

Root and Stem Growth Patterns of Young ‘Mauritius’ Lychee Trees

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Additional index words. *Litchi chinensis*, root observation chambers

Abstract. ‘Mauritius’ lychee (*Litchi chinensis* Sonn.) trees were planted in root observation chambers in July 1990 to determine the pattern of root and stem extension growth during 12 months. Root and stem lengths were measured at intervals ranging from 7 to 18 days from Aug. 1990 until Aug. 1991. During each period of active canopy growth, up to six stem tips were tagged and measured. Root growth was determined by measuring tracings of the extension of each root in a visible plane of the glass wall of the observation chambers. Stem growth was cyclic, with distinct periods of rapid extension followed by periods with no extension. In contrast, root growth was fairly continuous with only three periods of no visible root extension. Mean absolute extension rates were higher for stems than for roots. There were no consistent relationships between the timing of root and stem extension growth.

Lychee is well adapted to the semi-tropics where long, warm, rainy summers are dependably interrupted with cool, dry, frost-free winters (Knight, 1980; Menzel, 1983). However, the species has been spread to most of the subtropical and tropical areas of the world. Erratic fruit production is a serious problem with lychee cultivation, especially in warmer climates (Cull and Hams, 1974). Rarely is lychee mentioned in the literature without considerable attention devoted to this problem and speculation on cultural methods for meeting the exacting requirements for enhancing fruit production. Minimizing vegetative growth before bloom to enhance flower production has been the target of most recommendations (e.g., Menzel, 1990). However, Menzel (1984) indicated that poor fruit set and development may lead to substandard yield despite ample flowering.

Knowledge of vegetative and reproductive phenology is a prerequisite for defining proper timing of cultural inputs to optimize tree health and productivity. The annual pattern of lychee canopy growth has been described (Menzel et al., 1988) and so has the growth pattern of lychee reproductive organs (e.g., Chaitrakulsub et al., 1988; Huang and Xu, 1983). However, to our knowledge, there have been no reports on lychee phenology that include root growth patterns.

Lychee canopy growth occurs in recurrent flushes of the stems (Menzel et al., 1988).

Extent of coordination between root growth and canopy growth cycles for other fruit species exhibiting similar recurrent stem flushes has varied. A distinct flushing pattern of root growth that alternated with stem growth was reported for avocado (*Persea americana* Miller) (Ploetz et al., 1991; Whaley et al., 1988) and *Citrus sinensis* (L.) Osb. grafted on *C. jambhiri* Lush. or *Poncirus trifoliata* (L.) Raf. x *C. sinensis* rootstocks (Bevington and Castle, 1985). A continuous root growth cycle that appeared independent of the timing of stem growth cycles was reported for mango (*Mangifera indica* L.) (Parisot, 1988; Willis and Marler, 1993) and *C. aurantium* L. (Wutscher, 1973).

Our objective was to determine the root and stem growth patterns of young ‘Mauritius’ lychee trees in southern Florida. These data may aid in refining a lychee management system for directing whole-tree phenology to increase productivity.

Materials and Methods

Six root observation chambers were constructed and located at the Montgomery Foundation, Miami. Dimensions of the plywood chambers were 61 × 51 × 24 cm, and each contained 0.07 m³ of silica sand. The chambers were placed ≈25 cm above the ground on concrete blocks. The north side of each chamber was designed for root observation, with 5.5-mm-thick glass mounted with an angle inward from top to bottom. A plywood door covered each observation window. Weatherstripping sandwiched between each door and chamber excluded light while doors were closed. All exterior surfaces were painted white.

Air layers (Hartmann et al., 1990) were placed on stems (1.4 cm in diameter) of a field-

grown ‘Mauritius’ lychee tree in Feb. 1990 and were removed from the tree on 13 May 1990. The plants were grown in a full-sun nursery setting in 5.1-liter containers in a soilless medium consisting of peat, perlite, sand, and shredded bark chips in equal parts by volume. The plants were removed from the containers, bare-rooted, and planted in the silica sand in the observation chambers on 7 July 1990. Thereafter, they received daily irrigation or rainfall. In addition, 1 liter of complete nutrient solution was applied to each plant twice weekly. The solution consisted of 0.68 g HydroSol (W.R. Grace, Fogelsville, Pa.) and 0.45 g calcium nitrate/liter.

Root and stem growth were measured at intervals ranging from 7 to 18 days from Aug. 1990 until Aug. 1991. The length of up to six stems were measured on each canopy during periods of stem extension. Whenever fewer than six stems on a replication exhibited primary growth, the measurements were made on those stems that were growing. As a result, only two stems were measured on at least one replication for eight measurement periods, especially during the first few months of the study. The number of stem measurements normally was between four and six. Stem extension during each measurement period was calculated by subtracting stem length from the previous measurement period. In addition, growth of all visible white-tip roots was determined by opening the door of the observation chamber and tracing the extension on an acetate sheet overlay. The area of acetate sheets was 1600 cm² from Aug. 1990 until Mar. 1991, and 2086 cm² from Mar. until Aug. 1991. A different color of permanent marker was used for each measurement date to measure the extension since the last measurement period. Length of root extension was measured with a ruler on the acetate sheet. The rate of daily growth was calculated by dividing the extension of root or stem by the number of days between measurements.

Air temperature and relative humidity were recorded continuously by a hygrothermograph (WEATHERtronic model 5020; Qualimetrics, Sacramento, Calif.). Sand temperature at 30 cm deep was measured at 0600, 1200, 1800, and 2400 HR during several days each month using thermometers. We increased the frequency of these measurements to three times per week from Nov. 1990 through Mar. 1991, which were the months in which mean daily air temperature dropped to <25C. The substrate in the root observation chambers did not deviate in temperature from that of field soil adjacent to the site based on measurements using the same methods.

Canopy height and width were measured following the last root and stem measurements on 11 Aug. 1991. The plants were bare-rooted, separated into roots and canopy, and dried to constant mass at 60C.

Mean root and stem extension were calculated for each measurement period. Mean plant size was determined from ending plant measurements. Weather data were compiled, and mean highs and lows were calculated for each month. All data are presented as mean ± se.

Received for publication 6 Nov. 1995. Accepted for publication 23 Mar. 1996. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

Results and Discussion

Throughout the experimental period, mean monthly temperature and relative humidity extremes were typical for southern Florida (Fig. 1). The winter during which this study was conducted was relatively mild, with the absolute low for the entire experimental period, 4C, occurring on 17 Feb. 1991. This low was atypical, however, as seen by the 15C mean low temperature for the remainder of that week. Moreover, the midday temperature on the two days before and after this atypical low was quite high (mean of 25C).

Mean substrate temperature at 30 cm deep was similar to mean air temperature. The amplitude of daily changes about that mean was <15% of the amplitude of the daily changes in air temperature. The sand temperature was

23.4 ± 0.8C for the five months, with the daily air mean <25C.

During the experiment, lychee trees grew 30 cm in height and 100 cm in canopy diameter (Table 1). Total dry root mass exceeded that of the canopy, even though roots were confined by the 0.07-m³ chambers.

Growth patterns of the lychee trees taken as a group exhibited little harmony. Root growth was apparent on the glass observation windows by 7 Aug. 1990. Root growth was fairly continuous through the duration of the study, with only three observation periods where all six replications lacked visible root extension on the observation windows (Fig. 2). Mean stem extension was more erratic. For each individual replication, stem extension was cyclic, with a pronounced alternating rhythm of periods of extension followed by

Table 1. Characteristics of 'Mauritius' lychee trees during growth from Aug. 1990 to Aug. 1991 in root observation chambers.

Characteristic	Value
Beginning canopy height (cm)	38 ± 2
Ending canopy height (cm)	76 ± 5
Beginning canopy diameter (cm)	48 ± 4
Ending canopy diameter (cm)	145 ± 10
Whole plant dry mass (g)	1531 ± 125
Root : canopy ratio	1.1 ± 0.1

Mean ± SE, n = 6.

periods with no extension. The pattern of cycling was dampened for the mean growth response of the tree population (Fig. 2) because the canopy flushing cycles of each replication were not in synchrony. There were only four measurement periods throughout the study where stem extension was absent on all six replications (Fig. 2). Alternatively, there were 23 measurement periods where at least one replication exhibited no stem extension. Canopy flushing perhaps would have become synchronized among the replications if temperatures during the winter had been cool enough to temporarily arrest growth on all.

Under the conditions from Aug. 1990 to Aug. 1991, four well-defined canopy flushes occurred on each of the replications (e.g., Fig. 3). At least 1 month with no canopy extension growth separated most of the flushes. The amplitude and duration of each flush differed among and within replications. In contrast, root extension was highly variable throughout the experimental period for each replication. There were no consistent relationships between the timing of root and stem extension patterns. Certainly, the timing of rapid stem extension did not coincide with reduced root extension. For example, none of the six measurement periods in which replication 3 lacked root extension occurred simultaneously with rapid stem extension (Fig. 3). No stem extension occurred on four of the six measurement periods during which visible root extension was lacking. Furthermore, the measurement period in which most growing root tips were visible on the observation window for each replication invariably occurred concurrently with one of the four distinct stem flushes.

Most lychee root tips that we observed never ceased growth throughout the period in which they remained visible on the plane of the observation window. When visible root tips did temporarily cease extension, extension was typically observed for other root tips on the same plant. This pattern is clearly seen by comparing the measurement periods in which no stem or root extension occurred for an individual tree. For example, no visible root extension was evident during six of the 27 measurement periods for the tree depicted in Fig. 3. In contrast, canopy extension growth was not evident during 16 of the 27 measurement periods. Furthermore, the inherent problem that only a fraction of the entire root system is visible when using observation windows (Atkinson, 1980) should be brought into context. Since all canopy stem tips were visible, we can be confident in a complete lack of stem extension during the 16 measurement

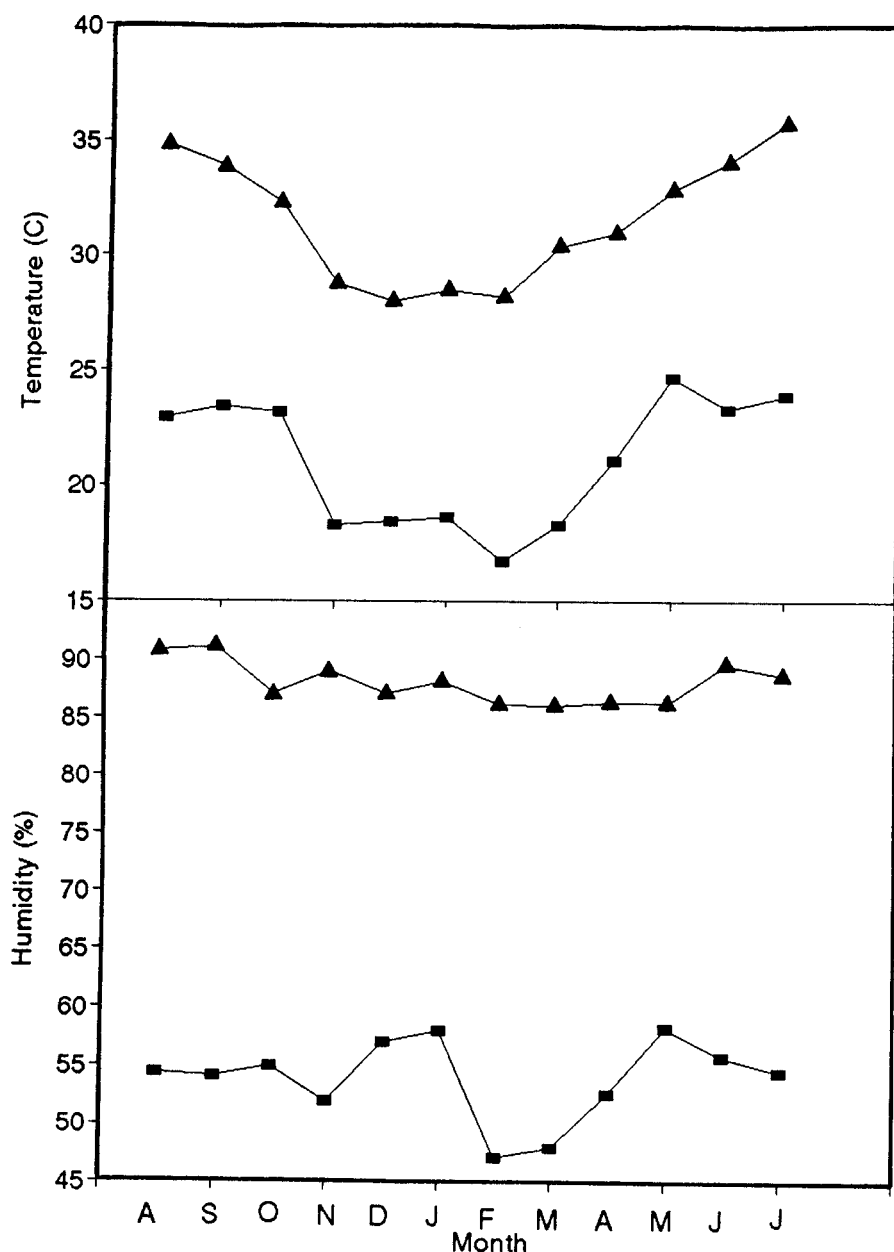


Fig. 1. Mean maximum (▲) and minimum (■) air temperature (top) and humidity (bottom) from Aug. 1990 through July 1991 at experimental site in Miami. SE bars were smaller than the symbols in every case.

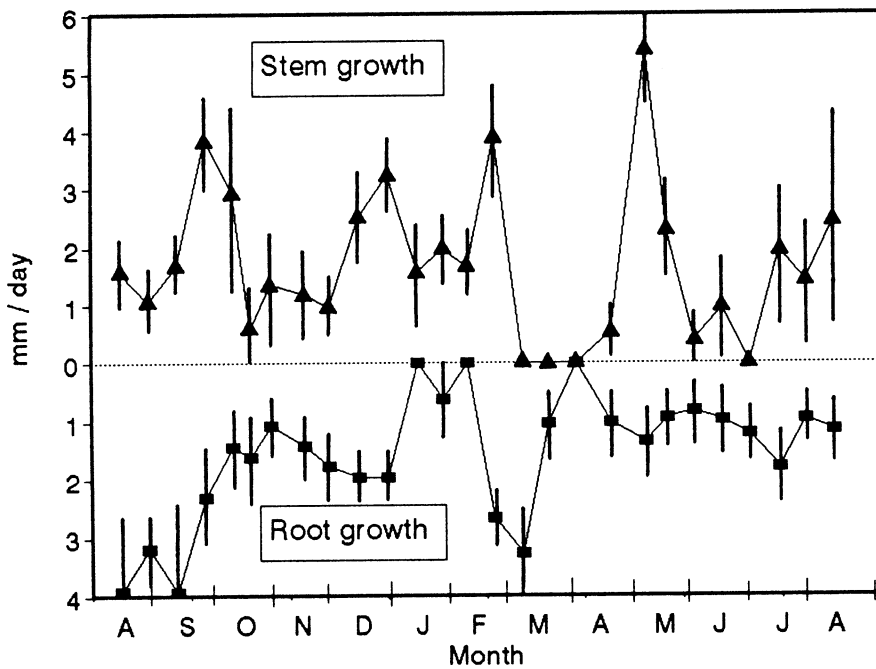


Fig. 2. Mean (▲) stem or (■) root extension rate of young 'Mauritius' lychee trees growing in root observation chambers from Aug. 1990 through Aug. 1991 in southern Florida. Data points are mean \pm SE, n = 6.

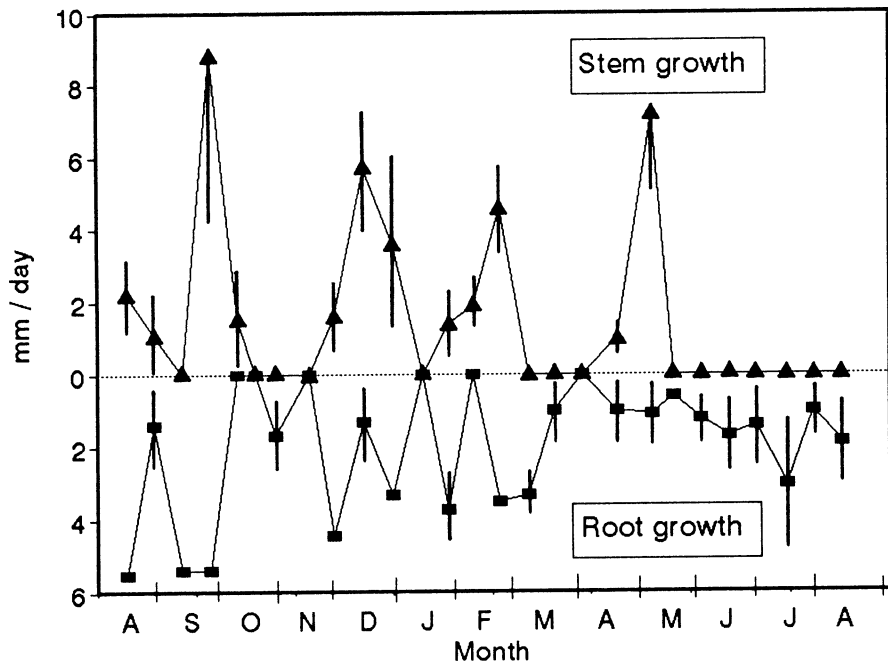


Fig. 3. (▲) Stem or (■) root extension rate of one young 'Mauritius' lychee tree (replication 3) growing in a root observation chamber from Aug. 1990 through Aug. 1991 in southern Florida. Data points are mean \pm SE. Where SE bars are not visible the datum point is one observation.

periods we claim lacked stem extension. Alternatively, during the six periods where we did not see root extension on the visible plane of the observation window, root extension may have been occurring on the tree in other areas of the rooting substrate that could not be observed.

The maximum root extension rate was 9.7 mm-day⁻¹, which occurred in July 1991. This rate approximates the maximum root growth rate reported for several other woody fruit species (Atkinson, 1980). The mean maxi-

um root extension rate for the six replications was 7.4 mm-day⁻¹. Stem extension rate exceeded that of roots. Mean maximum stem extension rate for the six replications was 13.1 mm-day⁻¹. The overall maximum stem extension rate was 19.3 mm-day⁻¹, which occurred in Oct. 1990.

We used simple linear correlation analysis to determine the relationship of root or stem extension at each measurement with the mean maximum or minimum temperature of air or soil for the preceding measurement period.

Without exception, these relationships were not significant, indicating that the temperature extremes throughout this study did not limit canopy or root growth; correlation coefficients ranged from 0.01 to 0.26.

Whiley et al. (1988) described a management model for increasing avocado (*Persea americana* Miller) productivity and indicated a similar model may be appropriate for lychee. Root growth competes with canopy vegetative and reproductive growth for carbohydrates, and their model focuses on management of growth cycles to balance this competition. The underlying principle of this phenology model is management of reserve carbohydrate. Carbohydrate reserves generally are at a maximum during late winter when trees are relatively inactive and root growth is limited by low soil temperature (Whiley et al., 1988).

Flowering has been strongly correlated with starch levels in lychee stems (Menzel et al., 1989; Nakata and Watanabe, 1966). In this light, the data from our study indicate that the consistent root growth occurring throughout a warm winter in the subtropics, and presumably throughout the year in the tropics, may provide a steadfast sink that fosters the discordant reproductive development of the lychee tree in warm climates.

Thus, we believe that managing root growth and development should be targeted as the focus for refining a management program for lychee production in warm climates. To balance the natural root, canopy, and reproductive development, fertilization or irrigation timing may not be adequate to amplify productivity of lychee trees in warm climates. Instead, cultural manipulations for the timely arrest of root growth may be required. Limiting root development by root restriction or pruning may have merit as a means of controlling vegetative vigor and enhancing fruit production (Richards, 1986) and has been implicated as being effective with lychee (Menzel, 1983).

In summary, an understanding of root growth and its relationship to canopy growth is important for effective lychee crop management. The proper timing of cultural inputs to maximize productivity depends on a thorough understanding of above- and belowground growth and development. The relationship among fruit, stem, and root growth of mature, field-grown lychee trees remains to be determined. The young, nonbearing lychee trees in this study exhibited cyclic canopy growth, with periodic flushes alternating with periods where no visible stem extension occurred. In contrast, lychee roots exhibited no consistent pattern of extension during this study in which relatively mild temperatures characterized the winter season.

Literature Cited

- Atkinson, D. 1980. The distribution and effectiveness of the root of tree crops. Hort. Rev. 2:424-490.
- Bevington, K.B. and W.S. Castle. 1985. Annual root growth pattern of young citrus trees in relation to shoot growth, soil temperature, and soil water content. J. Amer. Soc. Hort. Sci. 110:840-845.

- Chaitrakulsub, T., P. Chaidate, and H. Gemma. 1988. Study of fruit development of *Litchi chinensis* Sonn. var. Hong-Huay. Jpn. J. Trop. Agr. 32:201–207.
- Cull, B.W. and F.D. Hams. 1974. Litchi finds a new home in Queensland. Queensland Agr. J. 100:597–603.
- Hartmann, H.T., D.E. Kester, and F.T. Davies. 1990. Plant propagation principles and practices. 5th ed. Prentice-Hall, Englewood Cliffs, N.J.
- Huang, H. and J. Xu. 1983. The development patterns of fruit tissues and their correlative relationships in *Litchi chinensis* Sonn. Scientia Hort. 19:335–342.
- Knight, R.J. 1980. Origin and world importance of tropical and subtropical fruit crops, p. 1–120. In: S. Nagy and P.E. Shaw (eds.). Tropical and subtropical fruits: Composition, properties, and uses. AVI, Westport, Conn.
- Menzel, C.M. 1983. The control of floral initiation in lychee: A review. Scientia Hort. 21:201–215.
- Menzel, C.M. 1984. The pattern and control of reproductive development in lychee: A review. Scientia Hort. 22:333–345.
- Menzel, C.M. 1990. Nitrogen—The key to successful lychee production. Calif. Grower 14(7):28, 30.
- Menzel, C.M., T.S. Rasmussen, and D.R. Simpson. 1989. Effects of temperature and leaf water stress on growth and flowering of litchi (*Litchi chinensis* Sonn.). J. Hort. Sci. 64:739–752.
- Menzel, C.M., B.J. Watson, and D.R. Simpson. 1988. The lychee in Australia. Queensland Agr. J. 114(1):19–27.
- Nakata, S. and Y. Watanabe. 1966. Effect of photoperiod and night temperature on the flowering of *Litchi chinensis*. Bot. Gaz. 127:146–152.
- Parisot, E. 1988. Study of the growth rhythm in young mango plants (*Mangifera indica* L.). III. Growth and development of young mango plants. Fruits 43(3):235–247.
- Ploetz, R.C., J.L. Ramos, J.L. Parrado, and E.S. Shepard. 1991. Shoot and root growth cycles of avocado in South Florida. Proc. Fla. State Hort. Soc. 104:21–24.
- Richards, D. 1986. Tree growth and productivity—The role of roots. Acta Hort. 175:27–36.
- Whiley, A.W., J.B. Saranah, B.W. Cull, and K.G. Pegg. 1988. Manage avocado tree growth cycles for productivity gains. Queensland Agr. J. 114(1):29–36.
- Willis, L.E. and T.E. Marler. 1993. Root and shoot growth patterns of 'Julie' and 'Keitt' mango trees. Acta Hort. 341:264–270.
- Wutscher, H. 1973. Interrelationship of root and shoot growth and seasonal growth pattern of citrus seedlings. J. Rio Grande Valley Hort. Soc. 27:34–39.