

Growth, Cropping and Sturdiness of Two-year-old Mango Trees in Relation to Branching Initiated by Pruning

S.A. Oosthuyse

Merensky Technological Services, P.O. Box 14, Duivelskloof 0835

ABSTRACT

Canopy development deficiencies relating to cropping ability, growth or structural strength are associated with the limited capability of young mango trees (*Mangifera indica L.*) to branch. These deficiencies can be overcome by tipping (specific removal of the apical bud by pruning) the terminal shoots after each flushing cycle. Branching is caused, and consequently, branching points are created in the canopy. In the present study, terminal shoots of Sensation and Kent mango trees were tipped during the first two years of the trees' development. The number of terminal shoot tipped per tree was varied, and in certain instances pruning was excluded. Variables relating to cropping ability, growth or sturdiness were regressed on number of branching points in the canopy when the trees were first allowed to crop, two years after planting.

Positive, linear equations best described the relationship between number of branching points and number of terminal shoots, fruit bearing terminal shoots, or number of fruit retained. A slight reduction in average fruit weight, terminal shoot length and number of terminal shoot leaves accompanied the increase in number of branching points. A direct relationship existed between number of branching points and framework weight, root weight, or total number of leaves. Logarithmic or multiplicative equations best described the relationship between number of "distally situated" branching points and trunk or scaffold branch circumference. Circumference of the "most recently" tipped terminal shoot was more closely related to the number of leaves on the new shoots having arisen after tipping, than to their number or total length. The increase in number of terminal shoots and leaves caused by tipping was considered to be the basis for the relationships observed.

UITTREKSEL

Blaredak ontwikkelings tekortkominge verwant aan die vermoë, groei en strukturele sterkte word geassosieer met die beperkte vermoë van jong mangobome (*Mangifera indica L.*) om te vertak. Hierdie tekortkominge kan oorkom word deur die terminale lote na elke "flush" siklus te tip (die spesifieke verwydering van die apikale groeipunt deur snoeiing). Vertakking word veroorsaak en gevvolglik word vertakkingspunte in die blaredak geskep. In hierdie studie is die terminale lote van "Sensation" en "Kent" mangobome getip gedurende die eerste twee jaar na aanplanting. Die aantal terminale lote wat getip is het van boom tot boom gewissel en in sekere gevalle is glad nie gesnoei nie. Veranderlikes soos opbrengs, groei en stewigheid is vergelyk tydens vrugset, twee jaar na aanplanting.

Positiewe liniére vergelykings kan die verhouding tussen die aantal vertakkingspunte, aantal terminale lote, die aantal vrugdraende stingels en die opbrengs die beste beskryf. 'n Effense vermindering in die gemiddelde vrugmassa, terminale stingellengte en die aantal terminale-stingel blare het saamgegaan met die verhoging in die aantal vertakkingspunte. Direkte verwantskappe bestaan tussen die hoeveelheid vertakkingspunte en die raamwerk massa, wortel massa en die totale hoeveelheid blare. Logaritmiese of vermeerderings-vergelykings beskryf die onderskeie verhoudings tussen die aantal distaal geleë vertakkingspunte en stam- of stuttkomtrek. Die omtrek van die mees onlangs getipte lote het beter verband gehou met die aantal blare op die nuwe lote wat ontwikkel het na snoeiing, as met hul totale hoeveelheid of hul totale lengte. Ons kan dus aanneem dat die verhoging in die aantal apikale groeipunte en blare wat deur die snoeiing veroorsaak is, die basis kan wees vir die verhoudings wat waargeneem is.

INTRODUCTION

Training of young mango trees by pruning has received little attention and no scientific study. Trees of the important mango cultivars whose fruit are exported from South Africa to western Europe (Irwin, Tommy Atkins, Zill, Sensation, Kent, and Keitt), generally do not branch during flushing cycles unless the apical buds on terminal shoots become reproductive. As a result, the canopies of young trees generally comprise of long, unramified limbs.

Cropping potential is low as a direct result of there being few terminal shoots from which inflorescences can develop. Canopy development is slow due to the lack of leaves. Pronounced bending of branches under the weight of fruit occurs during the period of fruit growth, often resulting in the undesirable occurrence of fruit coming to rest on the orchard floor.

Canopy ramification normally increases with time due to the development of axillary buds at the uppermost portion of branches having been bent over by the fruit,

and axillary bud development close to the points of peduncle attachment following harvest.

In the present study, it was aimed to ascertain whether the deficiencies associated with poor branching of young mango trees can be overcome by tipping terminal shoots after each flushing cycle to encourage branching. This was achieved by making observations and establishing relationships between the number of branching points thus created in the tree canopy, with variables relating to cropping ability, growth or structural strength (sturdiness).

MATERIALS AND METHODS

The proportion of panicles retaining fruit until harvest is found to be high in Sensation, whereas low in Kent. These cultivars were therefore used in order to ascertain whether the effect of tipping on cropping ability would persist despite cultivar differences in ability to retain fruit.

A row of 35 Sensation trees and a row of 17 Kent trees were used at Constantia Estate in the north eastern Transvaal (latitude: $23^{\circ}40'S$; longitude: $30^{\circ}40'E$; elevation: 457 m). The soil is a sandy loam containing 10 to 30% clay. The rootstock utilized was Sabre, and the planting spacing adopted was 3 x 7 m. The trees were planted in May (Sensation) or September (Kent) 1990. Two to three months after planting, once the trees had become established, they were headed 65 cm above ground level (37 cm above the graft union) to initiate branching.

From the time of initial heading until that of first cropping (July 1992 to January 1993), vigorous terminal shoots on each tree were tipped once having matured. The number of terminal shoots tipped was varied between trees. On one extreme, no tipping was performed, whereas on the other, most of the terminal shoots branched due to terminal inflorescence development or tipping. Care was taken not to introduce systematic variation in number of branching points in relation to relative tree position in the row. The absence of such variation was confirmed in December 1992 by regressing the number of branching points per tree on tree position. The significance level (p) for linear regression was 0.684 and 0.684, and the coefficient of correlation (r^2) was 0.005 and 0.01 for the Sensation and Kent rows respectively.

Branching occurred naturally from the terminal shoots having borne inflorescences during the winter months of 1991. The inflorescences were removed soon afterwards in the early summer when re-flowering from axillary buds near their point of panicle attachment would no longer occur.

To assess the effect of tipping on cropping ability, the number of branching points, terminal shoots, terminal shoots bearing fruit, and fruit per tree were counted in December 1992. At this stage, the trees had respectively flushed, flowered, undergone fruit set, and were no longer shedding fruit. The effect of tipping on trunk and branch thickening was assessed by additionally measuring the circumference of the trunk 14 cm above the graft union, and the circumference of a 1st and 2nd scaffold branch. The nomenclature used to describe the various branches is shown in Fig. 1. In determining the relationships pertaining to the latter branches, the number of branching points in the canopy portions distally subtending these branches were counted.

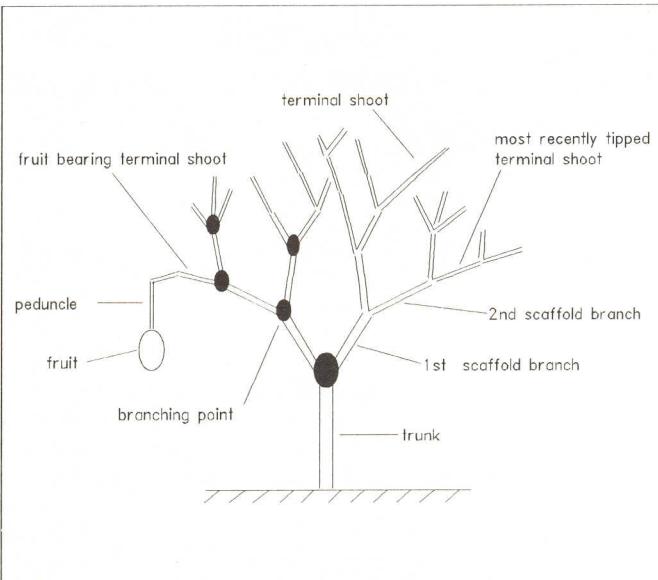


Fig. 1 Naming of the various tree components.

To gain greater clarity as to the effect of branching on stem thickening, the relationship between the circumference of a "most recently tipped" terminal shoot (Fig. 1), and the number, total length or leaf number of the terminal shoots having arisen from it in response to tipping, were determined. This was done by counting and taking measurements from two branch units per tree. The lengths of the terminal shoots measured here were also used to determine the relationship between number of branching points in the tree canopy and terminal shoot length.

To establish the effect of tipping on average fruit weight, the fruit from each tree were individually weighed during harvest in January 1993. The effect of tipping on tree growth was ascertained by decapitating five of the Sensation trees just above the graft union after harvest, and determining the weight and leaf number of each. The number of branching points in the trees selected ranged from two (an unpruned tree) to 39 (most frequently tipped tree). The root systems of two of these trees (the unpruned tree and a tree comprising of 10 branching points) were carefully dug-up, rinsed, and their weights ascertained.

Tensiometer stations, each consisting of two tensiometers (Irrometer, model R) inserted to depths of 30 and 60 cm, were used to schedule irrigation, the pressure deficit per station never having been allowed to exceed an average of - 50 kpa. Composted chicken manure (85%) supplemented with guano (10%) and dried kelp (5%) (500 g), in addition to LAN (28% N) (30 g), was applied monthly, and fungicides and insecticides administered regularly to control harmful insects and pathogens.

In analyzing the relationships under study, polynomial, logarithmic and multiplicative regression fits were screened using a step-wise regression procedure (Statgraphics computer package, STSC, Rockville, MD, USA). The choice of estimating equation was based on residual inspection, the magnitude of the coefficient of correlation or determination, and the fit-type generally encountered for a category of relationship, e.g., the relationships pertaining to stem thickening.

RESULTS AND DISCUSSION

Almost every terminal shoot bore an inflorescence during late winter and early spring of 1992. The percentage of panicles retaining fruit was 78% ($\pm 10\%$) in Sensation and 38% ($\pm 8\%$) in Kent.

Tipping, when performed frequently, prevented long, thin branches from developing, and eliminated the problem of fruit coming to rest on the orchard floor due to branch bending under the weight of fruit. It is noteworthy, however, that the length of the trunk (65 cm), which determined the elevation of the canopy above ground level, was of significance in the aversion of this problem. Fig. 2 shows one of the Sensation trees in April 1992, prior to flowering, and the same tree in September 1992, once fruit growth and development was underway.

Positive, linear equations best described the relationship between number of branching points and number of terminal shoots (Figs. 3- A & 4- A). This result is consistent with theoretical expectation. Furthermore, positive, linear equations best described the relationship between number of branching points and number of fruit bearing terminal shoots or number of fruit retained by the canopy (Figs 3- B, C & 4- B, C). This would be anticipated if the probability of a inflorescence bearing terminal shoot setting fruit is independent of the number of terminal shoots present, and thus, the number of branching points in the canopy.

In Sensation, more than 80% of the variation was accounted for in the case of the relationship between

number of branching points, and number of fruit bearing terminal shoots or number of fruit retained (Fig. 3- B, C). This signifies that the number of branching points in the canopy was the most significant factor determining cropping ability. In Kent, these relationships were relatively weak, the number of branching points accounting for less than 50% of the variation in each case (Fig. 4- B, C). This would indicate the additional significance of other factors in determining cropping ability, like, for instance, the percentage of hermaphrodite flowers born by the panicles themselves (Mullins, 1987). Nevertheless, the relationships show that, in both cultivars, cropping ability was directly related to the number of branching points in the canopy, and thus the number of terminal shoot tipped after each flushing cycle.

A reduction in average fruit weight accompanied the increase in number of branching points in both cultivars (Figs. 5- A & 6- A). However, the relationships were imprecise, and the reduction in weight was small relative to the increase in number of branching points. Similar reductions in terminal shoot length or number of terminal shoot leaves accompanied the increase in number of branching points (Figs. 5- B, C & 6- B, C). These reductions may have been more directly related to the reductions in fruit weight, particularly in view of the finding by Chacko *et al.* (1982) of a positive relationship between fruit size and the number of terminal shoot leaves able to supply assimilates to the fruit during its development.

Positive, linear equations best described the relationship between number of branching points and number of canopy leaves or framework weight (Fig. 7- A, B).

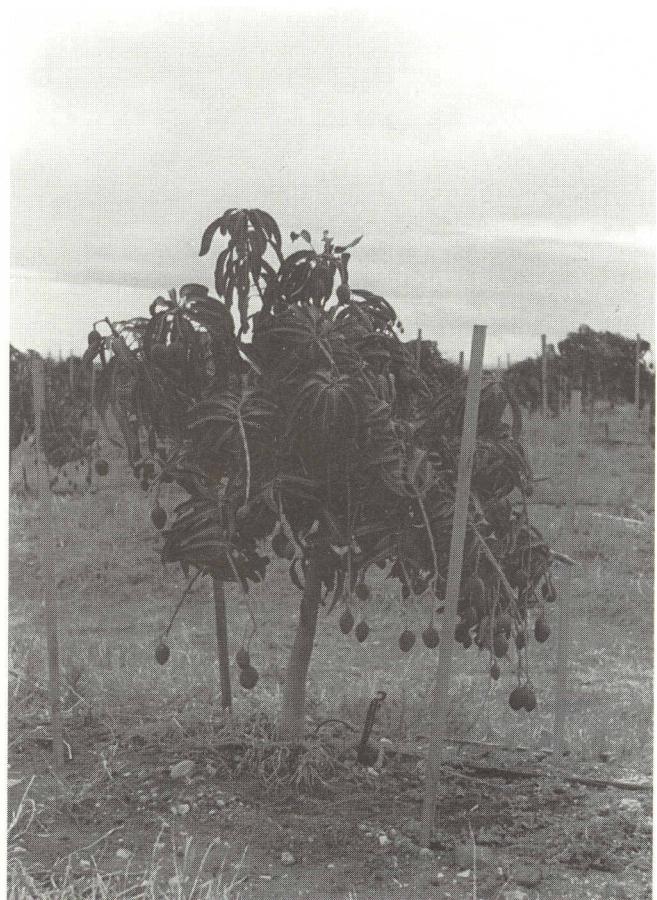
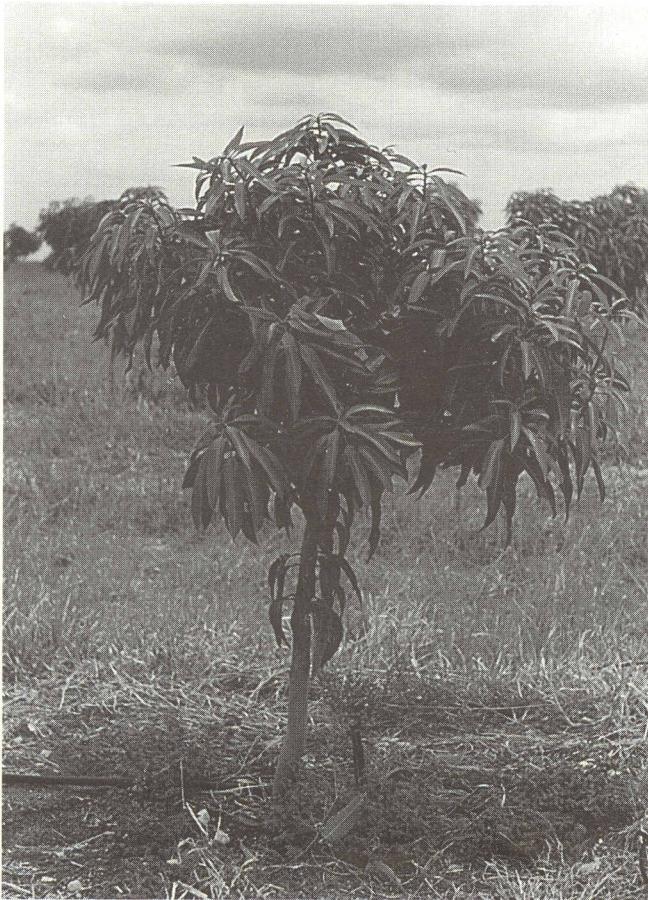


Fig. 2 A Sensation tree in April 1992, prior to flowering (left), and the same tree in September 1992, once fruit growth and development was underway (right).

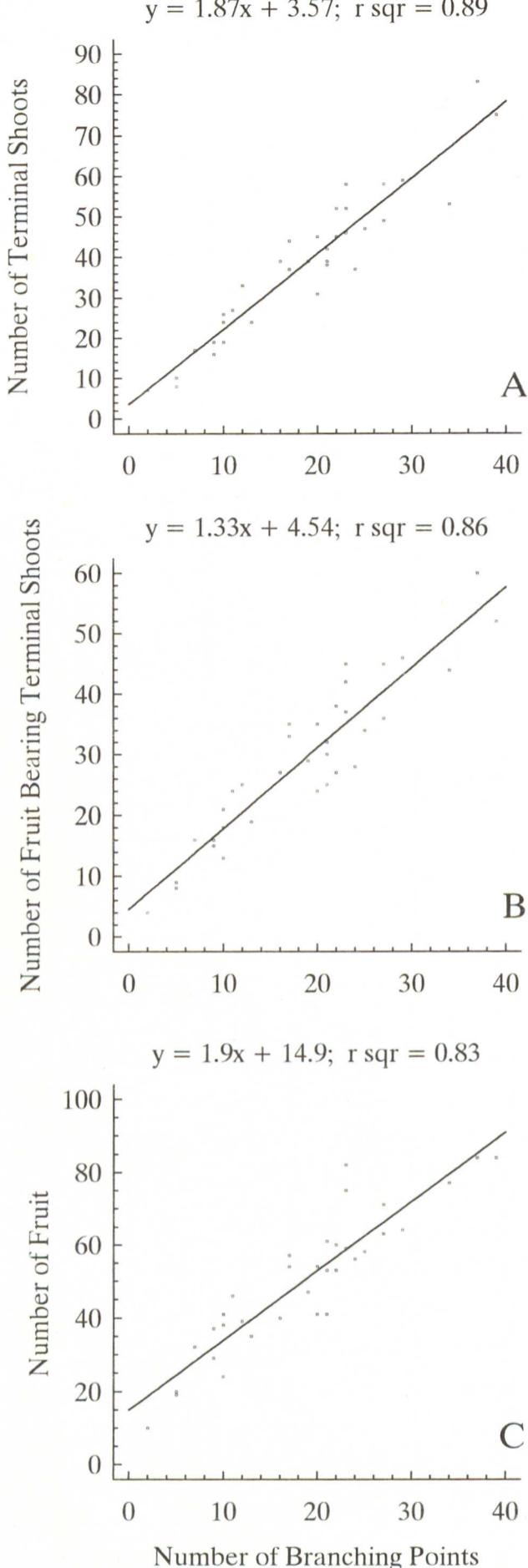


Fig. 3 Relationship between number of branching points, and number of terminal shoots (A), number of terminal shoots bearing fruit (B), or number of fruit (C) in Sensation. [p (model) < 0.001 (A); 0.001 (B); 0.001 (C)]

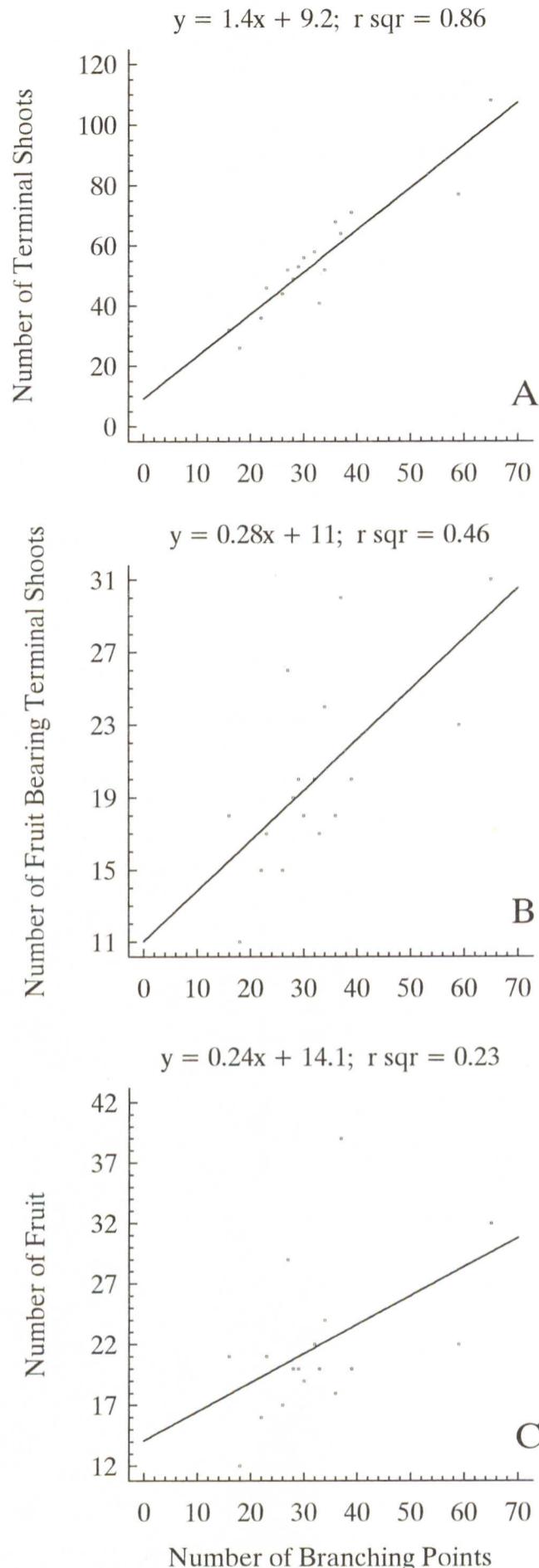


Fig. 4 Relationship between number of branching points, and number of terminal shoots (A), number of terminal shoots bearing fruit (B), or number of fruit (C) in Kent. [p (model) < 0.001 (A); 0.004 (B); 0.050 (C)]

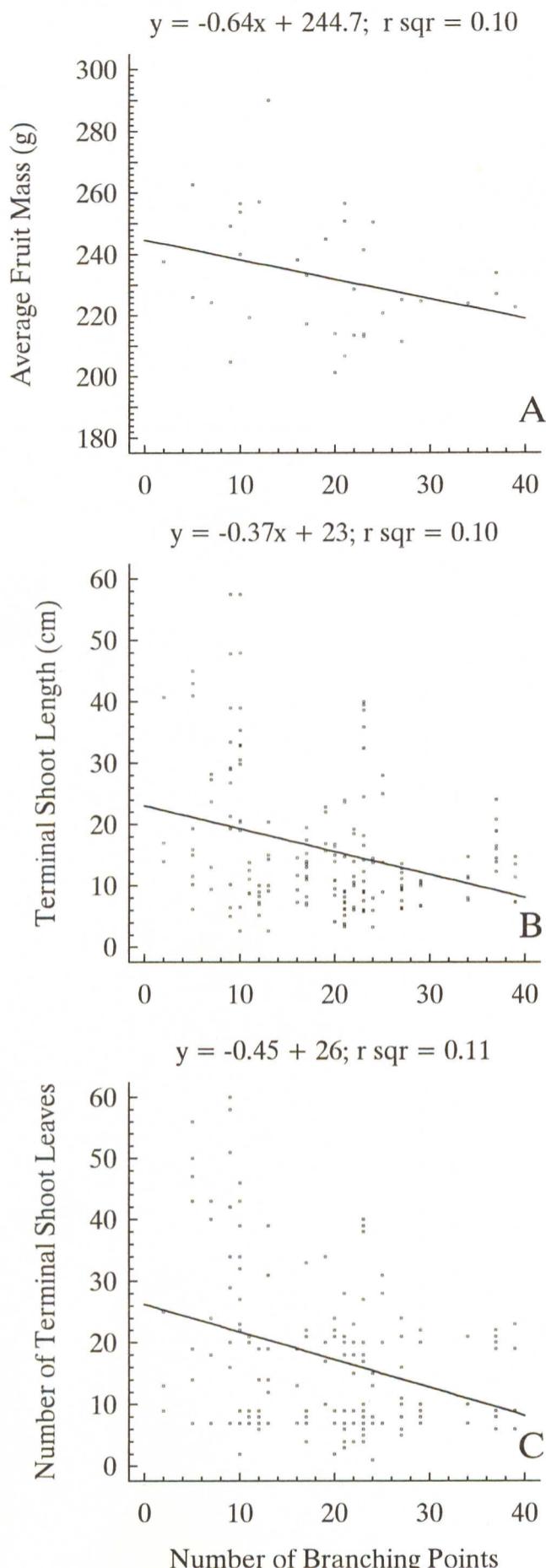


Fig. 5 Relationship between number of branching points, and average fruit weight (A), terminal shoot length (B), or number of terminal shoot leaves (C) in Sensation. [p (model) < 0.069 (A); 0.001 (B); 0.001 (C)]

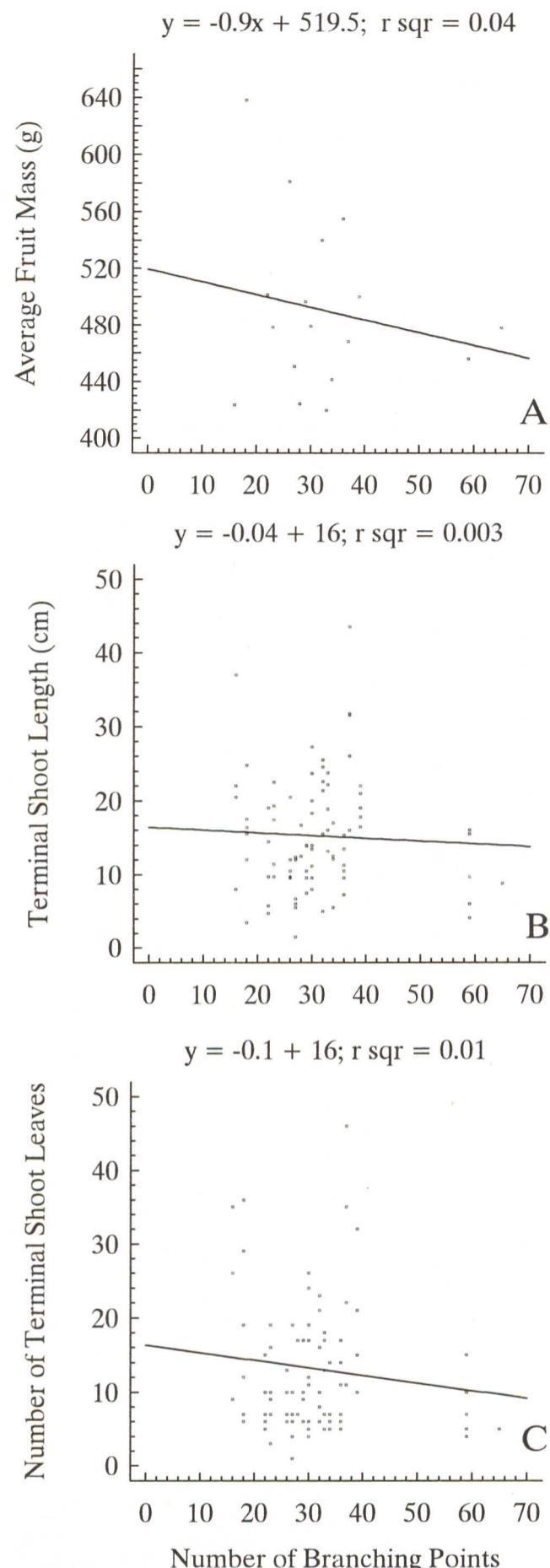


Fig. 6 Relationship between number of branching points, and average fruit weight (A), terminal shoot length (B), or number of terminal shoot leaves (C) in Kent. [p (model) < 0.456 (A); 0.635 (B); 0.256 (C)]

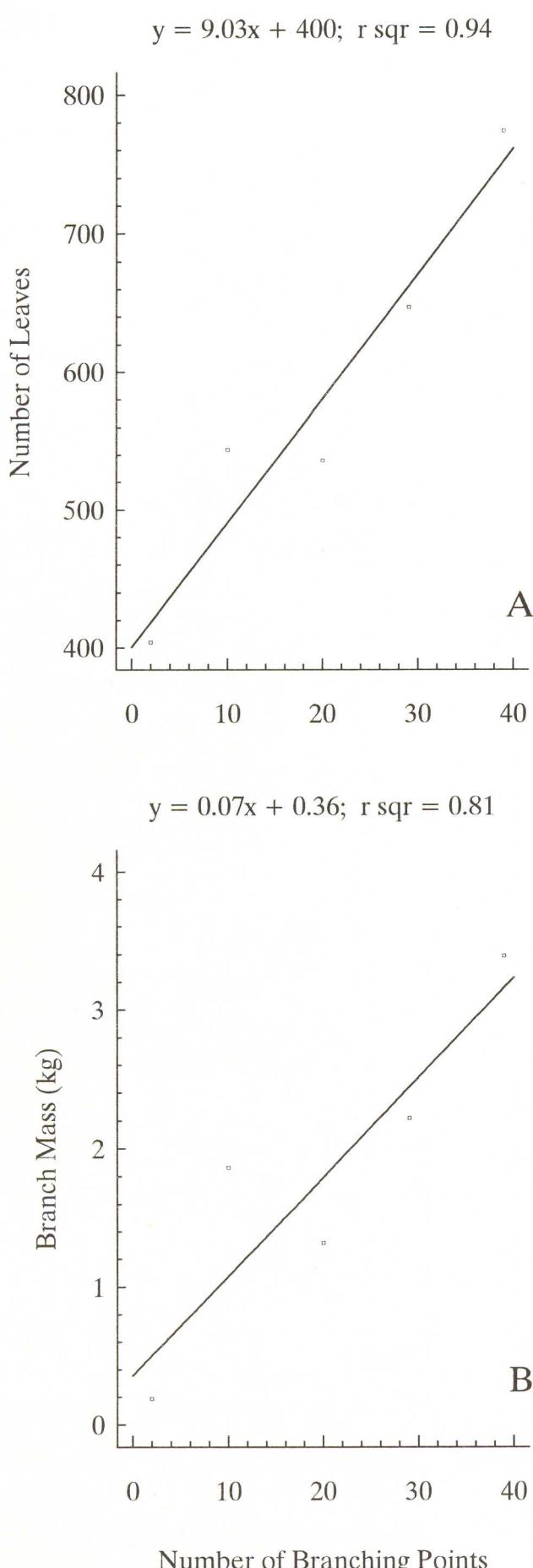


Fig. 7 Relationship between number of branching points, and leaf number (A), or total framework weight (B) in Sensation. [p (model) < 0.038 (A); 0.010 (B)]

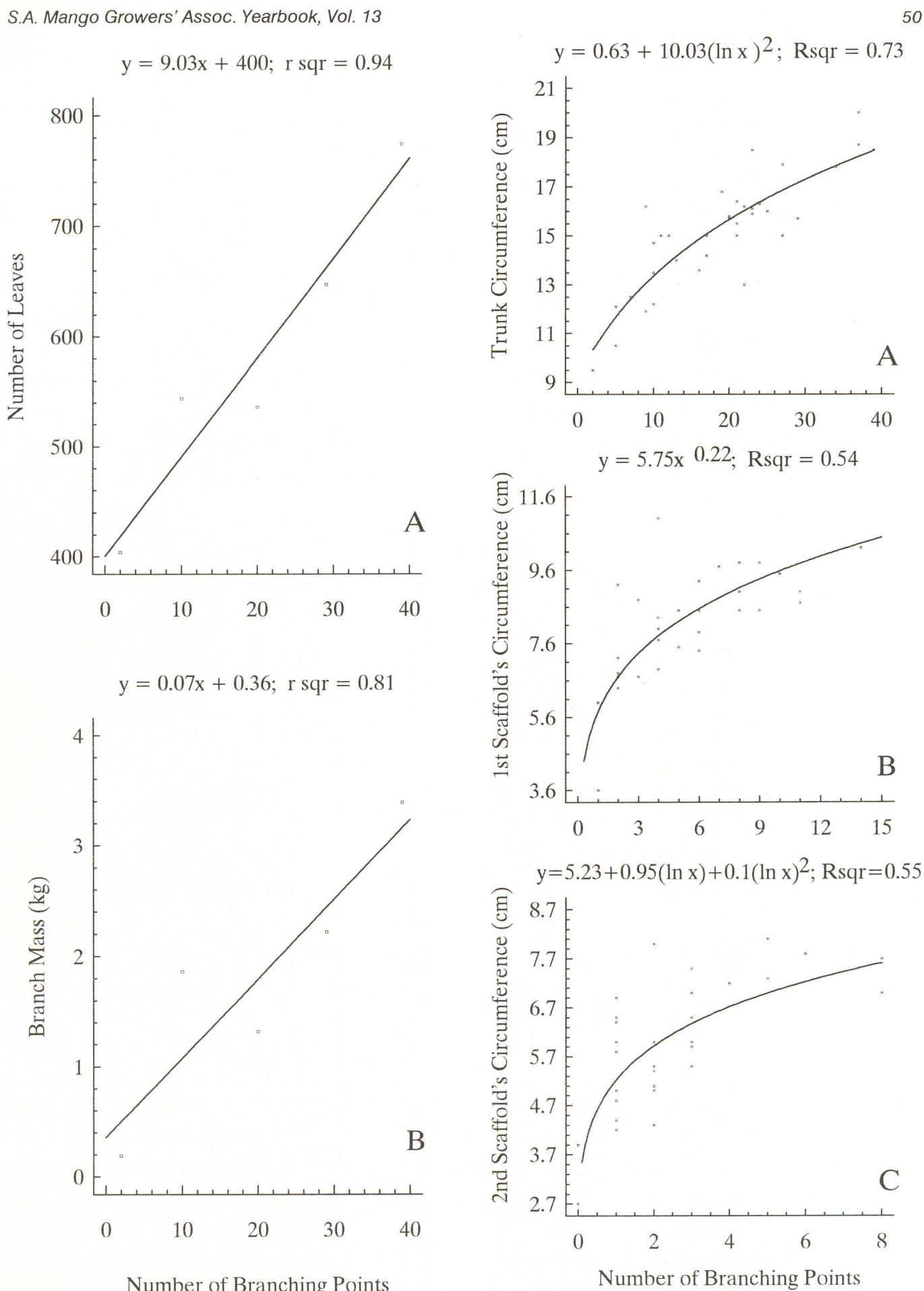


Fig. 8 Relationship between number of distally situated branching points, and circumference of the trunk (A), circumference of the 1st scaffold branch (B), or circumference of the 2nd scaffold branch (C) in Sensation. [p (model) < 0.001 (A); 0.001 (B); 0.001 (C)]

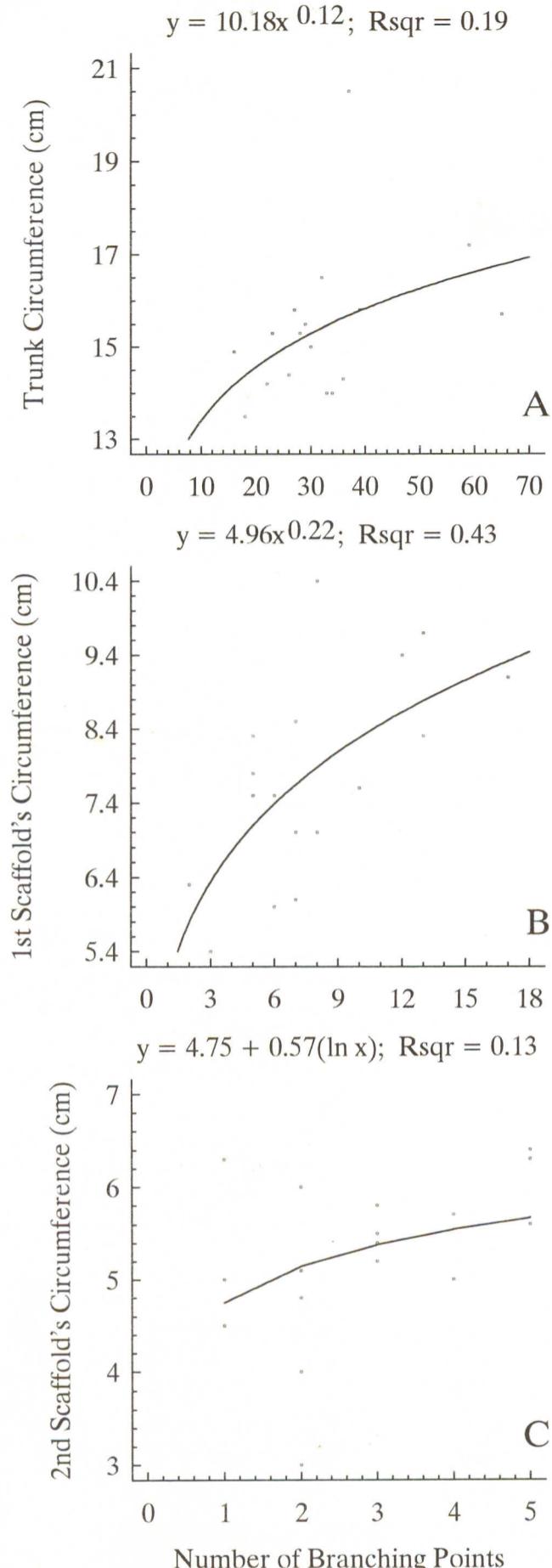


Fig. 9 Relationship between number of distally situated branching points, and circumference of the trunk (A), circumference of the 1st scaffold branch (B), or circumference of the 2nd (C) scaffold branch in Kent. [p (model) < 0.078 (A); 0.005 (B); 0.163 (C)]

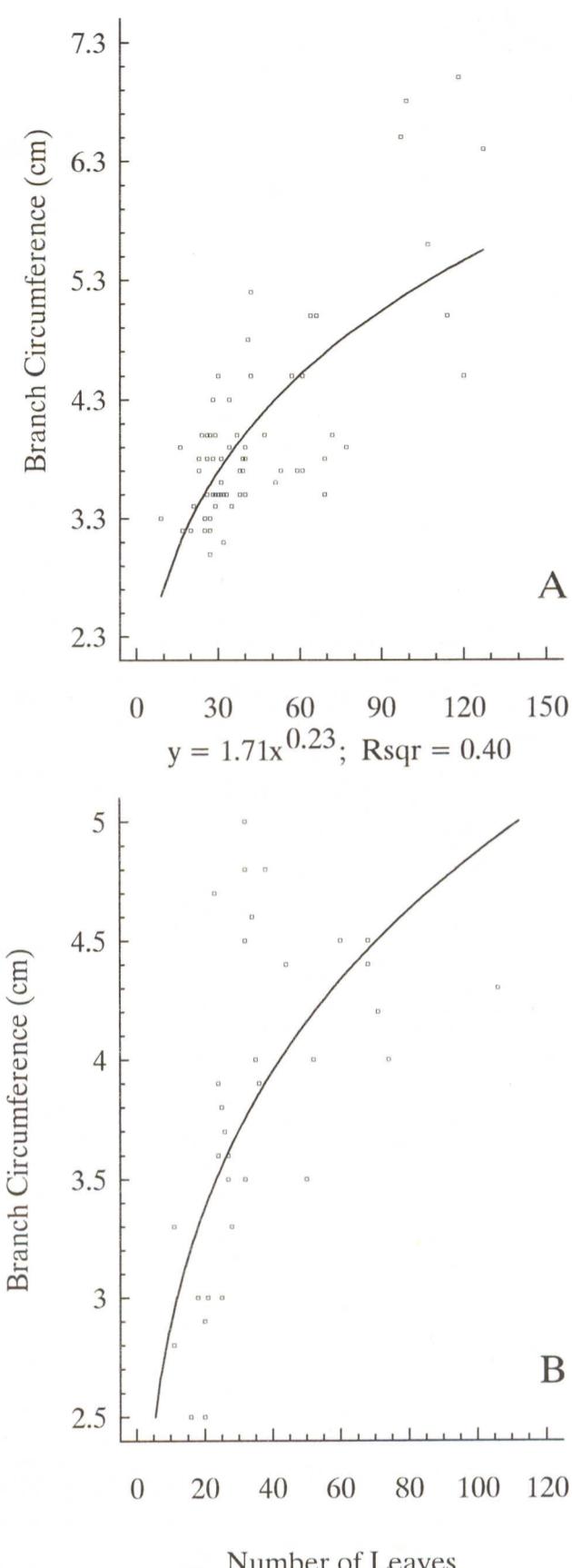


Fig. 10 Relationship between circumference of the "most recently tipped" terminal shoot and number of leaves on the new shoots having arisen subsequently in Sensation (A) and Kent (B). [p (model) < 0.001 (A); 0.001 (B)]

Number of branching points and root weight were also positively related (0.305 kg: unpruned tree with 2 branching points; 1.843 kg: tree with 10 branching points). These results substantiate the positive effect of tipping on tree growth, which might be expected in view of tipping having effectively increased the number of leaves by causing branching.

In general, logarithmic or multiplicative equations best described the relationship between number of distally situated branching points, and circumference of the trunk, circumference of the 1st scaffold branch, or circumference of the 2nd scaffold branch. Logarithmic or multiplicative equations were therefore fitted in every instance (Figs. 8- A, B, C & 9- A, B, C). Implied by this type of fit is a progressive reduction, with increasing number of distally situated branching points, of the positive effect on circumference, and relatively large differences over the lower ranges in number. The relationships nevertheless show that the amount of secondary growth in the trunk or in the 1st or 2nd scaffold branch was positively related to the number of branches and terminal shoots distally adjoining the trunk or the branches in question. Tree sturdiness thus increased in proportion to the number of terminal shoots tipped during the period of canopy development.

Stem cross-sectional area is linearly related to stem cylindrical volume or weight, for which cambial activity is most directly reflected. Further, a linear increase in stem cross-sectional area (x) accompanies a multiplicative increase in circumference ($k \cdot x^{1/2}$). In transforming the circumference measurements recorded to estimates of cross-sectional area, logarithmic or multiplicative equations were still most representative of the relationships relating to branch thickening (data not shown).

The circumference of a "most recently tipped" terminal shoot was more closely related to the number of leaves on the new terminal shoots having arisen after tipping (Fig. 10- A, B), than to the number of new terminal shoots [R^2 (Sensation) = 0.02; R^2 (Kent) = 0.11], or to their total length [R^2 (Sensation) = 0.44; R^2 (Kent) = 0.39]. This would suggest that the increase in branch or trunk thickening accompanying the increase in number of distally situated branching points, was primarily related to the associated increase in number of leaves.

Nutritional relationships, specifically relating the supply of photoassimilates by leaves, are well recognized between crown size and stem growth (Brown, 1971). A causal relationship between shoot growth and cambial activity was originally revealed by Hartig (1862). Jost (1891, 1893) however showed that an adequate supply of nutrients did not cause diameter growth unless the cambium was first activated by some stimulus coming from the young growing shoot. Munch (1938) reported that growth hormones produced by expanding buds and young leaves stimulated the cambium, and that stimulus movement occurred basipetally. Snow (1935) first demonstrated the stimulation of cambial division by auxin. Since then, auxin's involvement in cambial control has been positively identified in numerous plant species (Avery et al., 1937; Wareing, 1958; Brown, 1970, Roberts, 1976). Other growth substances have also been implicated, including gibberellins produced by developing leaves (Wareing, 1958; Wareing and Phillips, 1978), cytokinin presumed to originate in the root (Pieniazek and Saniewski, 1968, Grochowska and Karaszewska, 1980), and natural inhibitors (Wareing and Roberts, 1956).

In view of it being recognized that the supply hormones and photoassimilates of distal origin determine cambial activity, the relationships concerning stem thickening might be explained in terms of the rate limiting effect of hormones on cambial activity over the lower ranges in branching point number, and the rate limiting effect of assimilates over the higher ranges where linearity was more closely approximated. A linear relationship between trunk cross-sectional area and total above-ground weight was demonstrated by Westwood and Roberts (1970) in apple trees.

In mango, studies on the regulation of cambial activity are lacking, although the observation that radial growth cycles showed a strong tendency to succeed shoot growth cycles has been reported (Chacko, 1984). The critical role of young leaves for normal shoot development, particularly in relation to their ability to produce gibberellin, was demonstrated by Chacko (1992).

Techniques of pruning young mango trees of a number of cultivars, incorporating pruning to encourage branching during each flushing cycle, were previously proposed by the author (Oosthuysse, 1992), and have been successfully implemented at a number of mango estates in the north eastern Transvaal. The relationships presented in this study clearly show the marked positive effect of tipping on the growth, structural strength and cropping ability of young mango trees. These effects might be considered to have particular relevance to high density orchards where establishment costs are high and cash flow considerations are critical.

ACKNOWLEDGEMENTS

Thanks are due to A.H. Basson of Constantia Estate for assistance in performing the study, D.L. Milne for his valuable comments, M.L. Manyama and B.M. Mmola for data collection, and W. Saaiman for abstract translation. A. Altenroxel, J.W. Botha, A.M. Basson, J.A.H. Minnaar, and J. du Preez are acknowledged for their keen interest in commercially adopting the pruning techniques originally proposed.

LITERATURE CITED

- AVERY, G.S., P.R. BURKHOLDER, AND H.B. CREIGHTON. 1937. Production and distribution of growth hormone in shoots of *Aesculus* and *Malus* and its probable role in stimulating cambial activity. *Amer. J. Bot.* 24:51-58.
- BROWN, C.L. 1970. Physiology of wood formation in conifers. *Wood Science* 3:8-22.
- BROWN, C.L. 1971. Growth and Form, p. 125-167. In: M.H. Zimmerman and C.L. Brown (eds.). *Trees: Structure and function*. Springer-Verlag, Berlin.
- CHACKO, E.K. 1984. Physiology of vegetative and reproductive growth in mango (*Mangifera indica* L.) trees. *Proc. First Aust. Mango Res. Workshop*, CSIRO, Melbourne, p. 54-70.
- CHACKO, E.K. 1992. The role of immature leaves in shoot growth of mango (*Mangifera indica* L.). *IV International Mango Symposium Abstracts*, Univ. Florida, IFAS, p. 33.
- CHACKO, E.K., Y.T.N. REDDY, AND T.V. ANANTHANARAYANAN. 1982. Studies on the relationship between leaf number and area and fruit development in mango (*Mangifera indica* L.). *J. Hort. Sci.* 57:483-492.

- GROCHOWSKA, M.J. AND A. KARASZEWSKA. 1980. The role of IAA, GA and their interaction in apical dominance of an apple tree. *Fruit Sci. Rep.* 7:91-100.
- HARTIG, T. 1862. Über die Bewegung des Saftes in den Holzpflanzen. *Bot. Ztg.* 20:73-76.
- JOST, L. 1891. Über Dickenwachstum und Jahresringbildung. *Bot. Ziet.* 49:485-630.
- JOST, L. 1893. Über Beziehungen zwischen der Blattentwicklung und der Gefassbildung in der Pflanze. *Bot. Ziet.* 51:89-138.
- MULLINS, P.D.F. 1987. The effect of varying climatic regimes on floral development and behaviour in mango (*Mangifera indica* L.) cvs Haden and Sensation. Masters thesis, University of Natal, Pietermaritzburg, South Africa.
- MUNCH, E. 1938. Investigations on the harmony of tree shape. *Jahrb. Wiss. Bot.* 86:581-673.
- OOSTHUYSE, S.A. 1992. Ideas on pruning of mango trees. *S.A. Mango Growers' Assoc. Yearbook* 12:1-8.
- PIENIAZEK, J. AND M. SANIEWISKI. 1968. Hormone control of cambial activity and xylem differentiation in apple shoots. *Acta Agrobot.* 12:113-129.
- ROBERTS, L.W. 1976. Cytodifferentiation in plants. Cambridge University Press, Cambridge.
- SNOW, R. 1935. Activation of cambial growth by pure hormones. *New Phytol.* 34: 347-360.
- WAREING, P.F. 1958. The physiology of cambial activity. *J. Inst. Wood Science* 1:34-42.
- WAREING P.F. AND I.D.J. PHILLIPS. 1978. The control of growth and differentiation in plants. Pergamon Press, New York.
- WAREING P.F. AND D.L. ROBERTS. 1956. Photoperiodic control of cambial activity in *Robinia pseudoacacia*. *New Phytol.* 55:289-388.
- WESTWOOD M.N. AND A.N. ROBERTS. 1970. The relationship between trunk cross-sectional area and weight in apple trees. *J. Amer. Soc. Hort. Sci.* 95:28-30.

Gestig 1925

Established 1925

Diens Met Sekuriteit

Service With Security

PETER EN KIE/& CO

Reg no. 59/0063/07

Eienaars/Proprietors: C J PETER EN KIE (EDMS) BPK/AND CO (PTY) LTD

MARKAGENTE

MARKET AGENTS

DIE NASIONALE VARSPRODUKTE-
MARK VAN DURBAN
FLOWERWEG 81
WENTWORTH 4052

DURBAN

DURBAN NATIONAL FRESH PRO-
DUCE MARKET
81 FLOWER ROAD
WENTWORTH 4052

Alle korrespondensie aan:

All correspondence to:

Posbus - PO Box
1270
Jacobs
Fax (031) 465-3316
Telefone - Telephones
(Durban dial code 031)
465-3032/4/5/6

EERSTE NASIONALE BANK BPK
JACOBS
FIRST NATIONAL BANK LTD
JACOBS

FOON NA URE	PHONE AFTER HOURS
MIKE RIBIERO	Vrugte 42-1254
STONEY STEENKAMP	Uie/Onions 86-6619
ARMANDO D'OLIVEIRA	Mangoes 764-5441
CHIPPIE LUBBE	Vegetables 466-3791 Tomatoes
KAS VENTER	Aartappels 42-5574 Potatoes
CARL LUBBE	Algemeen 466-2455