

Tree Spacing Trends and Options for Yield Improvement in Mango

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ABSTRACT

Mango yields world-wide are generally poor, ranging from 4 to 9 t.ha⁻¹ in the major producing countries. This is partly attributable to wide tree spacings, which are traditionally based on expected eventual tree size. Little consideration is generally given to canopy size maintenance once overcrowding eventually occurs. Yields for more closely spaced trees of well managed orchards in Florida and Puerto Rico, where annual or biennial hedging is employed to maintain canopy size, generally exceed 20 t.ha⁻¹. Recent studies show the marked positive effect on yield by radically increasing planting density. High density planting is discussed with a view to optimal tree spacings, canopy size maintenance, and pruning of young trees to improve growth, cropping ability and sturdiness.

UITTREKSEL

Mango opbrengste wereldwyd is oor die algemeen swak, en wissel van 4 tot 9 t.ha⁻¹ in die hoof produserende lande. Dit kan gedeeltelik toegeskryf word aan wye boomspasiering, wat gebaseer is op die verwagte uiteindelijke boomgrootte. Min aandag word egter gegee aan die onderhouding van die blaredak volume wanneer die bome mekaar begin verdruk. Opbrengste vir naby gespasioerde bome in goed bestuurde boorde in Florida en Puerto Rico, waar jaarlikse of tweejaarlikse streng snoeiing om blaredakvolume te behou, toegepas word, oorskrei in die algemeen 20 t.ha⁻¹. Onlangse studies toon die merkbare positiewe effek op opbrengs deur die drastiese verhoging in plantdigtheid. Hoë-digtheids aanplanting word bespreek met die oog op optimale boomspasierings, blaredak onderhouden die snoei van jong bome om groei, opbrengsvermoë en stewigheid te verbeter.

Introduction

Mango (*Mangifera indica* L.) is widely grown in tropical and subtropical regions of the world, and is reported to be one of the top five fruit crops (Amm, 1990). Current annual production can be estimated at being in the region of 16 million tonnes. Despite its prominence, mango would appear to be the least professionally grown of the major fruit crops when considered on a global scale.

Overview of Current Production, Spacings and Methods of Size Control

India currently produces approximately 60% of the world's annual crop (± 10 million tons) (Chadha & Pal, 1992). Majumder, Sharma, and Singh (1982) referred to mango cultivation in India as being primitive, adding that studies to effect improvement are seriously lacking. Average annual production of full-bearing orchards is estimated at 8,7 t.ha⁻¹ (Majumder & Sharma, 1985). Mango trees are generally owned by residents having small plantings of large trees close to their dwellings (Tomer, 1993, pers. comm.).

Chadha (1985) recognized that tree spacings limited tree populations per hectare, and therefore productivity. Conventional orchard spacings range from 10 to 12 m between trees in the row and between rows (69 to 100 trees/ha).

Pruning is not performed commercially in India, although a positive effect of pruning on bearing regularity was reported for certain cultivars (Chadha, 1985).

Mexico, the second largest producer of mangoes, currently produces about 6% of the world's crop, the annual harvest being approximately one million tonnes

(De Swart, 1992). Average yield was estimated at 8,4 t.ha⁻¹. The spacings (in-row x between-row) of 6 x 12 m (136 trees/ha), 6 x 11 m (153 trees/ha), 7 x 10 m (140 trees/ha) and 13 x 13 m (56 trees/ha) are commonly adopted. Pruning is emphasized to maintain tree size or allow better light penetration into the canopy. To control size, rows of trees are severely cut back once the canopies are considered to have become too large. Trees treated in this way take three to four years to produce fruit again. Better light penetration is achieved by thinning out branches, particularly the central ones.

The remaining major mango producing countries are Indonesia, Pakistan and Brazil, each of which produce between 3 and 4% of the world's crop. In Indonesia, the national average annual yield is 4,7 t.ha⁻¹, of which only 15 to 20% is marketable (Tjiptono, Lam, Kosiyachinda, Mendoza & Leong, 1984). The majority of mango trees are owned by non-specialized fruit farmers who have one to ten trees around their houses.

Other countries of prominence include China, Philippines, Thailand, Haiti and Bangladesh, each producing between 1 and 2,5% of the world's annual crop. Approximately 10% of world production is attributable to the remaining producing countries.

South Africa produced 42 thousand tonnes of mangoes during the 1991/92 season. This tonnage represents about 0,25% of world production. Average annual yield per hectare is estimated at 4,2 t. It is noteworthy, however, that 8% of the South African mango growers produce 75% of the crop (Colyn, 1993, pers. comm.). Yields for the more productive growers ($\pm 15\%$) range from 10 to 15 t.ha⁻¹. The block spacings of 12 x 12 m (64 trees/ha), 10 x 10 m (100 trees/ha), 8 x 8 m (156

trees/ha) and 5 x 5 m (400 trees/ha) were traditionally adopted, although variations to original recommendations are widespread. The spacing of 8 x 8 is probably most customary, although in the case of the popular export cultivars, e.g., Sensation and Tommy Atkins, the rectangular spacing of 5 x 8 m (240 trees/ha) is common.

Low average tonnages locally can be attributed to many factors, and in particular, panicle diseases during the period of panicle development and maturation which negatively affect initial set, and water stress due to the absence of irrigation which limits panicle development and initial set as well as enhances fruit drop.

Low yields are additionally attributable to wide tree spacings, since the canopies of trees often take more than 10 years to fill their allocated space in the orchard row, particularly under dry-land conditions. In some instances, the inter-row space may never be occupied due to poor conditions for growth. In the situation of trees growing under irrigation or in regions with a high rainfall, eventual overcrowding and the consequent depressive effect of mutual shading on flower induction, negatively affect yield, limiting fruiting to the upper portion of the canopy.

Little is done in South Africa to control tree size. Overcrowding is sometimes dealt with by severely pruning back alternate trees or trees in alternate rows. Entire branches are occasionally removed to improve light penetration.

In Puerto Rico (Fruits International) and Southern Florida (J.R. Brooks & Son), where orchards receive adequate water and panicle diseases are controlled to a large extent, annual yields generally exceed 20 t.ha⁻¹, and during exceptional years, may be as high as 30 t.ha⁻¹. The spacings of 4 x 6 m (475 trees/ha) in Puerto Rico and 3 x 6,4 m (528 trees/ha) in Southern Florida are often adopted. Trees are grown as a hedge-row, and canopy size is maintained by annual or biennial hedging directly after harvest.

It summation, it might be stated that yields per hectare world-wide are extremely low when average tonnages are compared with average tonnages for well managed orchards in Puerto Rico and Southern Florida. This may be expected when it is recognized that the major mango producing countries all reside in the Third World where expenditures on education, research and technology relating to mango cultivation are generally small. It would seem, however, that much room for improvement exists in view of production in Florida and Puerto Rico.

Current spacings have, for the most part, been based on estimated eventual tree size, this factor apparently contributing to the poor yield position. Little consideration is given to procedures of maintaining size once overcrowding eventually commences. Severe pruning, regular hedging or tree removal (Toohill, Wright, & Bakeret, 1985; Muller, 1991) are sometimes employed. These measures, besides hedging, drastically reduce productivity during the years that follow their performance, since they result in a dramatic reduction in bearing surface, albeit from tree canopies of declining efficiency.

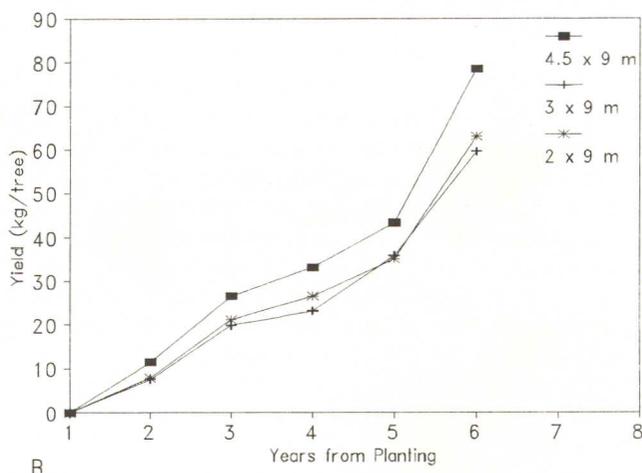
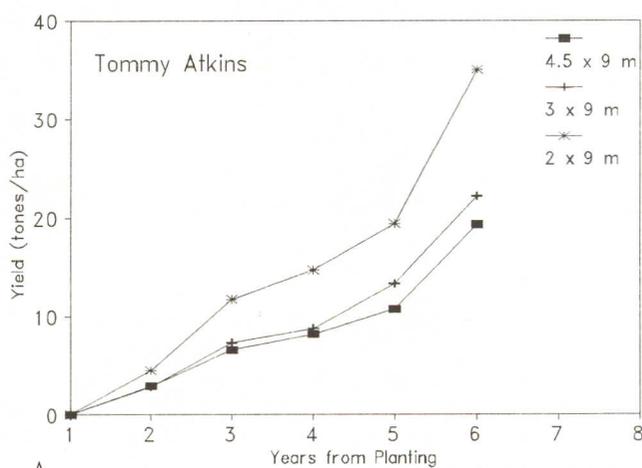


Fig. 1 Yield per hectare (A) and individual tree yield (B) of "Tommy Atkins" mango trees planted at various spacings (data supplied by T.F. Elphick & Son, Malelane).

Spacing Trends

A number of reports show the beneficial effect of increasing planting density on yield per hectare. High density spacings having received study include 2,5 x 2,5 m (1600 trees/ha) (Majumder & Sharma, 1985), and 2,5 x 3,0 m (1333 trees/ha) (Ram & Sirohi, 1985, 1991). An annual yield of 22 t.ha⁻¹ was achieved after nine years in the former study (Amrapali), and an annual yield of 18 t.ha⁻¹ after 12 years in the latter (Dashehari). Trees planted at 12 x 12 m (64 trees/ha) in the latter study yielded less than 2 t.ha⁻¹ in their 12th year.

New plantings in South Africa are spaced more closely than older plantings. In recent years, spacings of 3 to 5 m between trees in the row and 8 m between rows have often been adopted (250 to 415 trees/ha). The spacings of 4 x 6 m (417 trees/ha) and 3 x 7 m (476 trees/ha) are also prevalent.

Yields of high density plantings of the cultivars Tommy Atkins and Irwin were recently made available by the company, T.F. Elphick and Son, at Malelane in the eastern Transvaal. These results show the benefits of greater annual yields and annual yield increases with increasing planting density (Figs. 1 & 2).

Six years after planting, Tommy Atkins trees planted at the spacing of 2 x 9 m (550 trees/ha) bore 81% more

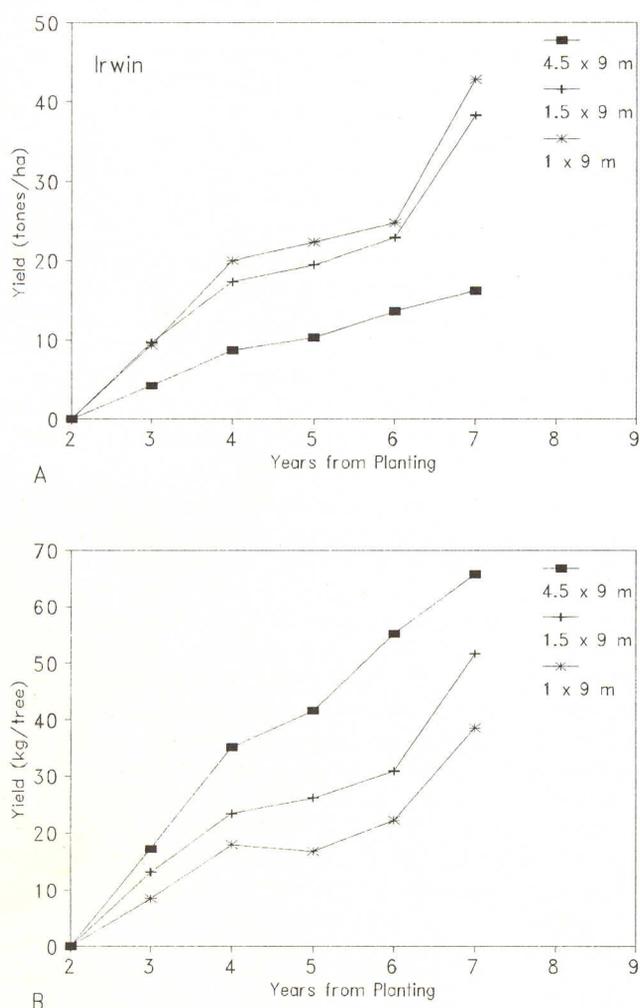


Fig. 2 Yield per hectare (A) and individual tree yield (B) of "Irwin" mango trees planted at various spacings (data supplied by T.F. Elphick & Son, Malelane).

fruit per hectare (35,1 t) than trees of the same cultivar planted at 4,5 x 9 m (19,4 t) (247 trees/ha) (Fig. 1-A). Cumulative tonnage after 6 years was 79% greater for the former than for the latter spacing (85,4 t.ha⁻¹ vs 47,6 t.ha⁻¹). Taking current costs of development as well as running costs into consideration, Du Preez (1992) estimated a positive cumulative net return after four years for the 2 x 9 m spacing, whereas a positive net cumulative return after six years was forecast for the 4,5 x 9 m spacing. Yield per tree was 19% less after 6 years for the former than for the latter spacing (Fig. 1-B).

Seven years after planting, Irwin trees planted at the spacing of 1 x 9 m (1110 trees/ha) bore 164% more fruit per hectare (42,8 t) than trees of this cultivar planted at 4,5 x 9 m (16,2 t) (Fig. 2-A). Cumulative tonnage after 7 years was 125% greater for the former than for the latter spacing (119 t.ha⁻¹ vs 53 t.ha⁻¹). Du Preez (1992) estimated a positive cumulative return after five years for the trees planted at 1 x 9 m, whereas a positive cumulative return after six years was predicted for the trees planted at 4,5 x 9 m. Yield per tree was 41% less after 6 years for the former as opposed to the latter spacing (Fig. 2-B).

The Irwin tree spacing of 1,5 x 9 m (740 trees/ha) gave a greater cumulative net return after 5 years than the 1 x 9 m spacing (Du Preez, 1992). Furthermore, the difference in cumulative net return persisted with time.

Yield per tree for the former spacing was only 21% less than that for the latter spacing (Fig. 2-B). This result would seemingly suggest that an optimum spacing exists, the spacing of 1 x 9 m exceeding the optimum in terms of decreasing spacing in the row.

Optimization of In-row Spacing

Shading has a negative effect on flower induction, and thus reduces the proportion of terminal shoots bearing inflorescences. An increase followed by a decrease in individual tree yield would thus be expected with time, due to the initial absence of mutual shading followed by its imposition as the trees grow. Fig. 3 shows Irwin trees, planted at 1 x 9 m, having already filled their space in the orchard row and mutually shading one another.

The ideal time to commence size maintenance would be at the stage when individual tree yield becomes maximized. The optimal in-row spacing to adopt will depend on the production level attained on a per unit area basis for a particular between-row spacing, the time taken for maximum production to be realized, and the expected orchard life, considering the present value of net returns over the orchard's life as the determining criterion.

Understandably, the length of time one intends to retain an orchard will have a marked effect on the optimum in-row spacing to adopt. Furthermore, if an orchard is to be retained for a period of 10 years or longer, differences in establishment costs for different spacings will probably impact little on net present value.

It is generally recognized that young trees should be encouraged to grow rapidly until their allotted space in the orchard row is filled, and only then, measures to control canopy size be adopted. However, if the only options to prevent overcrowding have a pronounced negative effect on productivity, such as removing alternate trees or severely pruning trees back once overcrowding occurs, measures to slow growth and improve cropping efficiency before the in-row space is filled will prove to be beneficial for high density plantings, as is the case in avocado.

Measures to Reduce the Rate of Canopy Spread

To limit the rate of canopy spread in mango and thus facilitate the adoption of high density planting, there has been a strong drive towards the identification of plants for use as dwarfing rootstocks (Samaddar & Chakrabarti, 1985; Thimmaraju, Venkatrayappa, Mukunda, & Suladmath, 1985; Al-Amin & Namuco, 1992; Pinto & Byrne, 1992; Reddy & Kurian, 1992), interstocks (Srivastava, Chadha, Singh, Sinha, Rajput, Lal, & Suman, 1985; Resendiz, Vazquez, Garcia, & Toledano, 1992) or scions (Sharma & Majumder, 1985a, 1985b), and the evaluation of growth retardants, particularly the triazol, paclobutrazol (Kulkarni, 1988; Burondkar & Gunjate, 1991; Charnvichit & Tongumpai, 1991; Kulkarni, 1991; Werner, 1992). Commercial utilization has not been reported, however, except for the use of paclobutrazol, more for the purpose of inducing regular bearing than for size control (Burondkar & Gunjate, 1992). In the situation where the size of trees having filled their space in the orchard row can be maintained without adversely affecting productivity, these avenues may prove to be inappropriate, primarily in view of their negative effect on the rate of canopy development before the inter-row space is filled.



Fig. 3 Six-year-old "Irwin" trees at Malelane (T.F. Elphick & Son), planted 1 m apart in the orchard row, beginning to grow into one another. Mutual shading negatively affects flower induction and thus diminishes individual tree yield (photograph supplied by J. du Preez).



Fig. 4 Pruning of a branch behind the site where buds first broke and grew after the previous harvest.

Pruning to Maintain Canopy Size

Favourable reports of pruning have been made (Rao & Shanmugavellu, 1976; Chadha, 1985; Ravishankar, Nalawadi, & Rao, 1992). Annual or biennial hedging is adopted in Southern Florida and Puerto Rico. It would thus appear that pruning can be successfully adopted to maintain canopy size without adversely affecting productivity.

The critical factor to consider in pruning to maintain canopy size is the effect on flowering, and in particular, flower induction. Inflorescences or new shoots develop from apical buds on terminal shoots. Flower induction occurs during periods when environmental conditions are unfavourable for vegetative growth due to water stress or cold. Inductive success is said to relate to the time available for starch accumulation and the reduction in the level of gibberellin, the degree to which these events occur depending on the duration of growth cessation (Chacko, 1984; Chacko, 1991, Davenport, 1990, pers. comm.).

Mango trees in the north eastern Transvaal are harvested during the period from December until March. Tree growth mainly takes place after harvest when repetitive flushing occurs until late autumn or early winter, the

number of flushes produced depending on the time available before the onset of winter-cold. Trees thereafter enter a prolonged state of quiescent dormancy, which generally spans the months of April, May and June. Panicle development and flower anthesis subsequently occur during the months of July, August and September. Inductive conditions, and in particular low night temperatures, experienced shortly before and during winter budbreak are adequate for floral development of every apical bud, with the result that the events of flowering and fruiting generally occur in the absence of vegetative growth. In considering pruning to maintain canopy size, it might thus be concluded that to maximize the chances of flowering, pruning should be performed directly after harvest to maximize the time available for postharvest flush growth and the occurrence of physiological events leading to flowering.

To maintain canopy size, trees can be pruned by heading back branches directly after harvest at the site just behind that where budbreak and shoot growth first occurred after the previous harvest (Fig. 4). Cutting in this way results in the removal of the flush growth of the previous season, the aim being for this growth to be replaced during the postharvest growth period. In a recent study performed by the author (do, unpublished), pruning of Sensation trees in the manner described, resulted in earlier flushing after harvest, higher starch content in terminal shoots at the commencement of flowering, and a slightly improved yield. These results are especially significant, since Sensation is harvested late in the season (mid January to mid-February), and is the only export cultivar grown locally that crops erratically. Inability to crop is generally associated with the failure of trees or portions thereof having cropped heavily to flush after harvest and to subsequently flower.

Measures Employed to Hasten Growth and Enhance Sturdiness and Productivity of Young Trees

Mango shoots generally grow without branching unless the growing point is removed or damaged. Branching occurs naturally after harvest when axillary buds adjacent to the points of peduncle ("fruit stalk") attachment break and grow, or at the crest of branches bent over under the weight of fruit.

The number of inflorescences produced by a tree, being commensurate with cropping ability, is directly related to the number of terminal shoots present. Terminal shoots whose apical buds are removed by tipping (specific removal of the apical bud by heading), will branch as a consequence of break and growth of two or more axillary buds close to each cut. By tipping terminal shoots, the number of new terminal shoots is thus increased. Since the degree to which terminal shoots thicken is directly related to the number of new shoots developing from them, tipping enhances the degree of shoot thickening. Since the degree of thickening of the trunk or a proximally situated branch is similarly related to the number of branches and shoots that distally adjoin the trunk or branch, tipping enhances branch and trunk thickening, and therefore tree sturdiness. Root growth is additionally enhanced, since root development occurs in proportion to canopy development.

The orchard practice of tipping flush growth to stimulate branching and thereby enhance tree growth, sturdiness and cropping ability is commercially adopted by a number of newly established mango estates in the north



Fig. 5 A two-year-old Tommy Atkins mango tree whose terminal shoots were tipped from the time of planting (left). Lateral branch development from a terminal shoot following removal of the apical bud by tipping (right).

eastern Transvaal. Fig. 5 shows a two-year-old Sensation tree whose terminal shoots were tipped from the time of planting, and the branching response to tipping. Certain cultivars like Zill and Keitt may require more severe heading to stimulate adequate branching (J.H. Minnaar, 1992, pers. comm.). A detailed description of the methods of pruning employed has previously been published by the author (Oosthuysen, 1992b).

To maximize the rate of canopy expansion prior to the time trees fill their allotted space in the orchard row, trees should only be allowed to crop for the first time when the space in the orchard row has been filled. Cash flow considerations may inhibit growers from forcing trees to remain vegetative for a prolonged period, especially when the in-row spacing exceeds 2 m. The inhibiting effect cropping has on canopy expansion can be lessened by tipping the flush growth developing after harvest.

The last flush produced in the season should not be tipped. If tipped, branching will not occur, but instead, the trees will flower more intensely at the normal time of flowering due to floral development of more than one axillary bud beneath each cut. An increased flowering intensity was found to be associated with a marked reduction in fruit retention (Oosthuysen, 1991, 1992a).

Conclusion

Studies should be initiated locally to establish optimal tree spacings, adopting the methods of pruning mentioned. The "fan" experimental design for determining optimal planting density proposed by Freeman (1964) may prove to be ideal for this purpose.

A number of questions still require answering, however. For example, that of whether postharvest pruning

to maintain canopy size is suitable for the late cultivars grown in late areas where the period available for vegetative growth after harvest is short. Chemical growth retardants may prove useful in sustaining a high intensity of flowering of fully-grown trees if the problems relating to flowering are encountered, or alternatively, to reduce the annual pruning requirement in view of their retarding effect on shoot extension.

In conclusion, it might be stated that tremendous scope exists for increasing productivity of mango orchards around the world by increasing planting density and employing the pruning techniques mentioned.

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