MODELED SEASONAL PATTERN OF NITROGEN REQUIREMENTS OF MATURE, CROPPING PEACH TREES (*PRUNUS PERSICA* (L.) BATSCH)

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Abstract

Seasonal nitrogen (N) accumulation patterns of fruits, leaves, stems, branches, trunk and roots of mature, cropping peach (*Prunus persica* (L.) Batsch cv. O'Henry) trees were estimated by combining models of organ dry mass accumulation and seasonal organ N concentrations. Data for the models were collected from trees subjected to two different N treatments. The study estimates and compares the N demand of perennial and annual organs during the growing season for both treatments.

Although N demand was higher for N-fertilized trees, seasonal N accumulation patterns were similar for both treatments. Annual organs exhibited greater responses to N fertilization than perennial organs. The average daily N demand per tree remained nearly constant from 40 days after anthesis to harvest. Fertilized trees accumulated about 1 g N·tree^{-1}·day^{-1}, twice that of non-fertilized trees. For the orchard studied, a daily demand of approximately 1 kg N·ha^{-1} was estimated for fertilized trees while approximately 0.5 kg N·ha^{-1} was required for unfertilized trees. During the first 25-30 days, all N demand could be supplied by storage organs. The release of N from storage organs for current growth was apparently completed in about 75 days in both treatments.

1. Introduction

Nutrients are required for growth of various organs, and often must be available at specific times. Nitrogen is one of the most important macronutrients in crop fertilization and one that most often limits yield of peaches. The role of N reserves and current N applications in peach trees have been studied (Stassen *et al.*, 1982; Weinbaum *et al*, 1978, 1980, 1984a, b; Titus and Kang, 1982) but quantitative data are needed to determine the daily seasonal organ and total tree N demand in order to estimate the N supply required to balance that N demand. The goal of this research was to compare the simulated seasonal organ nitrogen demands and the total tree nitrogen utilization under low and high nitrogen conditions.

2. Material and methods

The PEACH computer simulation model, a model of the annual carbon supply and demand in peach trees (Grossman and DeJong, 1994) was used to predict changes in fruit and vegetative growth under different conditions of N supply. It is a state-variable model in which fruit, leaf, current-year stem, branch, trunk, and root mass are state variables, and

Proc. 5th Int. Symp. on Comp. Mod.
Eds. Wagenmakers, Van der Werf and Blaise
Acta Hort. 499, ISHS 1999 - IOBC/WPRS Bulletin

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minimum and maximum air and soil temperatures, degree-days, solar radiation and canopy light interception are the driving variables. Photosynthetic carbon assimilation and stored carbohydrates provide the supply of carbon that is demanded for maintenance respiration and growth. For N partitioning the same priorization as for dry mass in the PEACH model was followed.

Since the PEACH model assumes adequate N supply, high N (HN) simulations were run using default model data for photosynthesis and light interception. For low N (LN) treatment, the leaf photosynthesis rate was reduced to 86% and 63% for full sun and shade leaves, respectively, and light interception was reduced by 83% (Esparza, unpublished data on leaf photosynthesis and canopy light interception in a peach orchard receiving similar N fertilization).

The model was adjusted to give realistic vegetative growth output values, based on 1996 experimental data and previously recorded measurements from the same orchard. 'O'Henry' fruit dry mass values from 1996 were used to obtain the dry mass growth calibration curve for HN and LN treatments. The N treatments consisted of zero and 200 kg of N·ha^{-1}, applied in April. The 1994 fruit dry mass values (Saenz, 1996) were used to validate the modeled curves. Previously-determined values for stem and leaf growth were used to estimate RGR in the model, and new coefficients for branch and trunk curves in the HN treatment and for leaves and stems in the LN treatment were used to adjust the model for decreases in vegetative growth caused by low N (Saenz, 1996; Berman, 1996; Niederholzer, unpublished data). These coefficients were obtained using data from trunk, scaffold and branch measurements and data from total current year growth (data not shown). Data from excavated trees during the dormant period in 1994 were used to develop input data for branch, wood, and root initial dry mass used in the model, and the data from the excavated trees (Niederholzer, unpublished data) were used to validate modeled values.

N concentration data for fruits, leaves and stems obtained in 1996 were used to develop seasonal N concentration algorithms for trees from HN and LN treatments. Furthermore, leaf and fruit N concentrations data from Saenz (1996) were used to validate the algorithms. Again data from trees excavated during the dormant period in 1994 were used to develop input data for branch, wood, and root initial N concentration (Niederholzer, unpublished data) and the seasonal patterns used for branch, wood and root N concentration were proportional on that reported by Stassen *et al.* (1983).

An inverse logistic function, $(y = (1+Be^{-kx})/M)$ vs calendar days was fitted for all organ N concentration data using the non linear regression (PROC NLIN) procedure in SAS (SAS Institute, 1988).

Total N for each organ was estimated as the product of total organ dry mass, modeled for each day, and the simultaneous estimate of N concentration. N accumulation rate (NitAR) was determined using the equations described by Ryugo (1988) for dry mass:
$$NitAR = (N_2 - N_1) \cdot (t_2 - t_1)^{-1}$$
where N_2 and N_1 are the total N organ content at time t_2 and t_1 respectively. N in current year growth organs resulted from adding NitAR in fruit, leaf and stem. N in storage organs was the result of combining branch, trunk and root NitAR.

Weather data for 1994 and degree-days used in the PEACH Model were obtained from the California Irrigation Management Information System (CIMIS) weather station located at the Wolfskill Experimental Orchard (WEO) in Winters. For 1996 data, CIMIS weather stations located at Davis and Winters were used.

3. Results and discussion

The result of combining the dry mass output data of the PEACH model for fruits, leaves, stems, branches, wood, and roots and the N concentrations from the fitted functions allowed an estimation of the seasonal N accumulation in each part of the tree. Although it was impossible to validate many aspects of the model, the model predictions for total organ dry mass and N content were within 3% and 8% of the values (for HN and LN respectively) from the whole-tree excavations. Although both treatments had similar patterns for the respective organs and few differences were obtained in the relative proportion of N in each organ, HN organ values were higher during the whole fruit growth period.

Because of high leaf N concentrations, leaves accounted for the highest accumulated N content among the current year growth organs during the season (Figs. 1 and 2). Only fruits in the LN treatment had a higher value than leaves at harvest due to the relatively higher yield per total biomass compared with HN trees.

Because of their storage function, the perennial organs started the season with a given amount of N. By the time of bloom there was already some depletion of storage N. During the growing season until harvest, these N contents decreased gradually in the trunk and the roots. Although a decrease after bloom was estimated for branches, it was very small, and just previous to harvest there was a slight increase.

For the period of this study, leaves and fruit were more N demanding than perennial tissues. Although lower values were obtained for LN trees during the season, a similar pattern was obtained with a slower increase due to a strong N competition from fruits.

The modeled NitAR of fruit increased sharply early in the season, particularly for LN trees (data not shown). The increase corresponded with the exponential DW increase in stage I of fruit growth. A period of decreasing fruit NitAR followed corresponding with stage II of fruit development (pit hardening). The rapid resumption of growth (cell enlargement) in stage III is parallel to an increase in N demand to satisfy fruit growth. There was an almost constant linear increase of NitAR values during the second half of the season with similar values for both N treatments.

The perennial tree tissues had very different NitAR patterns compared with current-year organs in both N treatments. Branch NitAR values remained close to 0 because of their low DW increase and small change in N content during the season. On the other hand, modeled root NitAR decreased for most of the season and the trunk released N for three and a half months after anthesis. After this time, the modeled values indicated a switch to positive or nul values. This pattern was apparently due to the net N release from storage organs to current-year organs. The N supplied by these organs decreased with time, apparently as increasing uptake from the soil occurred.

Model calculations for current year organ demand versus storage organ supply until calendar day 90-95 indicate that all N was coming from perennial organ release (Figs. 3 and 4, areas above and below the x-axis). This period corresponds to the period required for the first leaves to become photosynthetically active and N uptake was apparently minimal as a consequence of low N demand (Weinbaum, 1994). From that time on, N demand increased as a result of the vegetative growth, and the sum of fruit and stem N demand was fairly constant for the rest of the growing season. On the other hand, the model indicated that N release from storage organs was completed by calendar day 145-150 in both treatments and restorage presumably began after harvest, as soon as fruits, the main N sinks, were removed and leaves started N remobilisation back to the tree. The

amount of N stored as reserves in postharvest would be expected to be similar to the N required for starting the next season.

Combining dry mass and N concentration data for each organ indicates that the total N content for each part of the tree was increased by N fertilization. Higher N contents for current year vegetative growth were obtained for HN trees while perennial organs had similar values for both N treatments. N content for each organ at harvest was higher for fertilized trees than for unfertilized trees. The final value for the whole tree N content was almost twice the amount of N for fertilized compared to unfertilized trees. Although higher values for N demand were obtained for N-fertilized trees, particularly for leaves and fruits, the seasonal pattern of the daily N increase for each organ was similar for both treatments, with higher values for HN tree organs. Annual organs from fertilized trees had greater response to N than perennial organs. The perennial tree tissues have very different patterns compared with current-year growth organs. Total tree N increment is an integrated value that takes into account the increases and decreases in N ratio and provides an estimate of the seasonal tree uptake. The average daily N increment from 40 days after anthesis to harvest was almost constant. For fertilized trees this value was about 1 g $N \cdot tree^{-1} \cdot day^{-1}$, twice that of non-fertilized trees. For the orchard studied, a daily increment of approximately 1 kg $N \cdot ha^{-1}$ was estimated for fertilized trees while approximately 0.5 kg $N \cdot ha^{-1}$ was required for unfertilized trees. During the first 25-30 days, virtually the whole N increment could be supplied by storage organs. The release of N from storage organs for current growth was apparently completed in about 75 days for both treatments.

Acknowledgements

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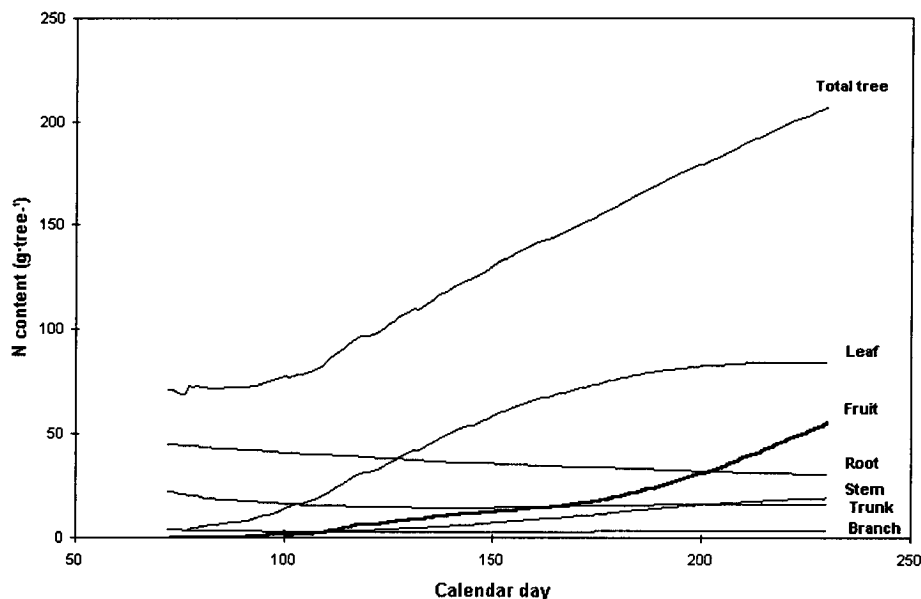
Figure 1 - Estimated seasonal patterns of total N distribution for the different parts of the tree in the high nitrogen treatment. Each curve value is the product of total organ dry mass modeled for each day, and the simultaneous estimate of N concentration for the respective organ.
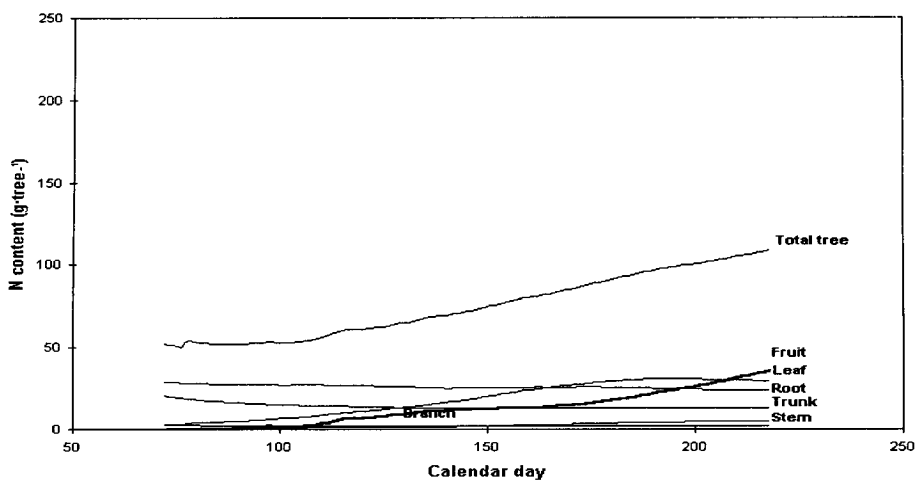
Figure 2 - Estimated seasonal patterns of total N distribution for the different parts of the tree in the low nitrogen treatment. Each curve value is the product of total organ dry mass modeled for each day, and the simultaneous estimate of N concentration for the respective organ.
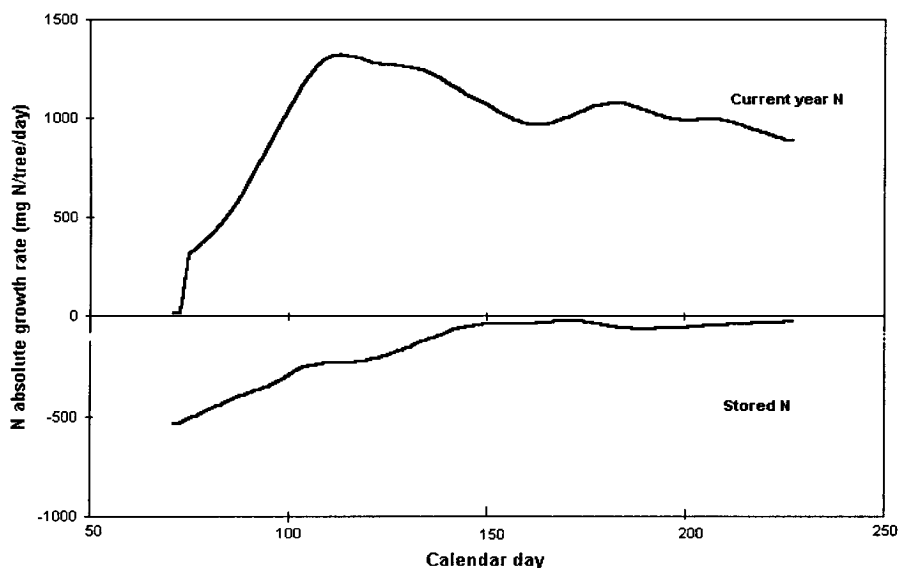

Figure 3 - Estimated seasonal patterns of nitrogen accumulation rate in current year organs vs storage organs for HN treatment.
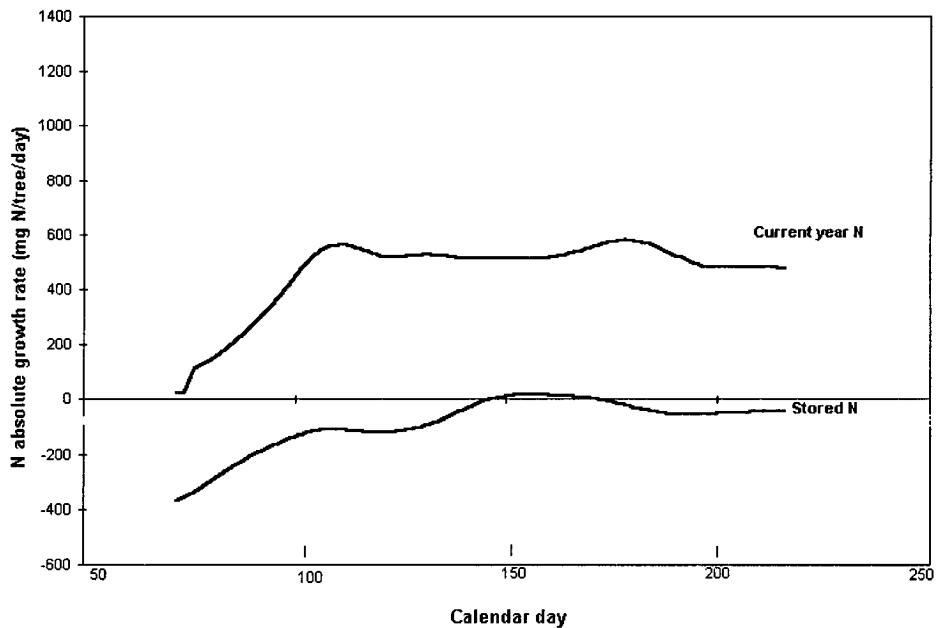
Figure 4 - Estimated seasonal patterns of nitrogen accumulation rate in current year organs vs storage organs for LN treatment. N in current year growth organs results from adding NitAR in fruit, leaf and stem. N in storage organs is the result of combining branch, trunk and root NitAR.