Ripening Behaviour and Quality on Ripening of Sensation Mango in Relation to Cold-storage Temperature and Tree Fertilization

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ABSTRACT

Newly picked Sensation mangos of similar maturity were obtained from five growers in the north eastern Transvaal, and immediately placed in cold-storage for three weeks at either 11, 13 or 15^{0}C. The tree fertilization schedule adopted differed between growers, particularly with respect to the amount of nitrogen (N) applied, which is categorized in the present study as either being low, moderate or high.

Ripening behaviour during cold-storage varied according to fruit source and cold-storage temperature. Skin colouration, pulp colouration, and softening of the "high-" and "moderate-N" fruit were strongly suppressed at 11 or 13^{0}C. At these temperatures, the above mentioned changes were suppressed to a lesser degree in the "low-N" fruit, and their extent bore a positive relationship with temperature. Irrespective of the source of the fruit, Skin colouration, pulp colouration, and softening occurred to a marked degree at 15^{0}C, although they showed some delay in the case of the "moderate-" and "high-N" fruit. Further, storage at 15^{0}C resulted in the fruit being soft on removal from cold-storage. In all the fruit, soluble solids content increased appreciably during cold-storage. However, the variation of the increases observed was relatively small with respect to fruit source or cold-storage temperature.

On full-ripening after cold-storage, skin de-greening was complete or almost complete in the "low-N" fruit, whereas the "moderate-" and "high-N" fruit had either failed appreciably to de-green or showed incomplete de-greening. The extent of de-greening also bore a positive relationship with the cold-storage temperature. Differences in pulp colouration, pH, and total soluble solids content in relation to fruit source or cold-storage temperature were less apparent, although a depression in soluble solids content was apparent in the "low-N" fruit.

The incidence of internal breakdown on full-ripening was least in the "low-N" fruit. A relationship between N application and the incidence of lenticel damage was unapparent.

Leaf macro- and micro-nutrient concentrations suggested the added involvement of calcium in the responses observed. It is concluded that the options of increasing the commercial transit temperature from 11^{0}C to 13^{0}C and adjusting the fertilization schedule, particularly in relation to a lesser incorporation of N, to effect an enhancement in the quality of Sensation mangos on ripening after sea export, should be further researched and commercially exploited.

UITTREKSEL

Sensation mangos met dieselfde graad van volwassenheid is verkry vanaf vyf kwekers in die Noord-oos Transvaal en is onmiddelik in koelopberging by 11, 13 en 15°C geplaas vir drie weke. Die boom bemestingsprogram wat gebruik is het verskil tussen die kwekers, veral in die hoeveelheid stikstof (N) wat toegedien is en word in hierdie studie gekategoriseer as hoog, matig of laag.

Rypwording gedurende die koelopberging het ooreenkomnstig met die vrugte bronne en opbergingstemperature gewissel. Skil- en pulpverkleuring en sagwording van die "hoë- en matige-N" vrugte is sterk onderdruk by 11 en 13°C. By hierdie temperature is bg. veranderings tot 'n mindere mate onderdruk in die "lae-N" vrugte en die graad van hierdie veranderings is positief gekorreleer met opbergingstemperatuur. Ongeag die bron van die vrugte het hierdie veranderings in 'n merkbare graad voorgekom by 15°C alhoewel daar 'n vertraging in die voorkoms van hierdie veranderinge in die geval van "hoë- en matige-N" vrugte was. Verdere opberging by hierdie temperatuur het veroorsaak dat die vrugte sag was tydens die uithaal uit die koelkamers. Die oplosbare vastestof inhoud van al die vrugte het aansienlik verhoog tydens koelopberging. Die variasie in die toenames wat waargeneem is was egter relatief klein met betrekking tot vrugbron en opbergingstemperatuur.

Met volle rypheid na opberging was skilontgroening heeltemal of feitlik heeltemal voltooi by "lae-N" vrugte, maar by "gematigde- en hoë-N" vrugte het ontgroening glad nie plaasgevind nie of, slegs gedeeltelik plaasgevind. Die graad van ontgroening het ook 'n positiewe korrelasie met opbergingstemperatuur getoon. Verskille in pulpverkleuring, pH en totale oplosbare vastestofinhoud se verwantskap met die vrugbron en opbergingstemperatuur was egter minder opvallend al het daar 'n verlaging in oplosbarevastestof inhoud voorgekom in "lae-N" vrugte.

Die voorkoms van interne verval tydens volle rypheid was die laagste in die "lae-N" vrugte. Daar was ook geen verwantskap tussen N-toediening en lentiselskade nie.

Blaar makro- en mikrovoedingstof konsentrasies het die verhoogde betrokkenheid van kalsium in die waargenome reaksies geïmpliseer. Hieruit kan afgelei word dat die verhoging van die kommersiële vervoertemperatuur van 11°C na 13°C en die ooreenkomstige verandering in die bemestingsprogram, veral in verband met verlaagde N-toediening, om 'n verbetering in die kwaliteit van Sensation Mangos tydens rypwording na see-uitvoere, verder nagevors en kommersieel toegepas moet word.

INTRODUCTION

Sensation mangos in the eastern Transvaal are picked for sea-export in January or February at the stage of maturity indicated by the initiation of pulp colouration. Fruit exported by sea take from 21 to 28 days to reach their destination after departure from packhouses in the region, the recommended transit temperature being 11°C. Although this temperature holds little risk of causing chilling injury to fruit picked at the recommended stage of maturity, reports have been made of the fruit being unattractive on and after arrival. The poor appearance is primarily due to failure of the skin or portions thereof to adequately de-green. Inferior prices are obtained, particularly if other mangos with a better appearance are available.

Fruit of good quality might be regarded as those that attain an attractive taste on ripening, are free of skin blemishes resulting from sunburn, sapburn, abrasions, scale, lenticel damage, and chilling injury, are free disease and physiological disorders, and as those that completely de-green on full-ripening. Failure to meet any one of these criteria would represent a reduction in quality. The degree of a detraction might be seen to depend on the extent of the negative effect on price. The measure of skin de-greening taking place has a strong bearing on the appeal of the fruit and, therefore, the price foreign consumers are prepared to pay.

Ground skin colouration during and after cold-storage has been found to positively correlate with storage temperature, fruit having been stored at elevated temperatures (> 10°C) generally being more attractive on full-ripening (Oosthuyse, 1990). Ground skin colouration has also been associated with the fertilization schedule followed by growers, particularly in relation to the amount of nitrogen applied seasonally to trees (Smith, 1992; Amm, 1993; Anon.). A high rate of application is considered to diminish the capacity of fruit to de-green after harvest, whereas fertilization schedules incorporating a low application rate, are considered to favour de-greening.

The aims of the present study were **(1)** to evaluate the temperatures of 11, 13 and 15°C for sea export of Sensation mangos to Europe, particularly in relation to their effect on skin colouration, and **(2)** to gain an idea of the effect of nitrogen fertilization to trees on de-greening of the fruit during and after cold-storage.

MATERIALS AND METHODS

Fifteen, 4 kg cartons of Sensation mangos (counts 10 to 14) were obtained from each of five mango growers in the north eastern Transvaal, and placed in cold-storage for 21 days at either 11, 13 or 15°C (± 0.5°C). The growers differed from one another with respect to the fertilization schedule adopted, particularly in relation to nitrogen application. Five of the cartons obtained from each grower were placed in each of three cold-storage rooms maintained at a set temperature. After cold-storage, the fruit were placed in a well ventilated ripening room maintained at 20°C (± 1°C). The relative humidity of the storage atmospheres exceeded 85%.

The fruit obtained from the various growers are named as follows:

Hoedspruit 1 (low N)
Hoedspruit 2 (high N)
Letsitele Valley 1 (moderate N)
Letsitele Valley 2 (moderate N)
Constantia (high N/high organic)

The names themselves indicate the regions from which the fruit were obtained. Nitrogen incorporation (N) is categorized as either being low, moderate or high, and is shown in the parentheses.

Nitrogen and composted chicken litter supplemented with guano and dried kelp were administered regularly in small doses to the trees from which the "Constantia" fruit were obtained. The remaining fruit were obtained from trees seasonally fertilized with nitrogen, either once soon after harvest (low N), or twice, once after harvest and once during flowering or the early stages of fruit growth and development (moderate or high N).

The fruit were placed in cold-storage within 24 hours after being picked (Feb. 9 or 11, 1993), and were at similar stages of maturity as was indicated by the degree of intensification of pulp colouration at the time of placement in cold-storage.

Packhouse treatment respectively included a soap wash, a 5 minute, 48 to 55°C, hot-water dip, either containing or not containing benlate at 1000 ppm, and waxing with a polyethylene wax.

Just prior to placement of the fruit in cold-storage, one fruit was randomly selected per carton, and the following records were taken:

Skin colouration (loss of green colour in association with yellow colour development) was rated as follows:

"0" - signs of any skin colouration absent
"1" - apparent transformation to a lighter green than the original green colour observed
"2" - regions of the skin yellow, the total area of yellowing being less than the total area still green
"3" - regions of the skin yellow, the total area of yellowing being greater than the total area still green
"4" - skin entirely yellow

Only the area of the skin not covered by red blush was considered. If traces of green were present, the rating of "4" was given.

In determining pulp penetration pressure, each fruit was first cut through "equatorially" with a sharp cutting device. A measurement was obtained per fruit-half by piercing the pulp midway between the seed and skin with a hand-held penetrometer (Facchini - FT 327, Alfonsine, Italy) to which the 6 mm plunger was attached. The mean of the two readings obtained per fruit was re-

corded, the unit of measurement being kg/A, where "A" is the piercing surface area of the plunger used.

Pulp colouration, or the transition in colour intensification of the pulp from white to the deep yellow/orange colour normally seen in fully ripe Sensation mangos, was rated. The rating given was either 0, 25, 50, 75 or 100%, depending on the extent of the transition.

Total soluble solids content was assessed by squeezing juice in the pulp of each fruit onto a hand held refractometer (Atago-N1, Tokyo, Japan).

To determine the progression of ripening during cold-storage, the foregoing assessments were made on two fruit per carton selected at random on the 7th, 14th, and 21st day (last day) of cold-storage.

Seven days after cold-storage, once all of the fruit had fully ripened, the following assessments were performed on two randomly selected fruit per carton for the purpose of assessing fruit quality on full-ripening:

Skin colouration was rated in the manner described previously.

Lenticel damage was rated by approximating the percentage of the skin over which darkened lenticels could be seen. The rating given was either 0, 25, 50, 75 or 100%.

Disease was not taken into account in view of its very low incidence (0.7%).

The fruit were then each cut through longitudinally with a sharp knife. Cuts were made on either side of the flattened margin of the seed and close to it.

Internal breakdown resulting from the physiological disorders, "soft-nose" or "jelly-seed," was rated as follows:

"0" - internal breakdown absent
"1" - internal breakdown localized to a small region of the pulp
"2" - approximately 25% of the pulp affected
"3" - approximately 60% of the pulp affected
"4" - almost all of the pulp tissue affected

Care was taken to cut away affected mesocarp before any further assessments were made.

Pulp colouration was assessed as previously stated. To assess total soluble solids content, a small quantity of juice in the pulp comprising each "cheek" was squeezed onto the hand-held refractometer previously specified, and the mean of the two readings obtained per fruit was recorded. As much juice as could be squeezed from the cheeks of a fruit was then placed in a beaker, and the pH of the juice assessed (pH meter: Metrohm Herisau - E488, Switzerland).

Leaf samples were taken from the orchard blocks from which the "Hoedspruit 1" and "Constantia" fruit were obtained for macro- and micro-nutrient analysis. This was done in late May 1993, once post-harvest flushing had ceased occurring and the newest growth flush had matured. It was aimed to ascertain whether differences in nutrient status existed between the trees in each orchard-block, and to determine whether any deficiencies were present. Four leaf samples, comprising of 40 leaves each, were taken from each block. Each sample was obtained by picking four leaves, one per tree quadrant, from each of 10 adjacent trees centrally situated in each orchard-block. The same trees were used for each collection, and the leaves picked from the base of the new terminal shoots located at chest height. The samples obtained were thoroughly rinsed in distilled water and oven dried at 70^{0}C for 3 days before being sent to the Institute for Tropical and Subtropical Crops at Nelspruit for analysis.

RESULTS

Physico-chemical attributes at harvest

The skin (regions not covered by blush) of the "Hoedspruit 1" fruit was generally of a lighter green than the dark-green colour normally found in unripe fruit. The "Hoedspruit 2" and "Letsitele Valley 1" fruit were either dark-green or had become a lighter green. The "Letsitele 2" and "Constantia" fruit was mostly dark-green.

Pulp colouration had, for the most part, commenced. Average colour intensity relative to that of full-colouration varied from 17 ("Letsitele 2" fruit) to 33% ("Hoedspruit 2" fruit).

The fruit were all "hard." Average pulp penetration pressure varied from 3.6 kg/A ("Hoedspruit 2" fruit) to 4.9 kg/A ("Constantia" fruit).

Total soluble solids content was low, the averages varying from 9.8 ("Letsitele 2" fruit) to 10.9 % ("Constantia" fruit).

Ripening behaviour during cold-storage

Skin colouration during cold-storage varied both according to fruit source and cold-storage temperature. Skin colouration of the "Hoedspruit 1" fruit placed at the various temperatures increased similarly (Fig. 1-A). Immediately after cold-storage, the skin region not covered by blush was either fully yellow or almost fully yellow. Skin colouration of the remaining fruit occurred at 15^{0}C, but was largely inhibited at 11 or 13^{0}C (Figs. 1- B to E). Moreover, there was a delay in colour development at 15^{0}C, the skin or sizable portions thereof being green when cold-storage was terminated. The appearance of the fruit from each source immediately after cold-storage is shown in Fig. 2.

Degree of softening and pulp colouration were highly correlated (Fig. 3- A). These changes differed in relation to both fruit source and cold-storage temperature (Fig. 1- F to O).

At 15^{0}C, softening occurred to the point of eating ripeness (pulp penetration pressure < 2 kg/A), irrespective of the source of the fruit. Pulp colouration attained levels of 80 to 100%. A lesser delay in pulp colouration was apparent in the case of the "Hoedspruit 1" fruit.

At 11 or 13^{0}C, softening and pulp colouration of the "Hoedspruit 1" fruit occurred to greatest extent. These fruit were still firm when removed from cold-storage, although those stored at 13^{0}C were on the verge of being in an eating-ripe condition. Pulp colouration here had generally intensified to approximately 50%. Softening and pulp colouration of the "Hoedspruit 2" and "Constantia" fruit were strongly suppressed at 11 or 13^{0}C. These changes in the "Letsitele 1" and "Letsitele 2" fruit were also suppressed at these temperatures, but to a lesser extent. Consequently, the "Hoedspruit 2," "Letsitele 1," "Letsitele 2," and "Constantia" fruit stored at 11 or 13^{0}C were "hard" when removed from cold-storage. Pulp colouration of these fruit varied from 20 to 40%.

Total soluble solids content increased markedly irrespective of the source of the fruit or the cold-storage

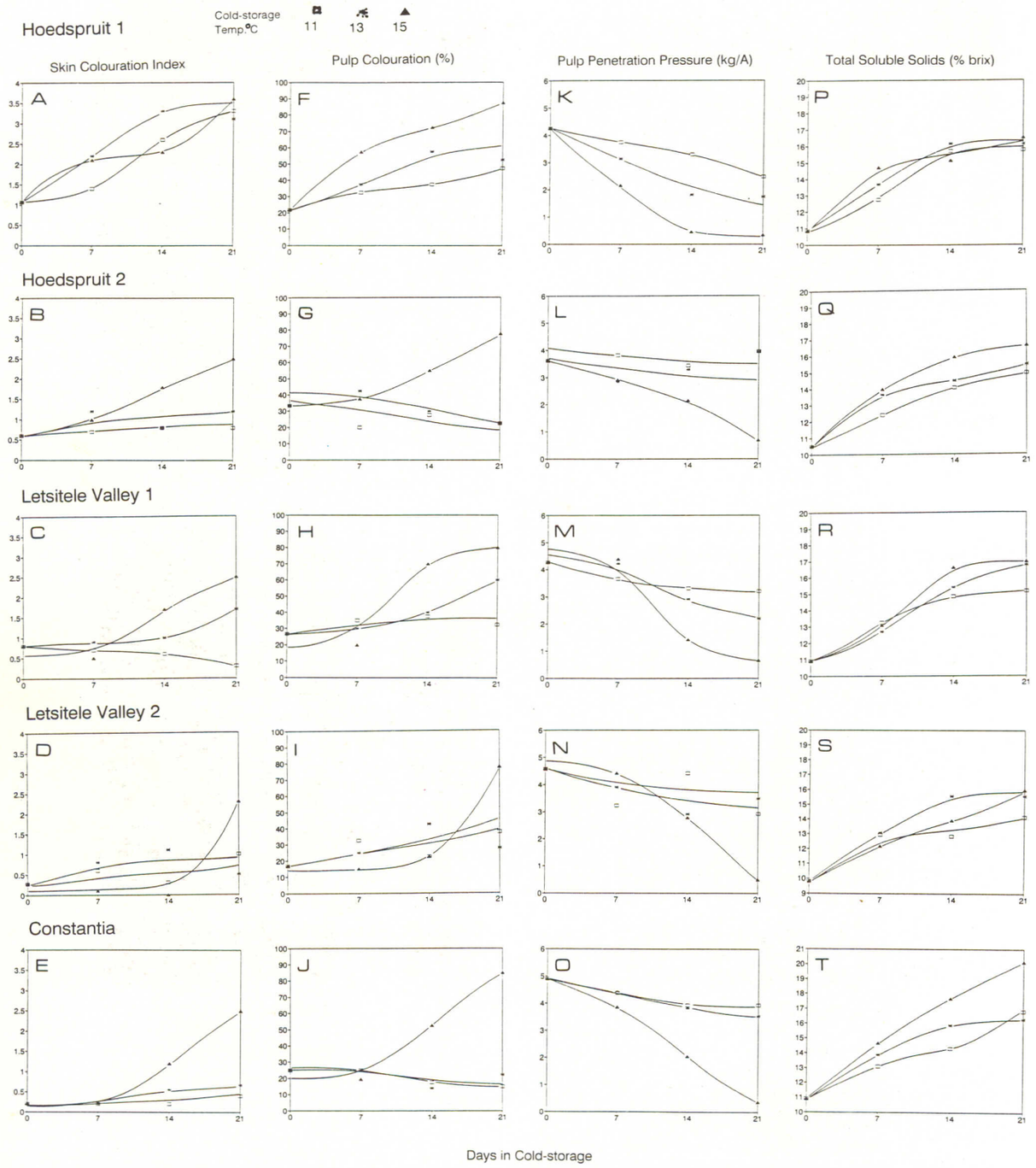

Fig. 1 Changes in skin colouration, pulp colouration, firmness (pulp penetration pressure) and total soluble solids content of the fruit during cold-storage.

temperature adopted (Fig. 1- P to T). A positive relationship between the increases in total soluble solids content and cold-storage temperature was apparent. Differences arising due to temperature or fruit source were not pronounced, however, except in the case of the "Constantia" fruit at 15^{0}C, which generally attained levels of over 20%. Mean total soluble solids content attained by the remaining fruit varied from 14 to 17%.

The regression between degree of softening and skin colouration, and that between degree of softening and total soluble solids content, were significant (Figs. 3- B & C), but less precise than the regression between degree of softening and pulp colouration (Fig. 3- B & C).

Fruit quality on full-ripening

Seven days after cold-storage, skin colouration varied according to fruit source and cold-storage temperature (Fig. 5- A). Storage temperature and skin colouration were positively correlated. In considering fruit source, skin colouration had occurred to the greatest extent in the "Hoedspruit 1" fruit, and the the least extent in the "Hoedspruit 2" fruit. Most of the former fruit were fully yellow, whereas most of the latter fruit had failed

Fig. 2 *Appearance of the fruit from each source directly after cold-storage.*

appreciably to de-green. Skin colouration of the "Letsitele 1," "Letsitele 2," and "Constantia" fruit was intermediate, most of these fruit having failed to de-green significantly. Regions of the skin remaining green acquired a speckled appearance, this occurrence making the fruit particularly unattractive (Fig. 4).

Variation in pulp colouration and pH relating to cold-storage temperature or fruit source was not apparent (Fig. 5- B & C). The pulp of most of the fruit attained the full colour intensity normally associated with ripe fruit. The juice pH varied from 4.8 to 5.3 on average.

A relationship between total soluble solids content and cold-storage temperature was not clear (Fig. 5- D). Marked differences relating to fruit source were apparent, however. The lowest level was attained by the "Hoedspruit 1" fruit (17%), and the highest level by the "Constantia" fruit (20%). The levels attained by the "Hoedspruit 2," "Letsitele Valley 1," and "Letsitele Valley 2" fruit were intermediate.

The "Constantia" fruit exhibited the highest incidence of lenticel damage (Fig. 6- A). Differences relating to fruit source were otherwise unclear. A relationship with cold-storage temperature was not apparent (data not shown).

The "Hoedspruit 1" fruit showed the lowest incidence of internal breakdown (Fig. 6- B). Differences relating to fruit source were otherwise unclear. A relationship with cold-storage temperature was unapparent (data not shown).

Differences in the severity of lenticel damage or internal breakdown in relation to fruit source or cold-storage temperature were unapparent (data not shown).

Leaf analyses

In comparing the leaf nutrient levels between the trees having borne the "Constantia" and the trees having borne the "Hoedspruit 1" fruit, of the macro- and micro-elements examined (Fig. 7- A & B), the former trees apparently contained higher concentrations of nitrogen, phosphorus, potassium, zinc, and manganese, whereas higher concentrations of calcium, magnesium, iron, and boron were apparent in the latter trees. The differences observed were not pronounced, and in every instance, the concentration fell within the limits set as guidelines to ascertain nutrient excesses or deficiencies (Table 1).

DISCUSSION AND CONCLUSION

The results presented suggest that the fertilization schedule followed by growers strongly influences the ripening behaviour of Sensation mangos during transit at a particular temperature, and the quality level attained by the fruit on full-ripening thereafter, particularly concerning their ability to de-green.

The fruit obtained from the trees fertilized with lesser amounts of nitrogen displayed a greater ability to de-green, to soften, and to develop pulp colour during cold-storage than the fruit obtained from the trees fertilized more heavily with nitrogen. On full-ripening, "low" nitrogen application was associated with complete or almost complete de-greening, a reduction in total soluble solids content, and a reduced incidence of internal breakdown.

Previous reports relating ripening behaviour of mangos to nitrogen fertilization, or fertilization in general, are lacking. An association between high nitrogen fertilization and the inability of mangos to adequately de-green is recognized, however. Moreover, an increase in the incidence of the physiological disorder, "soft-nose," has previously been associated with an increase in nitrogen application (Young *et al.*, 1965). Consistency between these observations and those of the present study, might be seen to indicate that the relationships showing clarity with regard to the rate of nitrogen applied, were in fact more directly related to nitrogen, and less directly related to any other element that was included in the fertilization schedule.

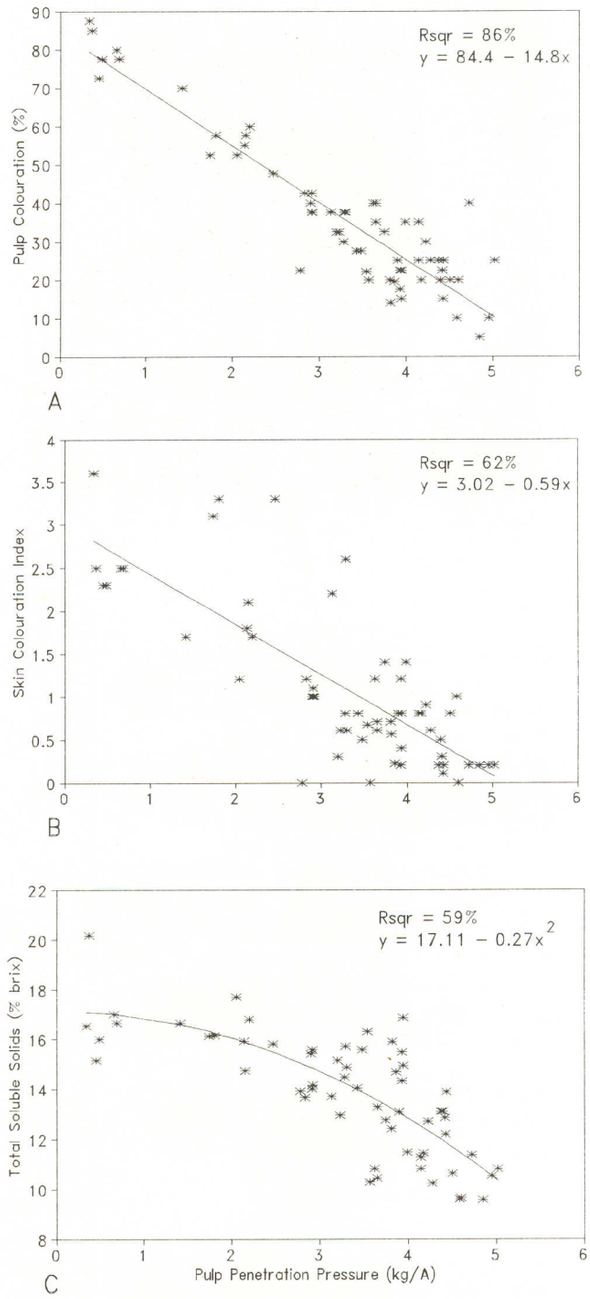

Fig. 3 *Respective relationships between degree of softening (reduction in pulp-penetration pressure) during cold-storage, and pulp colouration (A), skin colouration (B) or total soluble solids content (C).*

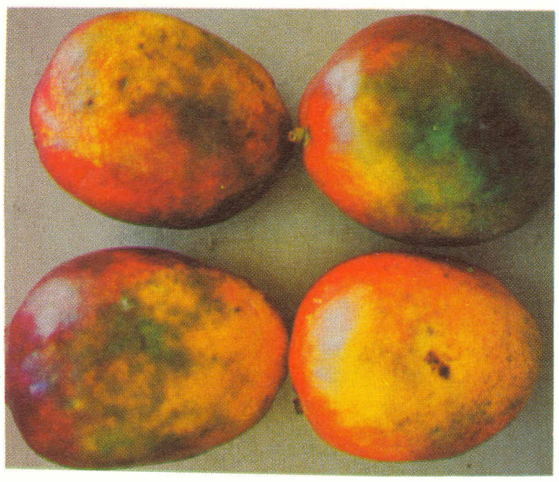

Fig. 4 *Speckled appearance of fruit that did not de-green adequately.*

The increases in total soluble solids content during cold-storage did not appear to relate specifically to the amount of nitrogen applied, nor was there any clear relationship between nitrogen application, and juice pH, pulp colouration or the incidence of lenticel damage on full-ripening. Variation of these attributes in relation to nitrogen application has not been previously reported in mango. However, a negative effect on pulp colouration of foliar application of nitrogen (4% KNO_3) has been observed in Tommy Atkins by the author (unpublished).

Although there was a tendency for total soluble solids content to decrease with decreasing nitrogen fertilization, the "Constantia" fruit generally attained an elevated content of soluble solids on full-ripening, which did not appear to relate directly to nitrogen application. The differences in nutrient concentration observed between the trees having borne the "Hoedspruit" 1 and "Constantia" fruit, do not suggest any obvious explanation. It might be postulated that the continuous availability of nutrients to the trees having borne the "Constantia" fruit, due to the greater regularity of fertilization and the continual presence of organic material, gave rise to this occurrence.

Deficiencies in nutrient content of the trees examined were not apparent, although, as might be expected, the nitrogen content of the trees having borne the "Constantia" fruit was apparently higher than that of the trees having borne the "Hoedspruit 1" fruit. Interestingly, the calcium content of the latter trees was greater than that of the former trees. Increased calcium fertilization has been associated with a reduction in the incidence of "soft-nose" (Young, *et al.*, 1965). Furthermore, Singh *et al.* (1993) reported an enhancement in skin colouration following pre-harvest calcium sprays to mango trees. An increase in shelf-life was also reported, which contrasts with the "Hoedspruit 1" fruit, in view of them having shown an enhanced ability to ripen during cold-storage.

In light of the above, it might be stated that the respective relationships between the levels of the various nutrients in mango trees, and yield, ripening behaviour or fruit quality on full-ripening are likely to be involved, and may relate more to relative as opposed to absolute concentrations. The criteria favouring one particular aspect need not necessary benefit another. For example, increased nitrogen application has been found to effect an increase in yield, but to also lessen the ability of the fruit to develop colour (Young, *et al.*, 1965; Smith, 1992). Ideally, the best trade-off situation, determined in terms of the maximization of revenue earned from a particular target market, would need to be ascertained.

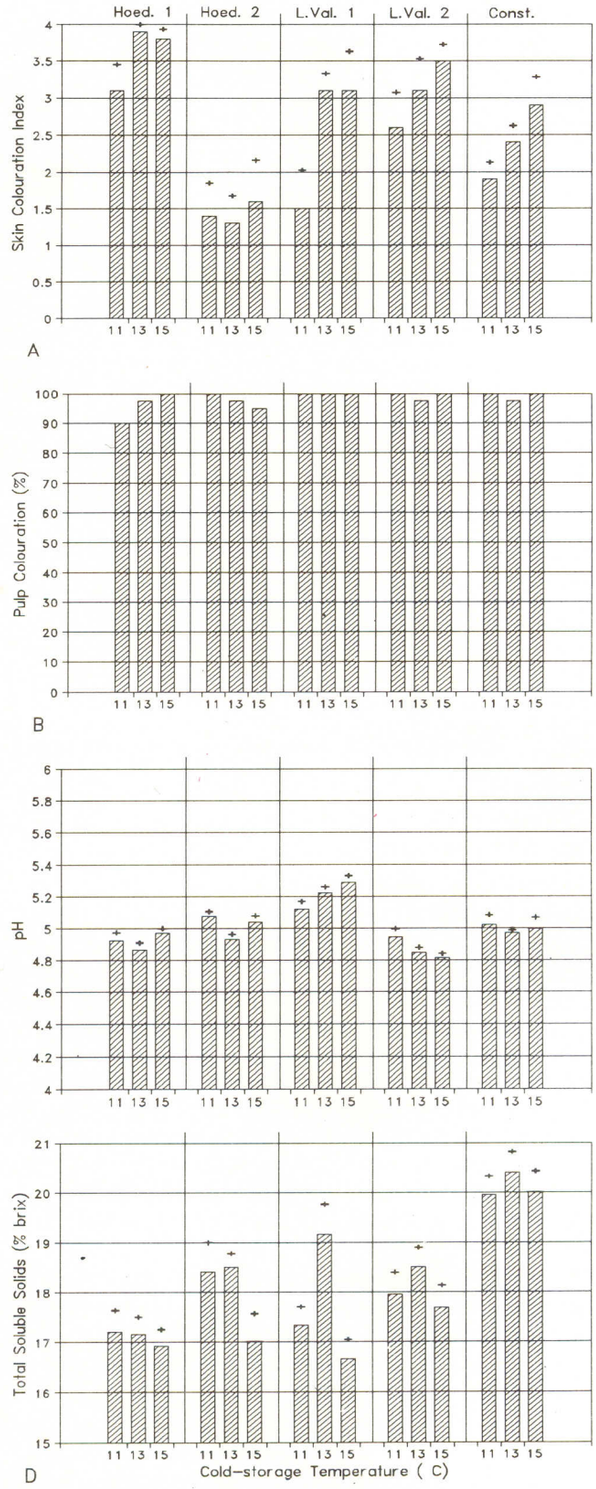

Fig. 5 *Skin colouration (A), pulp colouration (B), pH (C), total soluble solids content (D) 7 days after cold-storage (+ = + SE).*

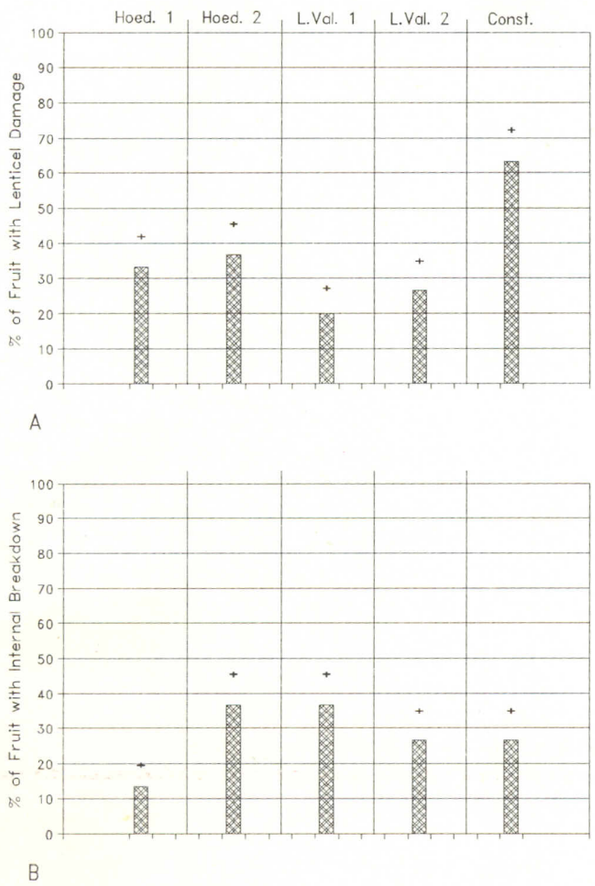

Fig. 6 The incidence of lenticel damage (A) and internal breakdown (B) of the fruit 7 days after cold-storage (+ = +SE).

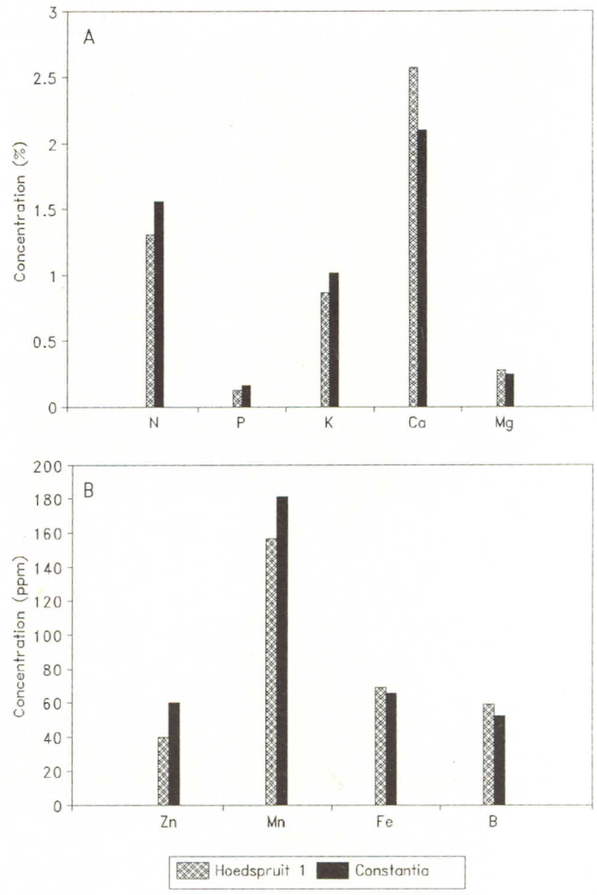

Fig. 7 Macro- and micro-nutrient concentrations in the leaves of the trees from which the "Hoedspruit 1" and "Constantia " fruit were obtained.

Appropriate fertilization for adequate maintenance of the ideal nutrient status to uphold, and variation of this status relative to stage of the phenological cycle, would further compound the issue. The differences in ripening behaviour and fruit quality on full-ripening encountered in the present study nevertheless warrant further research on the topic of fertilization, especially in relation to the responses to the major players, such as nitrogen and calcium.

The objective in exporting Sensation mangos to Europe by sea, is to have them arrive firm, but at a stage of ripeness that will result in the attainment of an eating-ripe condition quickly on exposure of the fruit to room temperature (Oosthuyse, 1992). Taking this requirement into consideration, as well as the differences in quality attained by the fruit stored at the various temperatures under study, it might be argued that 13^{0}C is a better transit temperature than 11^{0}C, specifically in view of the greater degree of skin colouration attained by the fruit stored at the former temperature.

The differences in strength between the relationships pertaining to degree of softening, extent of pulp colouration, and total soluble solids content, suggest a degree of independence between processes associated with ripening in Sensation. The relatively weak relationship between skin colouration and pulp softening might be seen to indicate that conditions ideally suiting skin colouration differ from those that ideally suit ripening of the pulp. Knowledge of these conditions may enable exposure of fruit to ripening conditions that would promote skin colouration to a greater extent than processes associated with pulp ripening. This would be beneficial in the sense of agents being able to provide retailers with well coloured fruit with an enhanced shelf-life. Predisposing the fruit to increased de-greening and impaired softening by reducing and increasing the compliments of nitrogen and calcium in the fertilization schedule re-

Table 1. Macro- and micro-leaf nutrient concentration limits set as guidelines to ascertain excesses or deficiencies of nutrients in mango trees (Western Australian Department of Agriculture, Bulletin No. 4125).

Major element	Percent of dry weight	Minor element	Parts per million of dry weight
Nitrogen	1.0 to 1.8	Zinc	20 to 150
Phosphorus	0.09 to 0.15	Copper	10 to 20
Potassium	0.8 to 1.5	Boron	30 to 100
Calcium	1.5 to 3.0	Manganese	60 to 500
Magnesium	0.25 to 0.80		

spectively, may further add towards the attainment of this objective.

In conclusion, it might be stated that the option of adjusting tree fertilization, particularly with regard to a lesser incorporation of N, and increasing the commercially adopted transit temperature from 11^{0}C to 13^{0}C, to effect an enhancement in the quality of Sensation mangos on ripening after cold-storage, appears to exist, and should therefore be further researched and commercially exploited. Investigation of the conditions that specifically favour skin colouration and those that specifically favour processes associated with pulp ripening, might also be considered in future research.

ACKNOWLEDGEMENTS

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