Research on Mango Aimed at Increasing Orchard Productivity and Export Fruit Quality

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ABSTRACT

Recent research information is presented that can effect a considerable increase the productivity of mango orchards, as well as an improvement of the quality of mangos supplied to markets in Europe. Increasing the planting density, tipping the terminal shoots of young mango trees after each flushing cycle, spraying with KNO_3 during flowering, and maintaining tree size by pruning directly after harvest once the desired canopy dimensions are attained, provide the opportunity of dramatically increasing orchard productivity and sustaining the level of productivity attained. Late picking for a general improvement in quality, carbon dioxide shock treatment to reduce losses due to postharvest diseases, and reduced nitrogen fertilization in the field to enhance skin colouration, are presented as options to increase the appeal of the fruit to buyers abroad.

UITTREKSEL

Onlangse navorsingsinligting is gelewer wat 'n aansienlike toename in in die opbrengs van mango-boorde, sowel as 'n verbetering in die die kwaliteit van die mangoes, wat aan die uitvoermarkte gelewer word, sal meebring. Verhoging van die plantdigtheid, die tip van jong terminale lote van jong mango bome na elke "flush" siklus, spuit met KNO_3 gedurende blomtyd en die instandhouding van boomgrootte deur snoeiing direk na oestyd sodra die gewensde boomvolume bereik is voorsien die geleentheid om boord produktiwiteit dramaties te verhoog en die vlak van produktiwiteit wat reeds bereik is te behou. Laat pluk van vrugte vir 'n algemene verbetering van kwaliteit, koolstof dioksied skok behandeling om verliese as gevolg van na-oes siektes te beperk en verminderde stikstof bemesting in die boord om skil verkleuring te verbeter, word gelewer as opsies om die voorkoms van die vrug meer aanvaarbaar te maak vir verbruikers oorsee.

Current Production World-wide

Mango is ranked in the top five as a fruit-crop. Annual production world-wide is estimated at being in the region of 16 million tonnes, of which 60% is contributed by India (9.6 million tonnes). Mexico, the next biggest contributor, produces a mere 6% of world production (one million tonnes). South Africa produces in the region of 43 thousand tonnes of mangos annually, this figure representing 0.25% of world production. Despite the prominence of mango world-wide, this tree-crop is one of the least professionally grown when considered on a global scale.

Yields worldwide are poor, ranging from 4 to 9 tonnes per hectare. The average annual yield in South Africa is 4,2 tonnes per hectare. It is noteworthy, however, that 8% of the South African mango growers produce 75% of the annual crop. Yields for the more productive growers range from 10 to 15 tonnes per hectare.

The poor yield position locally and world-wide is partly attributable to wide tree spacings, which are traditionally based on estimated eventual tree size. In South Africa, the block spacings of 12 x 12 metres, 10 x 10 metres and 8 x 8 metres were originally recommended.

Principles of Orchard Productivity Maximization

The general principles of having trees fill their allotted space in the orchard row as quickly as possible (Principle I), and maintaining canopy size once the allotted space is filled without adversely affecting yield (Principle II), require emphasis for maximizing the productivity of orchards.

High Density Planting

Yield data of high density plantings, recently made available by T.F. Elphick and Son at Malelane, clearly reveals the tremendous yield improvement possible in increasing the planting density. Fig. 1 shows the hectare yields from the time of planting for Tommy Atkins and Irwin mango trees planted at a number of spacings. It is clear to see that the yearly increment generally increased with the increase in planting density. A yield of 35 tonnes per hectare was achieved in year 6 for the Tommy Atkins trees planted at 2 x 9 metres, and a yield of 43 tonnes per hectare was achieved in year 7 for the Irwin trees planted at 1 x 9 metres.

The optimal spacing to adopt for each of the important mango cultivars grown locally has still to be ascertained, taking differences in establishment and running costs into account. Nevertheless, it would appear that tremendous scope exists for increasing orchard productivity by solely increasing the planting density. The positive effect on productivity of increasing the planting density relates to the satisfaction of Principle I.

Pruning of Pre-bearing Trees

By tipping (specific removal of the apical bud of terminal shoots by pruning) the terminal shoots of young mango trees after each flushing cycle, branching is encouraged and the number of terminal shoots increased as a result of the increased branching caused. The rate of canopy development and extent of thickening of branches in the canopy are enhanced, and as a consequence, the time until the trees are of a sufficient stature to support a first crop is reduced. Cropping

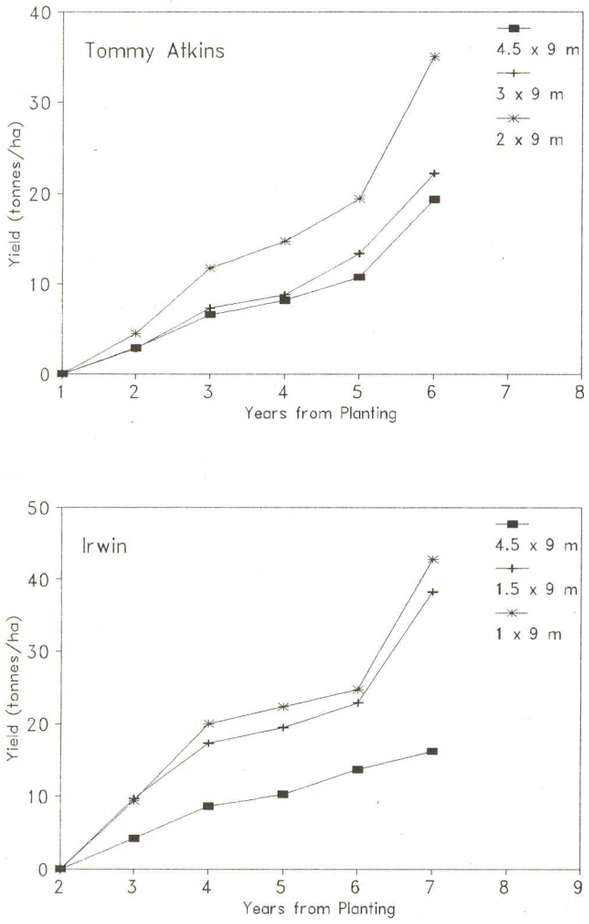

Fig. 1 Yield of Tommy Atkins and Irwin mango trees planted at a number of spacings.

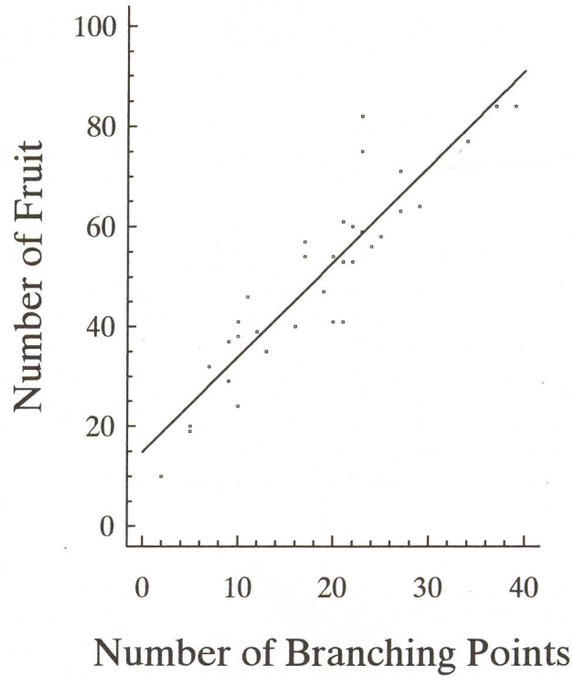

Fig. 2 Relationship between number of branching points in the canopy of two-year-old Sensation mango trees and the number of fruit produced by the trees in year 2.

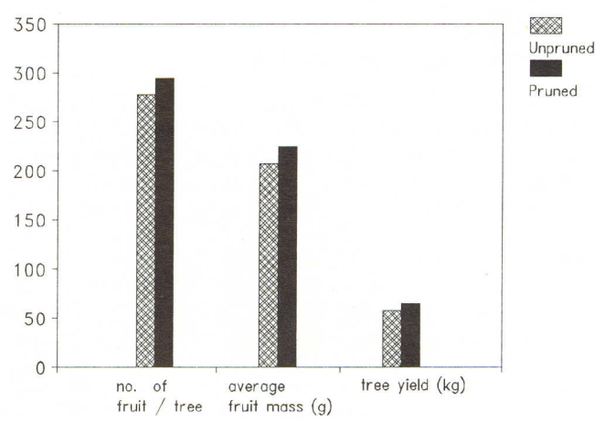

Fig. 3 Tree yield of Sensation mango trees pruned to maintain their size, in relation to unpruned trees.

potential is increased once the trees come into bearing as a direct consequence of the greater abundance of terminal shoots. The positive effect on productivity of encouraging branching by tipping relates to the satisfaction of Principle I.

The relationship between the number of branching points in the canopy of two-year-old Sensation mango trees and the number of fruit produced by the trees in year 2 is shown in Fig. 2. The trees that were not pruned produced between 10 and 20 fruit, whereas those that were pruned frequently produced more than 80 fruit.

Certain cultivars like Zill, Tommy Atkins, and Keitt usually require more severe pruning to stimulate adequate branching. A detailed description of the methods of pruning mango trees of the various cultivars grown locally for export was published previously by the author (Oosthuyse, 1992).

Canopy Size Maintenance

To maintain canopy size, trees can be pruned by cutting back branches directly after harvest at the site just behind that where budbreak and shoot growth first occurred after the previous harvest. Cutting in this way results in removal of the previous season's postharvest flush growth, the aim being for this growth to be replaced during the ensuing, postharvest growth period.

The yield results of Sensation mango trees having been pruned in the manner described, in relation to unpruned trees, is shown in Fig. 3. Tree productivity was not adversely affected by pruning (satisfaction of Principle II). In fact, the pruned trees produced slightly more fruit of a greater average weight than the unpruned trees. Moreover, the pruned trees flushed sooner after harvest, and flowered later and more uniformly than the unpruned trees. The absence of an adverse effect on yield of pruning to maintain canopy size relates to the satisfaction of Principle II.

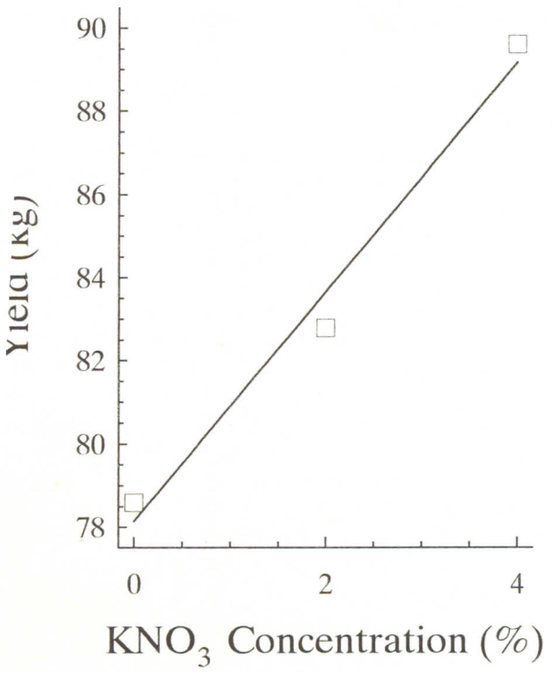

Fig. 4 Tree yield of Tommy Atkins mango trees sprayed with KNO_3 during full-flower (100% flower opening).

Potassium Nitrate Spray Application to Enhance Fruit Retention and Thereby Increase Yield

Mango trees set vast quantities of fruit initially if diseases affecting the inflorescences are controlled adequately, and temperatures during and soon after flowering are favourable. Despite good disease control, the number of fruit retained by most of the cultivars grown locally for export is less than 50% of the number of inflorescences developing. Included here are the cultivars Zill, Tommy Atkins, Kent, Haden and Heidi.

A KNO_3 spray to Tommy Atkins mango trees in full-flower (100% flower opening) significantly enhanced fruit retention. Application at 4% gave rise to better retention than application at 2%. Tree yield increased in proportion to the increase in retention caused (Fig. 4). Slight phytotoxic effects to leaves and inflorescences were observed following the 4% application.

Fruit Quality in Relation to Picking Date

The distinction between fruit maturation and fruit ripening should be clearly understood in mango. Stage or degree of maturity of a developing fruit, refers to a quantitative state relating directly to the time lapsed from fruit-set. Maturation thus refers to the age of a fruit whilst it is still attached to the tree. Associated with the advancement in stage of maturity is the initiation and gradual transition of pulp colouration. The degree of this transition is currently used as an index to asses picking date. A gradual increase in total soluble solids content and a gradual reduction in "hardness" are also associated with maturation in its advanced stages. A transition in skin colouration can occur when maturation is well advanced.

Ripening is a dramatic process by comparison, and refers to the rapid transition of the fruit from a non-edible

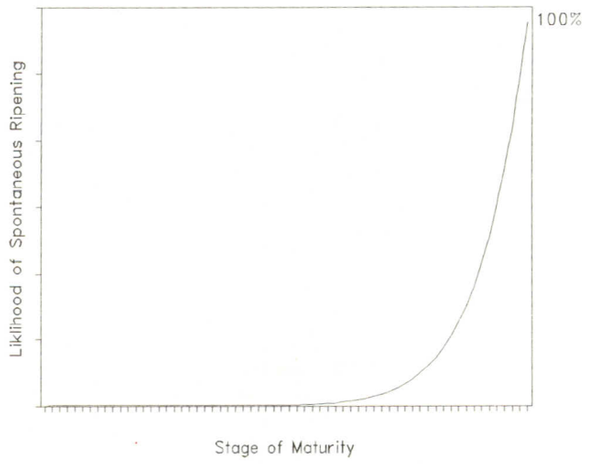

Fig. 5 Illustration of the relationship between fruit maturation and the likelihood of spontaneous ripening.

to an attractive, edible product. The principal change associated with ripening is softening. A transition in skin colouration and pulp colouration, an increase in total soluble solids content, and a reduction in organic acid content are also prominent features of the ripening process.

Spontaneous ripening refers to ripening of a fruit whilst it is still attached to the tree, and is soon followed by fruit drop. As fruit advance in stage of maturity, the likelihood of them ripening, spontaneously, increases. Fig. 5 illustrates the relationship between stage of maturity and the likelihood of spontaneous ripening.

Cultivars differ concerning the frequency at which spontaneous ripening occurs. In Sensation and Zill, for instance, the number of spontaneously ripening fruit increases rapidly once a certain stage of maturity is attained, whereas in Keitt and Tommy Atkins, the increase is far less pronounced. Hence, the fruit of certain cultivars can be left to mature for longer on the tree before spontaneous ripening reaches an unacceptable level, than is the case for other cultivars.

The stage of maturity at which the fruit are picked has a strong bearing on quality they attain on ripening, irrespective of whether the fruit are subjected to cold-storage or not. Fig. 6 shows the relationship between picking date, and change in firmness (pulp penetration pressure), change skin colouration, change pulp colouration, or change in total soluble solids content for Tommy Atkins mangos during ripening following 28 days of cold-storage. These results clearly show that the later the fruit were picked the more attractive the they became. To ensure quality, mangos should therefore be picked late.

Growers will be faced with having to pick before spontaneous ripening attains an unacceptable level. The level of spontaneous ripening that can be tolerated by a particular grower will depend on the marketing opportunities facing the grower. A level of 5 to 10% might be considered acceptable.

Fruit with development abnormalities, physiological disorders, or fruit that develop without fertilization having taken place (parthenocarpy) have a greater likelihood of ripening spontaneously at lesser stages of maturity than normal fruit. Hence, these fruit tend to ripen early. Spon-

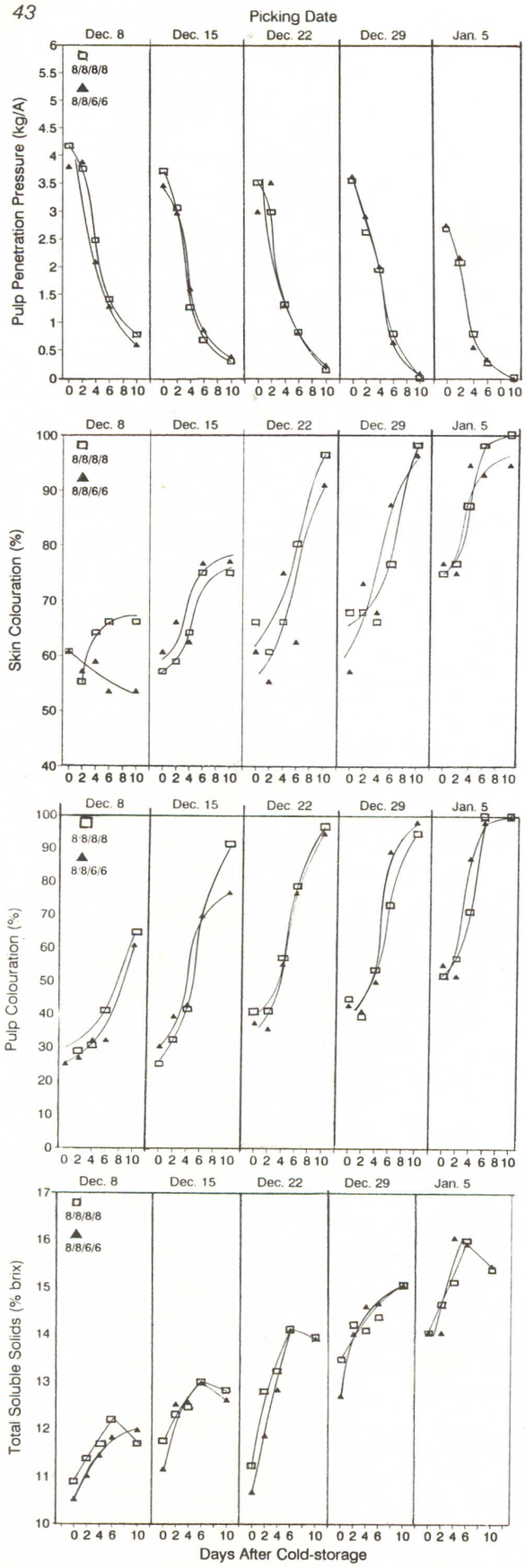

Fig. 6 Respective relationships between picking date, and changes in firmness (pulp penetration pressure), skin colouration, pulp colouration, and total soluble solids content of "Tommy Atkins" mangos during ripening following 28 days of cold-storage. (8/8/8/8: cold-storage for 28 days at 8^{0}C. 8/8/6/6: cold-storage for 14 days at 8^{0}C followed by 14 days at 6^{0}C)

taneous ripening of such fruit should not be misinterpreted as being indicative of the time to commence with picking operations.

Carbon Dioxide Shock Treatment to Reduce Losses Due to Postharvest Decay

Carbon dioxide shock treatment to harvested Kent mangos was assessed as a measure to reduce postharvest losses due to disease. The effect of this treatment on fruit quality upon ripening was also ascertained. The fruit were subjected to an atmosphere containing 15% oxygen and 30% carbon dioxide for 12, 24 or 36 hours, either just before or directly after cold-storage at 8^{0}C for 28 days. The fruit were held at 20^{0}C during shock treatment, and ripening occurred at 20^{0}C following cold-storage.

The percentage of fruit showing signs of disease on full-ripening was significantly reduced, irrespective of whether treatment was performed prior to or after cold-storage (Fig. 7). Fruit quality on ripening was not adversely affected. Shock treatment performed directly after cold-storage for 24 hours gave rise to the lowest incidence of disease.

In contemplating commercial utilization, carbon dioxide shock treatment could be applied to fruit prior to or after shipment in especially designed, controlled atmosphere chambers. Alternatively, treatment could be applied during shipment by enriching air delivered to cargo with carbon dioxide for a limited period.

Grower Related Differences in Fruit Quality

Premiums are obtained on European markets for well coloured, large mangos. An attractive appearance, which is positively related to the degree of red, orange or yellow skin colouration taking place, is the major determinant of buyer appeal.

Sensation fruit obtained from five different growers and stored under refrigeration for 28 days, differed vastly concerning origin in the degree to which skin colouration occurred. The fruit were either very attractive, intermediate or unattractive. Differences in the fertilization schedule followed by the growers was considered to be the most probable explanation for the differences in appearance observed. High levels of nitrogen fertilization, particularly during the period of fruit growth and development, appeared to negatively affect skin colouration.

Conclusion

High density planting, pruning to encourage early and heavy cropping as well as to maintain canopy size, potassium nitrate spray application during flowering to improve fruit retention, late picking to enhance fruit quality on ripening, carbon dioxide shock treatment to limit fruit losses due to postharvest disease, and reduced nitrogen fertilization to improve post-storage skin colouration, appear to offer enormous scope for increasing orchard productivity and consumer acceptance of mangos on foreign markets. These options do not, however, preclude fungicide sprays to trees to limit disease, particularly during flowering, nor do they preclude hot-water and fungicidal treatment of fruit in the packhouse to further limit postharvest losses arising due to disease infection.

Technological advantages bestowed on the South African Mango Industry will provide the Industry with an edge and ensure survival in the face of increasing com-

petition for foreign revenue from countries like Brazil and Peru in South America, and Burkina Faso, Mali and Ivory Coast in west Africa.

ACKNOWLEDGEMENT

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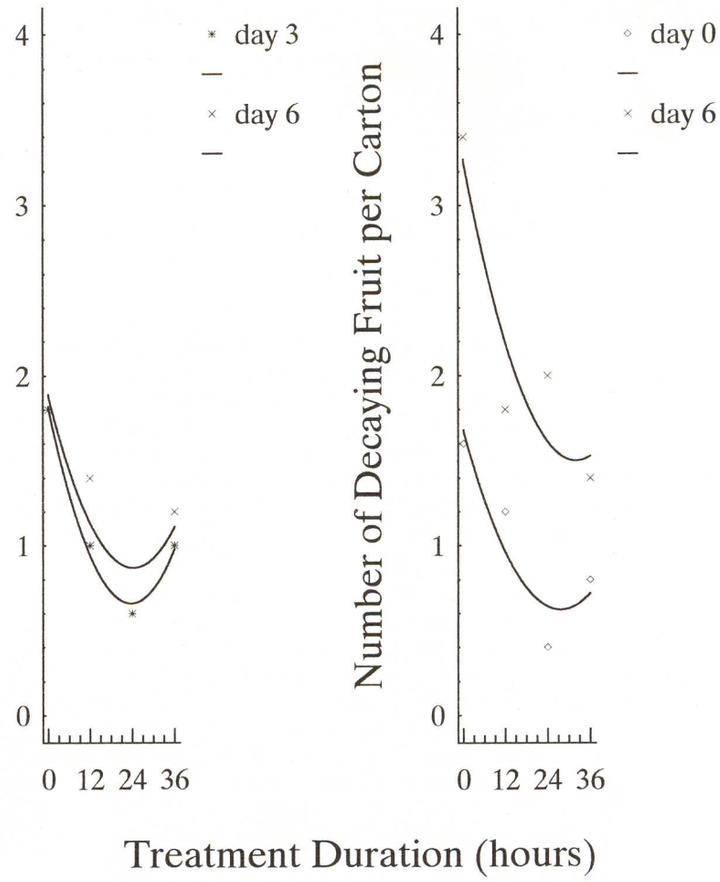

Fig. 7 *Effect of carbon dioxide shock treatment applied prior to (left) or after cold-storage (right) on the number of fruit per carton showing signs of disease during ripening. (day 0: directly after cold-storage; day 6: six days after cold-storage)*