rabe, 1994).

The usual N fertilisation practice in southern Africa is to apply soil N late winter and early spring at the sign of bud break (Rabe, 1994). Nitrogen utilised during late winter or early spring flush and fruit set period (Kato, 1986), is derived from storage N reserves (Dasberg, 1987; Mooney & Richardson, 1992). Therefore, the timing and the level of the normal soil application is such that it does not contribute significantly to the N requirement for the emerging flowering and vegetative flush (Rabe, 1994). Foliar-applied N resulted in less regreening of fruit than soil application (Jones & Embleton, 1959), and has a smaller carry over effect of N to the next season. An increase in leaf N from 2.3 to 2.5% was reported on fruit that received the highest soil N treatments in 'Valencia' orange and 'Marsh' grapefruit (Reuther & Smith, 1952; Jones & Embleton, 1959; Reitz & Koo, 1960) and it resulted in delay in fruit colour break. Soil nitrogen absorption rate depends on rootstock (Embleton *et al.*, 1973), soil temperature (Kato *et al.*, 1982) and type of irrigation (Intrigliolo *et al.*, 1992).

Therefore, the study was undertaken to evaluate the effect of substituting soil-applied N with foliar-applied N to obtain less residual soil N and consequently enhance possible early fruit colour development. It was hypothesised that substitution of soil N with foliar N would result in faster N assimilation and less residual effect in the soil and consequently enhance earlier fruit colour development.

## MATERIALS AND METHODS

*Experimental site and plant material.* The study was carried out over four consecutive seasons (1996 to 2000) on 'Mihowase' Satsuma (*Citrus unshiu* Marc) trees on 'Troyer' citrange rootstocks. The orchard is situated near Stellenbosch, South Africa (34°S 19°E, altitude ca.150 m) with a Mediterranean climate with hot, dry summers and winter rainfall. The trees selected were healthy, vigorous and uniform in canopy size and trunk girth.

*Experimental design and treatment details.* The trial was laid out as a randomised complete block design with seven treatments and seven four-tree replicates per treatment. All trees received 250 g lime stone ammonium nitrate (LAN) (28 % N), i.e. approximately 42 kg N/ha per application in autumn. In spring, trees were differentially fertilised with soil LAN and different sprays with low biuret urea (LBU) (46% N), at an equivalent rate of 3000 l/ha or 14 kg N/ha per application (Table 1). Leaf samples for N and fruit for internal fruit quality analyses were taken from two middle trees.

[Table 1]

*Fruit colour and tree appearance.* In 1998, at time of harvest, 12 fruit were randomly picked from each replicate for colour assessment and fruit colour was determined based on visual assessment using a fruit colour chart (No.36 of Outspan International) with ratings from 1 to 8, where 1 is fully orange and 8 is dark green. In 1999 and 2000, fruit colour was visually assessed in early March based on external colour development using Capespan

Colour Chart No 36 ratings 1 to 8; (1 = orange, 8 = dark green). Tree appearance was visually rated on a scale of 1 to 10 (1 = yellow and 10 = dark green).

*Fruit quality determination.* Internal fruit quality was not determined from 1997 to 1999. However, in 2000, at harvest 12 fruit were randomly sampled from each replicate for internal quality analyses. Fruits were squeezed using a hand reamer (citrus juicer). Juice was strained through two layers of muslin cloth and juice content (%) was determined by subtracting weight of reamed peel from total fruit weight. The Brix level (providing an indication of total soluble solids [TSS]) of the juice were determined with a hand-held refractometer (Atago N1). Titratable acidity (TA) expressed as percentage citric acid content was assessed by titration with 0.1 N sodium hydroxide (NaOH), using phenolphthalein as an indicator. The TSS:TA ratio was calculated by dividing the TSS values by TA values.

*Fruit size.* Fruit samples of approximately 7 kg were drawn from each replicate for sizing on an electronic sample grader at a commercial pack house.

*Yield.* Fruit were selectively picked on colour and size according to commercial standards and individual tree yields recorded at commercial harvesting dates. Harvesting dates were as follows: In 1997, on 19 April (after commercial harvest), in 1998, on 20 and 26 March, in 1999, 26 March, 8 and 26 April, in 2000, 2 and 13 April.



*Leaf nitrogen content analysis.* Twenty 5 to 6 month-old mature spring flush leaves were randomly sampled from each replicate in the beginning of March. Leaves were washed with distilled water, freeze-dried and milled. A sample of 0.2 g was placed into a 100 ml block digestion tube. To each tube 4 ml of concentrated sulphuric acid, 2.5 g catalyst mixture (15 g copper sulphate, 250 g potassium sulphate and stearic acid mixed in powder form) and 2 ml hydrogen peroxide (30 %) was added. The tubes were transferred to a mini Kjeldahl heating block at 370 °C for approximately an hour until the mixture turned light green. The sides of digestion tubes were rinsed down periodically with peroxide. The tubes were left to cool after removal, filled to 100 ml prior to filtration through Whatman No 2 filter paper. Samples were bottled and stored at -20°C until analysed. Total nitrogen was determined on Sanplus Segmented Flow Analysis System from Skalar using Method No 551- 965w/r issue 070798/MH and No. 356-001w/r issue 012998/MH/97203066.

#### *Statistical Analysis.*

Statistical analyses were performed using the GLM (General Linear Model) procedure of SAS version 6.12 (SAS Institute Inc., 1996).

## **RESULTS AND DISCUSSION**

*Leaf Nitrogen.* During 1997 and 2000, no clear trends were found in leaf N content between different N applications. However, a trend of higher foliar N content with increasing soil-applied N was observed (Table 2). The N content however never exceeded the optimum leaf N for Satsuma which ranges between 2.1 - 2.3 % (Gilfillan, 1992).

## [Table 2]

*Tree appearance.* During the 1999 season, the visual assessment of tree appearance indicated that trees receiving multiple soil applications of N tended to be a darker green (Table 2). However, trees that received N predominantly as foliar urea application tended to be more yellow, except when they received six urea applications. In 2000 all trees appeared to be quite green.

*Fruit colour.* In 1998, no clear significant differences existed in fruit colour (Table 2). In 1999, fruit from treatments with three soil N and three sprays applications were greener than all other treatments. In 2000, no significant difference was found in fruit colour. Citrus trees receiving excessive amounts of N tended to have poorly coloured fruits (Davies & Albrigo, 1994). High levels of leaf N during time of colour break in both 'Washington' navels and 'Valencia' orange delay colour break (Reuther & Smith, 1952). Levels of N above the 2.1 –2.3 % range, due to either soil application or foliar application of N may result in a delay of fruit colour development in Satsuma. Late summer soil-applied N increase leaf N level to 2.45% and resulted in green fruit colour in Marsh grapefruit (Smith *et al.*, 1969). Similar findings were also reported in apricot (Sud & Bhutani, 1988). Jones & Embleton (1959) reported that differences in fruit colour was due to timing of nitrogenous fertiliser applications, with later applications resulting in greener fruits. As seen in Table 3, there was a greater percentage of fruit picked selectively at first pick during 1998. In 1999 and 2000, contrary to expectations, there was no distinct difference between the treatments

despite large variations in amount of N applied. This lack of distinct differences, either in fruit colour or percentage of fruits picked selectively, is probably due to the fact that leaf N-levels were still within or below the norms suggested for Satsumas.

[Table 3]

*Fruit yield.* There were no clear significant differences in yield between the treatments applied in 1997, 1998 and 2000 (Table 4). In 1999, there was a tendency for multiple soil applications of N to increase yields. No significant difference in yields were obtained with soil-applied N versus foliar-applied in 'Valencia' orange' and 'Marsh' grapefruit (Reuther & Smith 1952; Reitz & Koo, 1960). A significant increase in yields were obtained with pre-bloom urea sprays as a supplement to soil-applied N in other studies (Ali & Lovatt 1992; Rabe & Van der Walt, 1992; Rabe, 1993; 1994; Fallahi *et al.*, 1997; Lovatt, 1998 Southwick *et al.*, 1999).

*Internal fruit quality.* Although differences in internal quality (*viz.*, TSS and TA) were observed during 2000, there was no consistent trend between treatments (Table 4).

[Table 4]

*Fruit size.* No consistent significant difference was found in fruit size between the various treatments despite large variations in amount of N applied (Table 5). Rabe (1994) reported that when 'Shamouti' midseason, 'Ellendale' tangor and 'Minneola' tangelo were treated with pre-bloom urea sprays no significant difference in fruit size was found.

[Table 5]

In conclusion, a reduction in leaf N levels was observed where soil-applied N was reduced. Despite tree appearance being more yellow in some years with foliar N sprays, no consistent reduction in fruit size and yields were found while, no enhancement in fruit colour was recorded, probably due to the fact that leaf N-levels were still within or below the norms suggested for Satsumas.

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Table 1. Nitrogen fertilisation trial layout on 'Mihowase' Satsuma.

Treatment	Soil Nitrogen (approximate application date)			Foliar nitrogen (approximate application date)						Total nitrogen applied from 1996 to 2000 (kgN/ha per annum)	% of highest N (1996-2000)
	Mid Apr	Mid Sep	Mid Nov	Mid Apr	Mid Aug	Mid Sep	Mid Oct	Mid Nov	Mid Dec		
3xLAN, 3xLBU	LAN	LAN	LAN	LBU	LBU	LBU				168	100
2xLAN, 3xLBU	LAN	LAN		LBU	LBU	LBU				126	75
1xLAN, 3xLBU	LAN			LBU	LBU	LBU				84	50
1xLAN, 3xLBU	LAN			LBU	LBU	LBU				84	50
1xLAN, 4xLBU	LAN			LBU	LBU	LBU	LBU			98	58
1xLAN, 5xLBU	LAN			LBU	LBU	LBU	LBU	LBU		112	66
1xLAN, 6xLBU	LAN			LBU	LBU	LBU	LBU	LBU	LBU	126	75

LAN (Limestone ammonium nitrate) = 42 kgN/ha per application

LBU (Low-biuret urea) = 14 kgN/ha per application

Table 2. Effect of soil-applied LAN and foliar urea on leaf nitrogen content (%), fruit colour and tree appearance of 'Mihowase' Satsuma.

Treatment	% leaf nitrogen				<sup>z</sup> Fruit colour		<sup>y</sup> Fruit colour		<sup>x</sup> Tree appearance	
	1997	1998	1999	2000	26/03/98	15/03/99	27/03/2000	15/03/99	27/03/2000	
3x LAN, 3x UREA	1.7 a	2.2 a	2.0 a	2.1 a	4.9 a	5.6 a	6.6 a	6.1 ab	6.9 a	
2x LAN, 3x UREA	1.5 a	2.2 a	1.6 ab	1.5 b	4.8 a	4.9 b	6.2 a	5.6 bc	6.4 ab	
1x LAN, 3x UREA	1.6 abc	2.1 ab	1.7 ab	1.8 ab	4.2 a	5.0 b	6.3 a	4.6 e	6.1 b	
1x LAN, 3x UREA	1.3 c	1.9 bc	1.7 ab	1.8 ab	4.1 a	5.1 b	6.3 a	5.0 cde	6.5 ab	
1x LAN, 4x UREA	1.6 abc	1.9 bc	1.7 ab	1.8 ab	4.3 a	4.8 b	6.7 a	4.8 de	6.5 ab	
1x LAN, 5x UREA	1.6 abc	1.8 c	1.6 ab	1.7 ab	4.9 a	4.9 b	6.5 a	5.4 cd	6.6 ab	
1x LAN, 6x UREA	1.4 bc	1.9 bc	1.5 b	2.1 a	4.5 a	5.1 b	6.5 a	6.8 a	6.9 a	
LSD (5%)	0.29	0.19	0.43	0.55	0.8	0.5	0.5	0.7	0.6	

Means followed by the same letters are not significantly different at 5% LSD.

<sup>z</sup>Determined using Outspan Colour Chart No 36 (rating 1-8; 1 = orange; 8 = green)

<sup>y</sup>Fruit colour was visually assessed (rating 1-8; 1 = yellow, 8 = green)

<sup>x</sup>Tree appearance was visually assessed (rating 1-10; 1 = yellow; 10 = dark green)

Table 3. Effect of soil-applied LAN and foliar urea on percent fruit picked selectively of 'Mihowase' Satsuma.

Treatment	% FRUIT PICKED SELECTIVELY										
	26/03/98	20/04/98	26/03/99	08/04/99	26/04/99	02/04/2000	13/04/2000	1 <sup>st</sup> Pick	2 <sup>nd</sup> Pick	3 <sup>rd</sup> Pick	2 <sup>nd</sup> Pick
3x LAN, 3x UREA	61	39	8.2 a	41.0 a	50.6 a	38.9 b	61.1 a				
2x LAN, 3x UREA	61	39	9.1 a	41.8 a	49.4 a	41.4 ab	58.6 ab				
1x LAN, 3x UREA	67	33	3.8 b	50.3 a	45.2 a	45.4 ab	54.6 ab				
1x LAN, 3x UREA	68	32	6.1 ab	47.0 a	45.4 a	50.2 a	49.8 b				
1x LAN, 4x UREA	69	31	7.3 ab	48.6 a	42.6 a	44.7 ab	55.3 ab				
1x LAN, 5x UREA	59	41	5.9 ab	41.9 a	44.4 a	37.3 b	62.7 a				
1x LAN, 6x UREA	69	31	7.8 a	45.5 a	46.4 a	38.9 b	61.1 a				
LSD (5%)			3.4	9.8	11.3	9.6	9.6				

*Means followed by the same letters are not significantly different at 5% LSD.*

Table 4. Effect of soil-applied LAN and foliar urea on yield and internal quality of 'Mihowase' Satsuma

Treatment	Yield (kg/tree)				Cumulative yield	Juice Content (%)	TSS (%)	TA (%)	TSS:TA ratio
	1997	1998	1999	2000					
	2000								
3x LAN, 3x UREA	34.2 a	49.5 ab	84.5 a	23.2 a	191	37.0 ab	10.4 abc	1.7 a	6.2 c
2x LAN, 3x UREA	33.4 a	51.3 ab	84.1 a	21.1 ab	190	37.7 ab	10.7 a	1.6 ab	6.8 a
1x LAN, 3x UREA	35.8 a	47.6 b	81.8 ab	20.1 ab	185	36.6 ab	10.2 abc	1.5 b	6.7 ab
1x LAN, 3x UREA	31.5 a	51.0 ab	75.5 ab	17.6 b	176	36.3 b	10.6 ab	1.7 a	6.2 bc
1x LAN, 4x UREA	38.9 a	57.3 a	75.1 ab	19.9 ab	191	39.6 a	10.0 bc	1.5 b	6.8 a
1x LAN, 5x UREA	29.3 a	48.0 b	69.4 b	21.9 ab	169	37.0 ab	9.9 c	1.5 b	6.5 abc
1x LAN, 6x UREA	40.1 a	55.5 ab	69.2 b	22.0 ab	187	37.9 ab	10.5 abc	1.6 ab	6.7 ab
LSD (5%)	24.3	8.1	14.6	4.9		3.2	0.7	0.2	0.5

Means followed by the same letters are not significantly different at 5% LSD.

Table 5. Effect of soil-applied LAN and foliar urea on fruit size of 'Mihowase' Satsuma.

Treatment	% FRUIT SIZE DISTRIBUTION BY MASS											
	1997			1998			1999			2000		
	>S3	<S3		>S3	<S3		>S3	<S3		>S3	<S3	
3xLAN, 3xUREA	61.1 a	38.9 a		99.7 a	0.3 b		67.0 a	32.7 a		95.4 a	0.0 a	
2xLAN, 3xUREA	57.8 a	42.1 a		97.9 b	2.1 a		61.9 a	37.9 a		93.9 a	2.8 a	
1xLAN, 3xUREA	63.3 a	36.8 a		99.4 a	0.6 b		67.0 a	33.7 a		92.5 a	0.2 a	
1xLAN, 3x UREA	63.0 a	36.0 a		99.2 ab	0.8 ab		69.0 a	30.9 a		91.4 a	0.8 a	
1xLAN, 4x UREA	65.1 a	35.0 a		99.4 a	0.6 b		60.4 a	39.6 a		90.3 a	0.4 a	
1xLAN,5x UREA	70.9 a	29.1 a		99.3 ab	0.7 ab		58.8 a	41.4 a		96.4 a	0.5 a	
1xLAN,6x UREA	66.7 a	33.3 a		98.0 ab	1.7 ab		63.1 a	36.6 a		94.9 a	0.6 a	
LSD (5%)	18.2	18.1		1.5	1.4		20.0	11.8		6.8	2.9	

*Means followed by the same letters are not significantly different at 5% LSD*

> S1 = 68-86 mm

S1 = 64 – 68 mm

S2 = 59 – 64 mm

S3 = 55 – 59 mm

< S3 = 48- 55 mm

### 3. PAPER 2: EFFECT OF MONO-POTASSIUM PHOSPHATE (MKP) AND UREA AMMONIUM PHOSPHATE (UAP) ON YIELD, RIND CHARACTERISTICS AND INTERNAL FRUIT QUALITY OF *CITRUS* SPP.

**Abstract.** Rind roughness is a general problem in the Citrusdal region of South Africa (Western Cape Province) limiting the percentage of fruits which can be exported. The effect of foliar mono-potassium phosphate (MKP) applied at 3% or 5% and urea ammonium phosphate (UAP) at 2%, 4 or 6 weeks, respectively, after full bloom (AFB) on yield, internal and external fruit quality (rind texture) of *Citrus* spp on rough lemon rootstock was evaluated. During the 1998/99 season, various selection viz., 'Nouvelle' tangor, 'Valencia' orange, 'Shamouti' midseason, 'Oroval' Clementine and 'Eureka' lemon were used for the study. In 1999/2000, only 'Shamouti' midseason and 'Valencia' orange were used. MKP and UAP had no consistent effect on yield (kg/tree), juice content (%), TSS, TA and TSS:TA ratio of 'Nouvelle' tangor, 'Valencia' orange, 'Shamouti' midseason and 'Oroval' Clementine. Inconsistent effects of MKP and UAP sprays were also found on % leaf N, P and K. MKP and UAP sprays significantly, but inconsistently improved rind texture of 'Nouvelle' tangor, 'Shamouti' midseason and 'Valencia' orange. However, no positive effect was found on rind texture of 'Oroval' Clementine and 'Eureka' lemon.

## INTRODUCTION

In the Citrusdal region of South Africa (Western Cape Province), rind roughness is a general problem which often limits the percentage of fruits which can be exported. The soil type in this region is sandy (< 10% clay content), and is often deficient in calcium and sulphate (A van der Merwe, pers. comm<sup>1</sup>). A reduced set resulting in larger fruits with rougher skin, is ascribed to the sandy-soil condition (pers. obs.). This is clearly seen in 'Shamouti' midseason, 'Valencia' orange and 'Oroval' Clementine mandarin. Rabe & Von Broembsen (1991) reported that 'Shamouti' midseason fruits have a low juice percentage and a thick rind. Vigorous rootstocks such as rough lemon gives rise to scion fruits having a rougher skin texture than fruits developing on scions grown on 'Troyer' citrange rootstock (Rabe & Von Broembsen, 1991).

The application of P and K fertilisers to citrus trees have been reported to improve internal and external fruit quality characteristics (rind texture) (Smith, 1966; Lavon *et al.*, 1996). P application has been reported to increase yield, size, juice volume, titratable acidity (TA) and reduce fruit peel thickness (Orphanos *et al.*, 1986; Goepfert *et al.*, 1987; Mann & Sandhu, 1988). K application has been reported to reduce TSS and increase TA and peel thickness (Goepfert *et al.*, 1987; Ahmed *et al.*, 1988; Ebrahim *et al.*, 1993).

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Beneficial effects attributed to mono-potassiumphosphate (MKP) application include a decrease in TA, peel thickness and rind roughness and increases in fruit size, juice content (%), TSS and TSS:TA ratio of 'Shamouti' midseason and 'Star Ruby' grapefruit (Lavon *et al.*, 1996). Other researchers found that MKP sprays reduce acidity, increase sugar content, increase the sugar-acid ratio and advance skin colouration in 'Mihowase' Satsuma mandarin (Kuretani & Terao, 1986; Kuretani *et al.*, 1986). No research reports could be found on the use of urea ammonium phosphate (UAP) on internal and external fruit quality of citrus.

The objectives of this study was to assess (i) the effectiveness of MKP and UAP foliar sprays in enhancing leaf levels of K and P, (ii) the effect of MKP and UAP sprays on yield, internal and external fruit quality (rind texture) of citrus species.

## MATERIALS AND METHODS

*Experimental sites and plant material.* The orchards are situated in the Citrusdal region (32°34'S 18° 59'E) Western Cape Province, South Africa which has a Mediterranean climate with hot, dry summers and winter rainfall. In 1998/99, various cultivars selections, viz., 'Shamouti' midseason (planted in 1987), 'Eureka' lemon (planted in 1972), 'Oroval' Clementine (planted in 1989), Valencia orange (planted in 1950) and 'Nouvelle' tangor (planted in 1989) on rough lemon rootstock and in 1999/2000, 'Valencia' orange (planted in 1950) and 'Shamouti' midseason (planted in 1987) were selected for the study.



*Experimental design and treatment details.* In 1998/99, seven treatments with ten replicates were laid out in a randomised block design for 'Eureka' lemon, 'Valencia' orange and 'Nouvelle' tangor. Treatments consisted of an unsprayed control, 3% MKP and 5% MKP sprays at 4 and 6 weeks after full bloom and 2% UAP sprays at 4 or 6 weeks after full bloom. In 'Shamouti' midseason and 'Oroval' Clementine the UAP treatments were excluded.

In 1999/2000, treatments consisted of an unsprayed control, 3% and 5% MKP sprays after 4 and 6 weeks after full bloom on 'Valencia' orange and 'Shamouti' midseason. Agral 90, at a rate of 20 ml per 100 l was added as a wetting agent. MKP and UAP was sprayed as a full cover spray until run-off at approximately 8 l/tree, i.e. varying between 4000 to 6000 l per hectare.

*Leaf sampling and analysis.* Leaf samples were taken from fruiting terminals for N, P and K analysis after spray applications and again in February of the following year. In each treatment, only five replicates were sampled and analysed. Leaf samples were analysed by the Central Agricultural Laboratories (SA) in 1998/99 and at the Department of Soil Science, University of Stellenbosch in 1999/2000 using the FFTRI Procedure & Technology No. 32 (Du Preez *et al.*, 1981).

*Fruit harvesting dates.* Harvest dates were as follows during 1999: 'Oroval' on 4 May, 'Eureka' on 14 June, 'Shamouti' midseason on 4 August, 'Nouvelle' tangor on 31 August

and 'Valencia' orange on 7 September. Harvest dates were as follows during 2000: 'Shamouti' midseason on 25th July and 'Valencia' orange on 4 September.

*Total yield.* Total yield was only determined for 'Nouvelle' tangor, 'Valencia' orange and 'Shamouti' midseason in 1998/99, and for 'Shamouti' midseason and 'Valencia' orange in 1999/2000 at time of commercial harvesting.

*Fruit size and texture determination.* Fruit size was determined with a caliper using 50 fruit per replicate. Rind texture of each fruit was rated using the Capespan texture chart rating 1 to 8 (1 = smooth rind and 8 = rough rind).

*Internal fruit quality.* At harvest, 12 fruit of average diameter were randomly sampled from each tree for evaluation of internal quality and peel thickness. Fruits were squeezed using a hand reamer (citrus juicer). Juice was strained through two layers of muslin cloth. Juice content (%) was determined by subtracting weight of reamed peel from total fruit weight. Total soluble solids content (TSS) of the juice was determined with a hand-held refractometer (Atago N1). Titratable acidity (TA), expressed as citric acid, was determined by titration with 0.1 N sodium hydroxide, using phenolphthalein as an indicator. The TSS:TA ratio was calculated by dividing the TSS values by the TA values.

*Data analysis.* Statistical analyses were performed using the GLM (General Linear Model) procedure of SAS version 6.12 (SAS Institute Inc., 1996).

## RESULTS AND DISCUSSION

*Leaf analysis.* No consistent effect of MKP sprays was found for N, P and K leaf content in either season (Tables 1 & 2). These findings contradict that of Lavon *et al.* (1996) who reported that MKP sprays increased N, P and K leaf concentration. No consistent effect on N, P and K was found after UAP sprays (data not presented).

[Tables 1 & 2]

*Yield.* MKP treatments had no consistent effect on yield of 'Nouvelle' tangor, 'Valencia' orange and 'Shamouti' midseason in all seasons (Tables 3, 4, 5, 6 and 7). Similar findings were also reported by Lavon *et al.* (1996). During the 1998/99 season, application of 2% UAP 6 weeks after full bloom to 'Nouvelle' tangor significantly decreased yield, a response that cannot be explained (Table 3).

[Tables 3, 4, 5 6 & 7]

*Fruit size.* MKP treatments had no effect on fruit size of 'Valencia' orange and 'Shamouti' midseason compared to the control (Tables 4, 5 and 7), again contradicting reports of Lavon *et al.* (1996) who reported that MKP spray increased fruit size of 'Shamouti' midseason and 'Star Ruby' grapefruit.

[Tables 4, 5 & 7]

*Internal quality.* No consistent effect of MKP treatment was found on juice content, TSS, TA and TSS:TA ratio of 'Nouvelle' tangor, 'Valencia' orange, 'Shamouti' midseason and 'Eureka' lemon (Tables 3, 4, 5, 6, 7 & 8), contradictory to results obtained by Lavon *et al.* (1996). MKP at 5% 6 weeks after full bloom significantly increased juice content and reduced TSS of 'Oroval' Clementine compared to the control (Table 9). MKP at 3% and 5% 6 weeks after full bloom reduce TSS:TA ratio compared to a control of 'Oroval' Clementine (Table 9).

[Tables 3, 4, 5, 6, 7, 8 & 9]

*Rind texture.* Except for 5% MKP sprayed 6 weeks after full bloom, all treatments improved rind texture of 'Nouvelle' tangor (Table 3).

During 1998/99, all MKP and UAP treatments significantly improved rind texture of 'Valencia' orange (Table 4). However, in the following season, only MKP sprayed at 3% 6 weeks after full bloom significantly improved rind texture of 'Valencia' orange (Table 5).

During 1998/99, 'Shamouti' midseason rind texture was not improved by MKP treatments (Table 6). However, in the following season all treatments, except MKP at 5% applied 6 weeks after full bloom, significantly improved rind texture of 'Shamouti' midseason (Tables 6 and 7). Similar findings were reported by Lavon *et al.* (1996).

MKP and UAP treatments had no positive effect on rind texture of either 'Eureka' lemon or 'Oroval' Clementine (Tables 8 and 9). These findings contradict reports that P and K improved rind texture of 'Valencia' orange (Reese & Koo, 1974) and 'Star Ruby' grapefruit and 'Shamouti' midseason (Lavon *et al.*, 1996).

[Tables 3, 4, 5, 6, 7, 8 & 9]

In conclusion, MKP and UAP had no consistent effect on yield, juice content, TSS, TA and TSS:TA ratio on all varieties evaluated. The leaf concentrations of N, P and K were inconsistently affected by MKP and UAP treatments. MKP and UAP spray significantly, but inconsistently, improved rind texture of 'Nouvelle' tangor, 'Shamouti' midseason and 'Valencia' orange. However, no positive effect on 'Oroval' Clementine and 'Eureka' lemon rind texture was found.

### LITERATURE CITED

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Table 1. Percentage leaf N, P and K of leaves sampled from the fruiting terminal on selected treatments after 6 weeks of MKP spray during 1998/99.

Treatment	Spray time*	'Nouvelle' tangor	'Oroval' Clementine	'Valencia' orange	'Shamouti' midseason
<b>% N</b>					
Control		2.07 a	2.57 a	2.16 b	2.09 ab
MKP 3%	4 AFB	1.97 a	2.28 ab	2.69 a	1.94 b
MKP 5%	6 AFB	2.04 a	2.07 b	2.66 a	2.19 a
Sign.level		0.2609	0.0288	0.009	0.0935
LSD (5%)		0.19	0.34	0.22	0.23
<b>Source</b>	df				
<b>Treatment</b>	2				
<b>Contrast</b>					
Control vs MKP	1	0.3723	0.0155	0.0003	0.8223
<b>% P</b>					
Control		0.12 a	0.17 a	0.12 a	0.13 b
MKP 3%	4 AFB	0.14 a	0.17 a	0.32 a	0.13 b
MKP 5%	6 AFB	0.15 a	0.17 a	0.11 a	0.18 a
Sign.level		0.2609	0.7321	0.3938	0.0171
LSD (5%)		0.03	0.02	0.37	0.04
<b>Source</b>	df				
<b>Treatment</b>	2				
<b>Contrast</b>					
Control vs MKP	1	0.1231	0.4439	0.5219	0.1152
<b>% K</b>					
Control		0.97 a	0.93 a	1.81 a	1.71 a
MKP 3%	4 AFB	1.08 a	0.81 a	1.68 ab	1.69 a
MKP 5%	6 AFB	1.08 a	1.04 a	1.58 b	1.92 a
Sign.level		0.4084	0.4138	0.0376	0.2778
LSD (5%)		0.32	0.38	0.16	0.34
<b>Source</b>	df				
<b>Treatment</b>	2				
<b>Contrast</b>					
Control vs MKP	1	0.2624	0.9618	0.0206	0.4752

Means followed by the same letter are not significantly different at 5% (LSD).

\*4 AFB (4 weeks after full bloom)

\*6 AFB (6 weeks after full bloom)



Table 2. Percentage leaf P and K of leaves sampled from the fruiting terminal sampled on selected treatments after spray and early February in all treatments of MKP spray of Citrus species during 1999/2000.

		<u>'Valencia'</u> <u>orange</u>	<u>'Shamouti'</u> <u>midseason</u>	<u>'Valencia'</u> <u>orange</u>	<u>'Shamouti'</u> <u>midseason</u>
Treatment	Spray time*	<u>Leaf samples after spray</u>		<u>Leaf samples in early February</u>	
		<b>%P</b>		<b>%P</b>	
Control		0.18 b	0.18 a	0.09 a	0.12 b
MKP (3%)	4 AFB	0.29 a	0.19 a	0.12 a	0.19 a
MKP (5%)	4 AFB			0.12 a	0.12 b
MKP (3%)	6 AFB			0.09 a	0.12 b
MKP (5%)	6 AFB	0.28 a	0.26 a	0.09 a	0.16 ab
Sign. Level		0.0931	0.2475	0.0765	0.0824
LSD (5%)		0.11	0.11	0.03	0.06
<b>Source</b>			df		df
<b>Treatment</b>			2		4
<b>Contrast</b>					
Control vs Trt	1	0.0322	0.2796	0.2112	0.0194
Early vs late	1			0.1972	0.2466
Conc	1			0.6867	0.4243
		<b>%K</b>		<b>%K</b>	
Control		1.36 a	1.55 b	1.57 b	1.77 c
MKP (3%)	4 AFB	1.46 a	1.76 b	1.59 b	1.99 ab
MKP (5%)	4 AFB			1.75 ab	2.09 a
MKP (3%)	6 AFB			1.63 b	1.94 abc
MKP (5%)	6 AFB	1.62 a	2.01 a	2.02 a	1.93 abc
Sign. Level		0.3322	0.0047	0.0765	0.0077
LSD (5%)		0.36	0.26	0.03	0.17
<b>Source</b>			df		df
<b>Treatment</b>			2		4
<b>Contrast</b>					
Control vs Trt	1	0.2464	0.0054	0.1634	0.0020
Early vs late	1			0.1946	0.0595
Conc	1			0.0231	0.4266

Means followed by the same letter are not significantly different at 5% (LSD).

\*4 AFB (4 weeks after full bloom)

\*6 AFB (6 weeks after full bloom)

Table 3. Effect of mono-potassium phosphate (MKP) and urea ammonium phosphate (UAP) on yield, internal and external fruit quality of 'Nouvelle' tangor during 1998/99.

Treatment	Spray time	Yield (kg/tree)	Juice content (%)	TSS (%)	TA (%)	TSS:TA ratio	Rind texture
Control		142.5 a	32.3 b	11.8 a	1.0 b	11.9 a	6.7 a
MKP (3%)	4 AFB	112.3 ab	33.2 ab	12.2 a	1.1 ab	11.3 ab	4.8 b
MKP (5%)	4 AFB	131.2 a	32.9 ab	12.3 a	1.2 ab	10.8 ab	5.7 b
MKP (3%)	6 AFB	122.0 a	34.2 ab	12.7 a	1.3 a	10.3 b	4.9 b
MKP (5%)	6 AFB	109.3 ab	35.3 ab	12.2 a	1.1 ab	11.4 ab	5.7 ab
UAP (2%)	4 AFB	115.4 ab	33.4 ab	12.0 a	1.0 b	11.9 a	3.7 b
UAP (2%)	6 AFB	86.7 b	36.1 a	12.3 a	1.1ab	11.7 a	4.8 b
Sign. Level		0.0779	0.2752	0.5082	0.1120	0.1514	0.0001
LSD (5%)		35.3	3.4	0.9	0.2	1.2	1.1
<b>Source</b>	df						
<b>Treatment</b>	6						
<b>Contrast</b>							
Control vs Trt	1	0.0317	0.1410	0.1400	0.7521	0.1764	0.0001
Early vs late	1	0.6244	0.1720	0.5244	0.4059	0.6402	0.8962
Conc	1	0.7995	0.6969	0.4839	0.2934	0.5839	0.0283

*Means followed by the same letter are not significantly different at 5% (LSD).*

\*4 AFB (4 weeks after full bloom)

\*6 AFB (6 weeks after full bloom)

Table 4. Effect of mono-potassium phosphate (MKP) and urea ammonium phosphate (UAP) on yield, fruit size, internal and external fruit quality of 'Valencia' orange during 1998/99.

Treatment	Spray* time	Yield (kg/tree)	Fruit size (mm)	Juice content (%)	TSS (%)	TA (%)	TSS:TA ratio	Rind texture
Control		139.1 a	76.2 a	31.2 a	9.5 a	1.5 a	6.5 a	2.5 a
MKP (3%)	4 AFB	144.5 a	75.5 a	30.3 a	9.5 a	1.4 a	6.8 a	1.4 b
MKP (5%)	4 AFB	145.0 a	74.8 a	31.4 a	9.8 a	1.5 a	6.8 a	1.5 b
MKP (3%)	6 AFB	127.5 a	74.7 a	30.6 a	9.5 a	1.4 a	6.6 a	1.7 b
MKP (5%)	6 AFB	142.7 a	73.8 a	30.5 a	9.8 a	1.4 a	6.9 a	1.6 b
UAP (2%)	4 AFB	123.9 a	73.8 a	32.4 a	9.7 a	1.4 a	6.8 a	1.6 b
UAP (2%)	6 AFB	127.6 a	73.2 a	29.1 a	9.9 a	1.5 a	6.7 a	1.5 b
Sign. Level		0.6864	0.4456	0.7165	0.2257	0.8644	0.6507	0.0005
LSD (5%)		34.4	3.1	0.7	0.5	0.3	0.5	0.5
<b>Source</b>								
<b>Treatment</b>								
<b>Contrast</b>								
Control vs Trt	1	0.7201	0.1210	0.7494	0.2375	0.6281	0.1509	0.0001
Early vs late	1	0.3796	0.7340	0.8490	0.8737	0.9620	0.9235	0.8975
Conc	1	0.4616	0.2311	0.7484	0.0602	0.5256	0.4181	0.4798

*Means followed by the same letter are not significantly different at 5% (LSD).*

\*4 AFB (4 weeks after full bloom)

\*6 AFB (6 weeks after full bloom)

Table 5. Effect of mono-potassium phosphate (MKP) foliar spray on yield (kg/tree), fruit size, peel thickness, internal and external quality of 'Valencia' orange during 1999/2000.

Treatment	Spray time*	Yield (kg/tree)	Fruit size (mm)	Peel thickness (mm)	Juice content (%)	TSS (%)	TA (%)	TSS:TA ratio	Rind texture
Control		238.6 a	75.2 ab	6.9 b	35.9 a	10.9 ab	1.4 a	8.0 a	3.6 a
MKP (3%)	4 AFB	242.8 a	74.6 ab	7.3 a	33.7 ab	11.0 ab	1.4 a	7.7 a	3.3 ab
MKP (5%)	4 AFB	228.8 a	74.9 ab	7.1 a	33.2 b	10.8 b	1.4 a	7.7 a	3.7 a
MKP (3%)	6 AFB	212.9 a	73.8 b	6.9 b	35.9 a	11.4 a	1.4 a	8.0 a	2.8 b
MKP (5%)	6 AFB	240.9 a	75.9 a	6.9 b	34.3 ab	11.1 ab	1.5 a	7.6 a	3.7 a
Sign. Level		0.6509	0.1386	0.2034	0.1062	0.0648	0.3527	0.2488	0.0482
LSD (5%)		47.3	1.7	0.4	2.5	0.4	0.1	0.4	0.7
<b>Source</b>	<b>df</b>								
<b>Treatment</b>	4								
<b>Contrast</b>									
Control vs Trt	1	0.2039	0.4510	0.2102	0.0905	0.5030	0.1496	0.2004	0.4439
Early vs late	1	0.3102	0.9291	0.0554	0.0775	0.0138	0.3864	0.3856	0.1879
Conc	1	0.0946	0.0325	0.4974	0.2462	0.1051	0.9727	0.2323	0.0092

*Means followed by the same letter are not significantly different at 5% LSD.*

\*4 AFB (4 weeks after full bloom)

\*6 AFB (6 weeks after full bloom)

Table 6. Effect of mono-potassium phosphate (MKP) foliar spray on internal and external quality of 'Shamouti' midseason during 1998/99.

Treatment	Spray time*	Yield (kg/tree)	Juice content (%)	TSS (%)	TA (%)	TSS:TA ratio	Rind texture
Control		81.1 a	35.2 a	9.9 a	1.2 a	8.6 a	5.7 a
MKP (3%)	4 AFB	70.8 a	36.9 a	9.9 a	1.2 a	8.5 a	4.6 a
MKP (5%)	4 AFB	67.4 a	34.8 a	9.8 a	1.2 a	8.5 a	4.6 a
MKP (3%)	6 AFB	60.9 a	35.1 a	9.7 a	1.2 a	8.2 a	5.1 a
MKP (5%)	6 AFB	58.1 a	35.8 a	9.9 a	1.2 a	8.4 a	4.8 a
Sign. Level		0.7379	0.8857	0.8787	0.8296	0.5930	0.7034
LSD (5%)		36.7	4.4	0.6	0.1	0.5	1.9
<b>Source</b>	<b>df</b>						
<b>Treatment</b>	4						
<b>Contrast</b>							
Control vs Trt	1	0.4097	0.8878	0.8889	0.3878	0.4002	0.2004
Early vs late	1	0.5209	0.4345	0.5502	0.7144	0.3053	0.6701
Conc	1	0.6736	0.5680	0.8964	0.4436	0.3475	0.6438

*Means followed by the same letter are not significantly different at 5% (LSD).*

\*4 AFB (4 weeks after full bloom)

\*6 AFB (6 weeks after full bloom)

Table 7. Effect of mono-potassium phosphate (MKP) foliar spray on yield (kg/tree), fruit size, peel thickness, internal and external quality of 'Shamouti' midseason during 1999/2000.

Treatment	Spray time*	Yield (kg/tree)	Fruit size (mm)	Peel thickness (mm)	Juice content (%)	TSS (%)	TA (%)	TSS:TA ratio	Rind texture
Control		98.9 a	79.3 a	8.3 a	29.6 a	10.2 a	1.5 b	6.7 a	3.1 a
MKP (3%)	4 AFB	111.1 a	75.2 b	8.0 a	31.9 a	9.9 a	1.6 a	6.4 a	2.3 b
MKP (5%)	4 AFB	111.9 a	77.8 ab	8.2 a	31.5 a	10.3 a	1.6 a	6.4 a	2.3 b
MKP (3%)	6 AFB	101.7 a	77.5 ab	7.9 a	30.3 a	10.2 a	1.6 a	6.4 a	1.9 b
MKP (5%)	6 AFB	105.2 a	77.9 a	8.2 a	31.7 a	10.2 a	1.5 b	6.6 a	2.4 ab
Sign. Level		0.7580	0.0682	0.8919	0.8303	0.4709	0.2335	0.3487	0.0340
LSD (5%)		23.9	2.8	0.7	4.8	0.4	0.1	0.4	0.7
<b>Source</b>	<b>df</b>								
<b>Treatment</b>	4								
<b>Contrast</b>									
Control vs Trt	1	0.3632	0.0485	0.4097	0.3478	0.8612	0.1490	0.1089	0.0034
Early vs late	1	0.3392	0.2048	0.9437	0.6778	0.6487	0.3572	0.2759	0.6003
Conc	1	0.7989	0.1162	0.5312	0.7917	0.1399	0.5525	0.5020	0.4126

*Means followed by the same letter are not significantly different at 5% LSD.*

\*4 AFB (4 weeks after full bloom)

\*6 AFB (4 weeks after full bloom)

Table 8. Effect of mono-potassium phosphate (MKP) and urea ammonium phosphate on fruit quality of 'Eureka' lemon during 1998/99.

Treatment	Spray time*	Juice content (%)	Rind texture
Control		28.6 a	1.9 a
MKP (3%)	4 AFB	29.5 a	1.9 a
MKP (5%)	4 AFB	31.3 a	2.4 a
MKP (3%)	6 AFB	28.6 a	1.9 a
MKP (5%)	6 APB	30.7 a	2.1 a
UAP (2%)	4 AFB	28.5 a	2.3 a
UAP (2%)	6 APB	28.9 a	2.1 a
Sign. Level		0.8085	0.5165
LSD (5%)		4.6	0.9
<b>Source</b>	df		
<b>Treatment</b>	6		
<b>Contrast</b>			
Control vs Trt	1	0.5770	0.3378
Early vs Late	1	0.5817	0.3563
Conc	1	0.2690	0.1476

*Means followed by the same letter are not significantly different at 5% (LSD).*

\*4 AFB (4 weeks after full bloom)

\*6 AFB (6 weeks after full bloom)

Table 9. Effect of mono-potassium phosphate spray on internal and external quality of 'Oroval' Clementine during 1998/99.

Treatment	Spray time*	Juice content (%)	TSS (%)	TA (%)	TSS:TA ratio	Rind texture
Control		46.7 b	10.0 a	1.1 a	9.9 a	1.5 a
MKP (3%)	4 AFB	52.7 ab	9.6 ab	1.1 a	8.7 ab	1.5 a
MKP (5%)	4 AFB	55.8 a	9.4 b	1.1 a	8.8 ab	1.6 a
MKP (3%)	6 AFB	51.0 ab	9.8 a	1.2 a	8.4 bc	1.5 a
MKP (5%)	6 AFB	56.2 a	9.4 b	1.2 a	8.1 c	2.0 b
Sign. Level		0.0264	0.1535	0.3867	0.0744	0.0558
LSD (5%)		6.3	0.6	0.2	0.3	0.4
<b>Source</b>	df					
<b>Treatment</b>	4					
<b>Contrast</b>						
Control vs Trt	1	0.0056	0.0578	0.2592	0.0084	0.3963
Early vs late	1	0.7703	0.5444	0.1170	0.2529	0.1334
Conc	1	0.0692	0.1287	0.8561	0.8345	0.0535

*Means followed by the same letter are not significantly different at 5% (LSD).*

\*4 AFB (4 weeks after full bloom)

\*6 AFB (6 weeks after full bloom)



#### **4. PAPER 3. EFFECT OF LATE-SUMMER APPLICATIONS OF PHOSPHORUS-AND POTASSIUM-CONTAINING COMPOUNDS ON FRUIT COLOUR OF MANDARINS.**

**Abstract:** Adequate rind colour is an important criterium to ensure acceptance of mandarin fruit. The effect of Seniphos<sup>®</sup> a mineral mixture of 310 g/L P<sub>2</sub>O<sub>5</sub>, 56 g/L CaO and 30 g/L total N and mono-potassiumphosphate (MKP) [52% P<sub>2</sub>O<sub>5</sub> and 34% K<sub>2</sub>O] on fruit colour, yield and internal fruit quality of 'Mihowase' Satsuma and 'Nules' Clementine on 'Troyer' citrange rootstock was evaluated in Stellenbosch (34°S 19°E), South Africa. Seniphos<sup>®</sup> and mono-potassiumphosphate (MKP) were applied at difference concentrations on 'Nules' Clementines during 1999 and 2000, and the trial was also expanded to include 'Mihowase' Satsuma in 2000. No effect was evident in either season on leaf P and K levels. Seniphos<sup>®</sup> and MKP applied during autumn colour break also did not influence fruit colour, yield and internal fruit quality, viz., juice content (%), TSS, TA and TSS:TA ratio of 'Nules' Clementine and 'Mihowase' Satsuma.

## INTRODUCTION

Marketing of citrus mandarins is hindered by inadequate rind colour development in early cultivars such as 'Mihowase' Satsuma and 'Nules' Clementine, despite having attained minimum maturity standards. Therefore a well-developed rind colour of citrus is an external parameter of major importance in the fresh fruit market. Fruit with poor colour results in a reduction in the percentage of exportable fruit.

Fruit colour development in citrus flavedo involves the unmasking of carotenoids, associated chlorophyll breakdown as well as an increase in carotenoid synthesis (Eilati *et al.*, 1969; Barterly & Scolnick, 1995). Colour changes in citrus are influenced by temperature (Cooper *et al.*, 1969; Patracek & Montalvo, 1997) and light (Khudairi & Arboleda, 1971; Thomas & Jen, 1975). Low temperatures cause mild injury of the rind, a process which increases production and release of ethylene and enhancing development of a deep orange colour (Young & Erickson, 1969).

Mono-potassiumphosphate (MKP) [52% P<sub>2</sub>O<sub>5</sub> (P=22.6%) and 34% K<sub>2</sub>O (K=28.2%)] applied as a foliar spray during autumn colour break has been shown to improve early colour development of 'Mihowase' Satsuma (Kuretani & Terao, 1986; Kuretani *et al.*, 1986). Application of a Seniphos<sup>®</sup>, a mineral mixture of 310 g/L P<sub>2</sub>O<sub>5</sub>, 56 g/L CaO, and 30 g/L total nitrogen, 1% NO<sub>3</sub><sup>-</sup> and 2% NH<sub>3</sub><sup>+</sup> was shown to improve red colour development of 'Starking Delicious' when applied during autumn colour break (Tan, 1979; Gómez-Cordovés *et al.*, 1996; Larrigaudiere *et al.*, 1996).

Therefore, the objective of this study was to evaluate the potential benefits of late-summer P and K application on early fruit colour development of 'Nules' Clementine and 'Mihowase' Satsuma fruits.

## MATERIALS AND METHODS

*Plant material and experimental site.* Healthy nine-year-old 'Nules' Clementine and ten-year-old 'Mihowase' Satsuma trees on 'Troyer' citrange rootstock, uniform in canopy size and trunk girth were used. Orchards are situated near Stellenbosch, South Africa (34 °S 19 °E), altitude ca. 150 m with mediterranean climate with hot, dry summers and winter rainfall.

*Experimental design and treatment details.* In 1999, eight treatments replicated 10 times in a randomised complete block design were used for the study on 'Nules' Clementine, whilst in 2000, three treatments replicated 10 times in a randomised complete block design were used for both 'Mihowase' Satsuma and 'Nules' Clementine. All trees sprayed by MKP received approximately 22 kg P/ha and 17 kg K/ha per application in autumn. All trees sprayed by Seniphos<sup>®</sup> received approximately 8 kg P/ha and 2 kg N /ha per application.

*Fruit colour, harvesting and yield.* Fruit were selectively picked based on external colour according to recommended minimum maturity standards of commercial harvest and rated using the Capespan Colour Chart No 34 ratings 1 to 8 (1 = orange and 8 = dark green). Individual tree yield was determined at commercial picking. Harvest dates were as

follows: In 1999, 'Nules' Clementine, fruit were picked on 11 May and in 2000 fruit were picked on 10 May. In 2000, 'Mihowase' Satsuma fruit were picked on 21 and 23 March. Fruit picked selectively at each time were expressed as a percentage of the total yield.

*Fruit quality determination.* At harvest, 12 fruit were randomly sampled from each tree for internal quality analysis. Fruits were squeezed using a hand reamer (citrus juicer). Juice was strained through two layers of muslin cloth and juice content (%) was determined by subtracting weight of reamed peel from the total fruit weight. The Brix level (providing an indication of total soluble solids [TSS]) of the juice was determined with a hand-held refractometer (Atago N1). Titratable acidity (TA) expressed as percentage citric acid content was assessed by titration with 0.1 N sodium hydroxide, using phenolphthalein as an indicator. The TSS:TA ratio was calculated by dividing the TSS values by the TA values.

*Leaf sampling and analyses.* Twenty 5 to 6 month-old mature spring flush leaves from fruiting terminals were sampled one week after Seniphos<sup>®</sup> and MKP sprays for P and K analysis. For each treatment, five replicates were sampled and analysed. P and K leaf concentrations were analysed by the Department of Soil Science, University of Stellenbosch by the FFTRI Procedure & Technology No 32 (Du Preez *et al.*, 1981).

*Statistical analyses.* Analyses of variance were performed using the GLM (General Linear Model) procedure of SAS (Statistical Analysis System) (SAS Inc., 1996).

## RESULTS AND DISCUSSION

*Leaf phosphorus and potassium.* Neither Seniphos<sup>®</sup> or MKP affected leaf P and K levels on 'Nules' Clementine in 1999 and 2000 and 'Mihowase' Satsuma in 2000 (Tables 1 and 2). This contradicts the findings of Lavon *et al.*, (1996) who reported that MKP sprays increased both P and K leaf concentration of 'Shamouti' midseason and 'Star-Ruby' grapefruit.

[Tables 1 & 2]

*Yield and internal quality.* Seniphos<sup>®</sup> and MKP had no effect on yield, juice content (%), TSS, TA and TSS:TA ratio of 'Nules' Clementine and 'Mihowase' Satsuma (Tables 3, 4 & 5) in contrast to reports by Kuretani *et al.* (1986) and Kuretani & Terao (1986) that MKP decreased TA and increased both TSS and TSS:TA ratio.

[Tables 3, 4 & 5]

*Percentage fruit picked selectively.* During 1999, no consistent effect was found between treatments on percentage fruit picked selectively of 'Nules' Clementine (Table 3). In 'Nules' Clementine, MKP sprayed at 3% reduced the percentage fruit picked selectively at the first pick during 2000 ( $P < 0.05$ ) (Table 4). These findings contradict reports by Kuretani *et al.* (1986) and Kuretani & Terao (1986) that foliar application of potassium phosphate during autumn colour break advanced colouration of 'Mihowase' Satsuma increasing the percentage of the first harvest. No effect of Seniphos<sup>®</sup> and MKP on

percentage fruit picked selectively was found on 'Mihowase' Satsuma during 2000 (Table 5).

[Tables 3, 4 & 5]

In conclusion, Seniphos<sup>®</sup> and MKP applied during colour break did not result in enhanced citrus colour development, yield and internal fruit quality, viz., juice content (%), total soluble solids (TSS), total acidity (TA) and TSS:TA ratio of 'Nules' Clementine and 'Mihowase' Satsuma.

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Table 1. Percentage leaf P and K from the fruiting terminal one week after Seniphos<sup>®</sup> and mono-potassiumphosphate (MKP) spray of 'Nules' Clementine during 1999.

Treatment	Spray date	% leaf P	% leaf K
Control		0.12 a	1.24 ab
Seniphos <sup>®</sup> 1%	31/03	0.16 a	1.18 b
Seniphos <sup>®</sup> 1%	14/04	0.13 a	1.25 ab
Seniphos <sup>®</sup> 1%	31/03 & 14/04	0.12 a	1.25 ab
Seniphos <sup>®</sup> 2%	14/04	0.13 a	1.18 b
MKP 3%	31/03	0.12 a	1.34 ab
MKP 3%	14/04	0.14 a	1.39 a
MKP 1%	14/04	0.12 a	1.23 ab
Sign. Level		0.5813	0.2991
LSD (5%)		0.05	0.19
<b>Source</b>	df		
<b>Treatment</b>	7		
<b>Contrast</b>			
Control vs Seniphos <sup>®</sup>	1	0.4950	0.7416
Control vs MKP	1	0.6707	0.1987

*Means followed by the same letter are not significantly different at 5% LSD.*

Table 2. Percentage leaf P and K from the fruiting terminal of 'Mihowase' Satsuma and 'Nules' Clementine one week after Seniphos<sup>®</sup> and MKP during 2000.

Treatments	<u>'Mihowase' Satsuma*</u>		<u>'Nules' Clementine**</u>		
	<u>% leaf P</u>	<u>% leaf K</u>	<u>% leaf P</u>	<u>% leaf K</u>	
Control	0.11 a	0.91 a	0.17 a	1.56 a	
Seniphos <sup>®</sup> 1%	0.12 a	0.92 a	0.23 a	1.51 a	
MKP 3%	0.15 a	0.99 a	0.19 a	1.71 a	
Sign. Level	0.3261	0.4532	0.3487	0.1685	
LSD (5%)	0.07	0.16	0.09	0.22	
<b>Source</b>	df				
<b>Treatment</b>	2				
<b>Contrast</b>					
Control vs Spray	1	0.3416	0.4689	0.2699	0.5872

*Means followed by the same letter are not significantly different at 5% LSD.*

\*Sampling date: 'Mihowase' Satsuma: 22 March, spray dates 28 February and 15 March

\*\*Sampling date: 'Nules' Clementine: 21 April, spray dates 15 March and 14 April

Table 3. Effect of Seniphos® and MKP on fruit colour development, yield (kg/tree), of 'Nules' Clementine (all treatments) and internal fruit quality parameters (selected) during 1999.

Treatment	Spray date	Total yield (kg/tree)	% Fruit 1 <sup>st</sup> Pick	Juice content (%)	TSS (%)	TA (%)	TSS:TA ratio
			<u>11/05/1999</u>				
Control		70.7 ab	55.8 a	56.2 a	9.67 a	1.17 a	8.28 a
Seniphos® 1%	31/03	64.6 ab	54.5 abc				
Seniphos® 1%	14/04	72.5 ab	55.7 ab				
Seniphos® 1%	31/03 & 14/04	74.1 ab	42.2 c	57.2 a	10.05 a	1.16 a	8.72 a
Seniphos® 2%	14/04	61.3 b	51.2 abc				
MKP 3%	31/03	79.6 a	46.1 bc	54.9 a	10.27 a	1.18 a	8.76 a
MKP 3%	14/04	65.0 ab	52.3 abc				
MKP 1%	14/04	63.1 b	60.9 a				
Sign. Level		0.2846	0.1122	0.3782	0.1638	0.7888	0.4030
LSD (5%)		15.8	12.61	3.32	0.64	0.08	0.81
<b>Source</b>	df						
<b>Treatment</b>	7						
<u>Contrast</u>							
Control vs Seniphos®	1	0.6837	0.3333				
Control vs MKP	1	0.8237	0.6060				

*Means followed by the same letter are not significantly different at 5% LSD.*

Table 4. Effect of Seniphos® and MKP on fruit colour development, yield (kg/tree) and internal quality of 'Nules' Clementine during 2000.

Treatment	Spray dates	Total yield (kg/tree)	% Fruit Picked	1 <sup>st</sup> Juice content (%)	TSS (%)	TA (%)	TSS:TA ratio
Control		43.8 a	49.8 a	40.3 a	11.1 a	1.2 a	8.9 a
Seniphos® 1%	15/03 & 14/04	44.7 a	48.4 a	42.7 a	11.0 a	1.3 a	8.7 a
MKP 3%	15/03 & 14/04	44.8 a	39.1 b	40.6 a	11.0 a	1.3 a	8.6 a
Sign. Level		0.9730	0.0362	0.2085	0.9437	0.5352	0.5453
LSD (5%)		7.9	8.6	2.9	0.6	0.1	0.6
<b>Source</b>							
<b>Treatment</b>							
<b>Contrast</b>							
Control vs Spray	1	0.8446	0.1053	0.2689	0.7509	0.2781	0.2919

Means followed by the same letters are not significantly different at 5% LSD.

Table 5. Effect of Seniphos<sup>®</sup> and MKP spray on fruit colour development, yield (kg/tree) and internal quality of 'Mihowase' Satsuma during 2000.

Treatment	Spray dates	Total yield (kg/tree)	% Fruit 1 <sup>st</sup> Picked	% Fruit 2 <sup>nd</sup> Picked	Juice content (%)	TSS (%)	TA (%)	TSS:TA ratio
Control		61.8 a	21/03	23/03/2000	27.9 a	11.3 a	1.3 a	8.8 a
Seniphos <sup>®</sup> 1%	15/02 & 28/02	65.6 a	16.8 a	20.6 a	28.2 a	11.4 a	1.4 a	8.5 a
MKP 3%	15/02 & 28/02	68.2 a	14.5 a	15.2 b	30.1 a	11.6 a	1.2 a	9.9 a
Sign. Level		0.3410	0.8777	0.3768	0.5171	0.6411	0.4237	0.3081
LSD (5%)		8.9	6.2	4.5	4.2	0.6	0.3	1.8
<b>Source</b>								
<b>Treatment</b>								
<b>Contrast</b>								
Control vs Spray	1	0.1857	0.6240	0.2425	0.5029	0.5293	0.6713	0.7077

Means followed by the same letters are not significantly different at 5% LSD.

## 5. OVERALL DISCUSSION AND CONCLUSION

The effect of foliar application of N (l.b. urea, 1%) substituting a significant proportion of soil-applied N and foliar application of Seniphos<sup>®</sup> a compound consisting of 310g/L P<sub>2</sub>O<sub>5</sub> and mono-potassiumphosphate (MKP) [52% P<sub>2</sub>O<sub>5</sub> and 34% K<sub>2</sub>O] during autumn colour break was evaluated in a bid to improve early fruit colour development of mandarins.

Despite tree appearance being more yellow in some years where N were predominantly applied as foliar sprays, no consistent reduction in fruit size and yield were found. There were no clear significant differences in fruit colour, possibly due to the fact that leaf N-levels were still within or below the norms suggested for Satsuma. Further research is required in other production areas with different soil types and climatic conditions. Higher applications of N levels that could result in an increase of leaf N level above the optimum norms for Satsuma should also be evaluated.

Application of P and K, applied as Seniphos<sup>®</sup> and MKP sprays did not influence fruit colour, yield and internal quality of mandarins. It would thus appear that there is no commercial reason for application of Seniphos<sup>®</sup> and MKP sprays to enhance early fruit colour of mandarins. Since there is no effect of these compounds on fruit colour, further research of MKP should focus on rind texture improvement.

The effect of foliar-applied MKP at 3% or 5% and UAP at 2% at 4 or 6 weeks after full bloom, respectively, in a bid to improve rind texture were evaluated. MKP and UAP sprays significantly, but inconsistently improved rind texture of 'Nouvelle' tangor,

'Shamouti' midseason and 'Valencia' orange. MKP at 3% and 5% were equally effective, suggesting that lower concentrations should be tried in future trials. This was not the case for 'Eureka' lemon and 'Oroval' Clementine. Currently neither MKP nor UAP sprays can be recommended to commercially improve rind texture of 'Oroval' Clementine and 'Eureka' lemon. Due to unavailability of UAP and high cost of MKP in the local market, further trials should continue reducing concentrations of MKP. Other high phosphorous-containing compounds such as mono-ammonium phosphate (MAP) in cultivars with coarse rind problems should also be evaluated.