Schaffer, B., K. D. Larson, G. H. Snyder, and C. A. Sanchez. 1988. Identification of mineral nutrient deficiencies associated with mango decline by DRIS. HortScience 23:617-619.
Schaffer, B. and G. O. Gaye. 1989. Gas exchange, chlorophyll and nitrogen content of mango leaves as influenced by light environment. HortScience 24:507-509.
Schaffer, B., P. Andersen, and R. C. Ploetz. 1991. Responses of fruit crops to flooding. Hort. Reviews (in press).
Schaffer, B. and S. O'Hair. 1987. Net CO_2 assimilation of taro and cocoyam as affected by shading and leaf age. Photosynthesis Res. 11:245-251.
Shetty, A. S. and G. W. Miller. 1966. Influence of iron chlorosis on pigment and protein metabolism in leaves of *Nicotiana tabacum* L. Plant Physiol. 41:415-421.
Spiller, S. and N. Terry. 1980. Limiting factors in photosynthesis. II. Iron stress diminishes photochemical capacity by reducing the number of photosynthetic units. Plant Physiol. 65:121-125.
Stocking, C. R. 1975. Iron deficiency and the structure and physiology of maize chloroplasts. Plant Physiol. 55:626-631.
Stolzy, L. H. and J. Letey. 1964. Characterizing soil oxygen conditions with a platinum microelectrode. Adv. Agron. 16:249-279.
Terry, N. 1980. Limiting factors in photosynthesis I. Use of iron stress to control photochemical capacity *in vivo*. Plant Physiol. 65:114-120.
Thomas, G. W. 1982. Exchangeable cations. In: A. L. Page et al. (eds.) Methods of soil analysis, part 2. Agronomy 9:159-165.
Trought, M. C. T. and M. C. Drew. 1980. The development of waterlogging damage in wheat seedlings (*Triticum aesitivum* L.). II. Accumulation and redistribution of nutrients by the shoot. Plant and Soil 56:187-199.
Young, T. W. and J. W. Sauls. 1981. The mango industry in Florida. Florida Coop. Ext. Ser., Univ. of Florida/IFAS, Gainesville, Florida.
Young, T. W., and R. C. J. Koo. 1971. Variations in mineral content of Florida mango leaves. Proc. Fla. State Hort. Soc. 82:324-328.

Proc. Fla. State Hort. Soc. 104:39-41. 1991.

AN EXPERIMENTAL SYSTEM TO STUDY MANGO FLOWERING USING CONTAINERIZED TREES PROPAGATED BY AIR-LAYERING

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Additional index words. Mangifera indica L., vegetative propagation, phenology, pruning, defoliation, chilling, floral development.

Abstract. **A method was developed to consistently induce floral differentiaton in mature 'Tommy Atkins' mango trees by exposure to chilling. Trees were propagated by air-layering branches of adult, field trees. Rooting of girdled branches was induced within 12 weeks with the aid of 2% naphthaleneacetic acid in lanolin paste. Rooted air-layers were pruned and completely defoliated upon potting to regenerate the canopies. Mature, fully-expanded vegetative shoots were obtained within 10 weeks of pruning. Trees with developmentally uniform canopies were exposed to a chilling treatment of 18/10° C (day/night temperature, 12-h photoperiod). Defoliation of shoot tips stimulated initiation of apical buds. Bud break of nearly all stimulated buds occurred after 7 to 8 weeks of chilling. More than 80% of buds differentiated floral primordia. Bud meristematic activity during chilling was required for floral differentiation. Chilling induced flowering of containerized trees regardless of time of the year.**

Studies on the reproductive physiology of woody perennial fruit trees, including mango, have been limited by the lack of reliable experimental flowering systems (Jackson and Sweet, 1972; Wareing, 1981; Chacko, 1984; Hackett, 1985). Floral initiation of perennial trees can occur under alternative environmental pathways (Bernier, 1988; Evans, 1969; Sedgley, 1990). Floral initiation of mango, for example, occurs during exposure to temperatures below 15° C (Nunez-Elisea and Davenport, 1991a, 1991b; Ou, 1982; Shu and Sheen, 1987; Whiley et al., 1989; Wolstenholme and Hofmeyr, 1985) or after a drought period of 2 to 3 months (Chacko, 1984; Singh, 1960; Verheij, 1986). Chilling and water stress also induced flowering of containerized 'Tahiti' lime trees (Southwick and Davenport, 1986).

Mango trees growing under natural conditions attain large size and display sporadic flushes of vegetative or floral growth (depending on the season) in different sections of the canopy. Asynchronous canopy growth may also be influenced by heterogeneous rootstocks and differences in soil moisture or nutrient availability within the root zone.

Experimental flowering systems should ideally minimize both plant and environmental variability, and give consistent and predictable flowering. In this report we describe a method to quickly produce mature experimental mango trees by air-layering and their phenological synchronization by canopy regeneration. Initial results of floral induction in containerized trees by exposure to a chilling treatment are also presented.

Production of experimental trees by air-layering. Mango (*Mangifera indica* L. cv. Tommy Atkins) trees propagated by air-layering were used in this system to insure genetic uniformity of plants and eliminate possible rootstock influences on canopy growth. Branches of mature field trees, measuring 2-3 cm in diameter and consisting of two or more main ramifications, were air-layered throughout the year. Branches were girdled by removing a 5-cm ring of bark (Lambe et al., 1991), 20 to 25 cm behind the point of main ramification. The distal edge of the girdle was treated with 2% NAA in lanolin to induce adventitious rooting (Lambe et al, 1991; Nunez-Elisea et al., 1989). Abundant rooting was observed within 12 weeks of treatment (Lambe et al., 1991; Nunez-Elisea et al., 1989). Rooted air-layers were detached and potted in 10-liter plastic containers in a peat moss and vermiculite media (1:1 v/v).

Canopy regeneration for phenological synchronization. Air-layering in the late fall pre-conditioned the girdled branches and accelerated floral initiation by up to 3 weeks in relation to the rest of the tree. The effect of preconditioning was eliminated from experimental trees by removing

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excess branch vegetation to form new, developmentally uniform canopies. Tree shape and size were standardized by retaining 2 or 3 main stems as the basic tree framework. These stems were shortened to a length of ca. 25 cm by cutting about 1 cm above the most distal bud. A slanted cut was used to avoid accumulation of moisture on the exposed *cut surface. All* leaves remaining on the framework were removed. Potted trees were fertilized with 60 g Osmocote (14-14-14 of N-P-K) around the trunk collar and mulched with sphagnum moss to retain moisture. Trees were placed outdoors to initiate growth, under a translucent, white fiberglass cover for protection against excessive sun and rain. They were irrigated to field capacity and no further irrigation was provided until new growth appeared.

The stages of vegetative development during canopy regeneration are shown in Figure 1. Swelling of axillary buds (due to initiation of meristematic cell division) occurred synchronously during the second week after pruning, and was quickly followed by bud break. Three to four vegetative shoots emerged from the most distal buds of each stem. Excess shoots were removed (shoot thinning) when they were still tender and 5 to 10 cm long. One or two shoots were retained per stem, preferably those growing in opposite lateral directions. Shoots that developed from the main trunk were removed. Trees were irrigated every 3 days.

Shoot maturity is a prerequisite for floral initiation (Chacko, 1991; Nunez-Elisea, 1989; Singh, 1959). Vegetative shoots reached their final size three to four weeks after bud break, but were still immature, with light green, flaccid leaves. Shoot maturation was hastened by reducing irrigation frequency to once every week. Shoots became lignified and turned darker green during the following 3 weeks. They hardened by the eighth week after bud break, at which time tree canopies were considered mature. Dormant trees at this developmental stage were used for studies of floral induction with chilling.

Induction of floral initiation with chilling. Mango trees initiate flowering during a period of vegetative growth cessation (Chacko, 1984; Singh, 1960; Verheij, 1986). Dormant buds of mango, in contrast to those of temperate fruit trees, are not yet developed and thus have the potential to differentiate vegetative or floral structures upon initiation (Mustard and Lynch, 1946; Singh, 1958). Floral development from differentiation to anthesis is a continuous process (Mustard and Lynch, 1946; Scholefield et al., 1986; Singh, 1958).

Chilling experiments to induce floral differentiation were conducted over a 14-month period. Dormant trees were transferred from ambient environmental conditions (see Figure 1) during the spring, summer, or fall into a controlled-environment growth chamber. Environmental parameters within the chamber were 18/10° C (day/night temperature), 12-h photoperiod, and 75% relative humidity. Photosynthetic photon flux at plant canopy level was 300 μmol m^{-2} s^{-1}, which is about 85% of that required by individual mango leaves for light saturation with respect to net CO_2 assimilation (Schaffer and Gaye, 1989). Dormant apical buds of all trees were stimulated to initiate during exposure to chilling by removing all the leaves (7 to 12) surrounding the shoot apex. This procedure accelerated *bud initiation* and synchronized growth within and among plants.

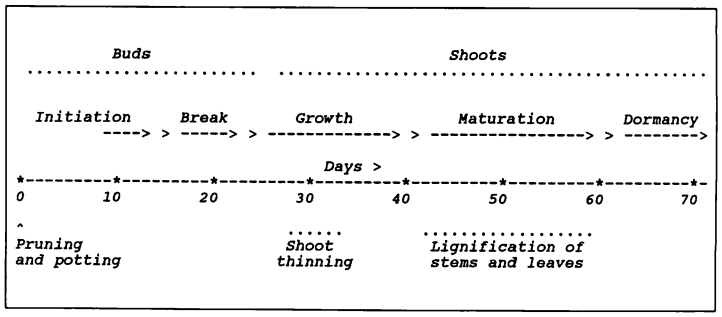

Fig. 1. Stages of vegetative development during canopy regeneration of containerized 'Tommy Atkins' mango trees. Trees were pruned to produce new canopies under ambient outdoor conditions (temperature of 20 to 32° C and relative humidity of 65 to 95%) in Homestead, Florida.

A time-course of developmental events occurring in response to defoliation of shoot tips during chilling is presented in Figure 2. Buds began to swell by the fourth week after defoliation of shoot tips. Trees transferred to warm conditions at this stage of bud development produced mainly vegetative growth; therefore, further bud development was allowed to occur under chilling conditions before trees were removed from the chamber. Longitudinal sections of buds exposed to 6 weeks of chilling treatment showed meristematic protrusions in the axils of the inner bud scales. The presence of these structures, which eventually develop into the flower-bearing branches of mango panicles, indicates progression towards floral differentiation (Mustard and Lynch, 1946; Scholefield et al., 1986; Singh, 1958).

Floral bud break was considered to be the stage at which external scales had loosened and could be manually removed to discern the underlying floral primordia. Breaking buds measured ca. 1 cm in length. With only slight variation among experiments, nearly all stimulated buds attained bud break 7 to 8 weeks after the start of the chilling treatment. Since buds had differentiated floral or vegetative primordia when they reached the bud break stage, trees at this stage were transferred back to warm, outdoor conditions to hasten development of the new growth.

More than 80% of all stimulated apical buds differentiated flowers as a result of chilling, either in purely generative panicles or in mixed shoots which had both leaves and axillary, flower-bearing branches. Chilling consistently induced flowering of potted trees regardless of the time of year that it was applied. Individual flowers on generative panicles or mixed shoots began to open about one week

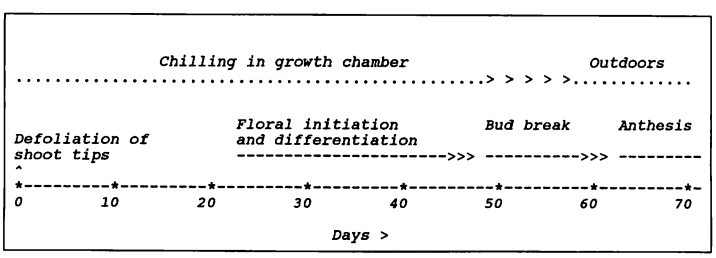

Fig. 2. Stages of floral development of containerized 'Tommy Atkins' mango trees in response to a chilling treatment of 18/10° C. Shoot tips were defoliated at the start of chilling to stimulate apical bud initiation. Trees were removed from chilling upon attaining bud break (after 7 to 8 weeks) and returned to ambient, outdoor conditions to promote growth.

after the trees were transferred to warm, outdoor conditions. Buds which did not generate flowers (about 20%) produced new vegetative shoots. In addition, trees that were stimulated to grow in a control chamber at 30/25° C (day/night temperature, 12-h photoperiod) or under warm, outdoor conditions only produced new vegetative growth.

In conclusion, mature experimental mango trees with regenerated canopies were produced in 4 to 5 months by air-layering and selective pruning. A chilling treatment of 18/10° C day/night for 7 to 8 weeks applied to potted trees at any time of the year consistently induced flowering. Bud meristematic cell division during chilling was necessary for differentiation of floral structures. The procedures described in this report are currently being used in further studies of the physiology and developmental aspects of mango reproduction.

Literature Cited

Bernier, B. 1988. The control of floral evocation and morphogenesis. Ann. Rev. Pl. Physiol. 39:175-219.

Chacko, E. K. 1984. Physiology of vegetative and reproductive growth in mango (*Mangifera indica* L.) In: Proc. First Australian Mango Research Workshop. Cairns, Qld. pp. 54-70.

Chacko, E. K. 1991. Mango flowering - still an enigma. Acta Hort. 29:12-21.

Evans, L. T. 1969. The nature of flower induction. In: The induction of flowering. McMillan and Co. (Aust.) pp. 457-480.

Hackett, W. P. 1985. Juvenility, maturation, and rejuvenation in woody plants. Hort. Rev. 7:109-155.

Jackson, D. I. and G. B. Sweet. 1972. Flower initiation in woody temperate plants. Hort. Abstr. 42:9-24.

Lambe, A., R. Nunez-Elisea, and T. L. Davenport. 1990. New developments in mango marcotting. Tropical Fruit World 1(3):80-82.

Mustard, M. J. and S. J. Lynch. 1946. Flower-bud formation and development in *Mangifera indica*. Bot. Gaz. 108:136-140.

Nunez-Elisea, R. and T. L. Davenport. 1989. Requirement for mature leaves during floral induction and floral transition in developing shoots of mango. 3rd Int. Mango Symp. Abstracts. p. 9.

Nunez-Elisea, R. and T. L. Davenport. 1991a. Effect of duration of low temperature treatment on flowering of containerized 'Tommy Atkins' mango. (Abstr.) HortScience 26:135.

Nunez-Elisea, R. and T. L. Davenport. 1991b. Effect of duration of low temperature treatment on flowering of containerized 'Tommy Atkins' mango. Proc. 18th Ann. Meet. Plant Growth Reg. Soc. Amer. (in press).

Nunez-Elisea, R., W. Ferreira, M. L. Caldeira, and T. L. Davenport. 1989. Marcottage of mango: a useful tool for physiological studies of flower induction. Abstract. 86th Annual Meeting of the Amer. Soc. Hort. Sci. p. 115.

Ou, S. K. 1982. Temperature effect on differential shoot development of mango during flowering period. J. Agric. Res. China. 31:209-214.

Schaffer, B. and G. O. Gaye. 1989. Gas exchange, chlorophyll and nitrogen content of mango leaves as influenced by light environment. HortScience 24:507-509.

Scholefield, P. B., D. R. Oag, and M. Sedgley. 1986. The relationship between vegetative and reproductive development in the mango in northern Australia. Aust. J. Agric. Res. 37:425-433.

Sedgley, M. 1990. Flowering of deciduous perennial fruit crops. Hort. Rev. 12:223-264.

Shu, Z. H and T. F. Sheen. 1987. Floral induction in axillary buds of mango (*Mangifera indica* L.) as affected by temperature. Scientia Hort. 31:81-87.

Singh, R. N. 1958. Studies in the differentiation and development of fruit buds in mango (*M. indica* L.). II. Morphological and histological changes. Hort. Adv. 3:37-43.

Singh, L. B. 1959. Movement of flowering substances in the mango (*Mangifera indica* L.) leaves. Hort. Adv. 3:20-27.

Singh, L. B. 1960. The Mango - Botany, Cultivation, and Utilization. Leonard Hill, London. 439 pp.

Southwick, S. and T. L. Davenport. 1986. Characterization of water stress and low temperature effects on flower induction in citrus. Plant Physiol. 81:26-29.

Wareing, P. F. and I. D. J. Phillips. 1981. Growth and Differentiation in Plants. 3rd Edition. Pergamon Press. 343 pp.

Whiley, A. W., T. S. Rasmusen, J. B. Saranah and B. N. Wolstenholme. 1989. Effect of temperature on growth, dry matter production and starch accumulation in ten mango (*Mangifera indica* L.) cultivars. J. Hort. Sci. 64:753-765.

Wolstenholme, B. N. and D. Hofmeyr. 1985. Effects of various floral induction treatments on container-grown mango trees. South African Mango Growers Assoc. Res. Rept. 5:36-38.

Verheij, E. W. M. 1986. Towards a classification of tropical fruit trees. Acta Hortic 175:137-149.

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FLOWERING OF 'KEITT' MANGO IN RESPONSE TO DEBLOSSOMING AND GIBBERELLIC ACID[1]

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Abstract. **Branches of mango trees (*Mangifera indica* L. cv. Keitt) were deblossomed and sprayed with 0, 10, 50, or 250 mg/liter GA_3 in late December to examine the effect of GA_3 on panicle formation. Growth of non-sprayed branches began within 3 weeks. Virtually all new growth consisted of axillary panicles. GA_3-treated branches began to grow 3 to 5 weeks later than branches of the controls and formed mainly axillary panicles. The delay of growth was greater with increasing GA_3 concentration. The primary effect of GA_3 was to delay bud initiation, thus preventing formation of both vegetative and panicle buds. Flowering of mango may be indirectly prevented by GA_3 application since GA_3 can postpone growth beyond the flowering period.**

Mango (*Mangifera indica* L.) panicles are formed during the winter on apical buds of the current year's wood in South Florida. Cool weather, with temperatures below 15° C, promotes floral differentiation (Wolstenholme and Hofmeyr, 1985; Shu and Sheen, 1987; Whiley et al., 1989; Nunez-Elisea and Davenport, 1991). Apical panicles inhibit growth of axillary buds, which remain non-differentiated (Reece et al., 1946, 1949). They are activated, however, if the panicle is removed or lost due to natural causes. If this occurs during the flowering season, the activated axillary

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