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Comparison of Resource Budget Models for Nonlinear Dynamics in Alternate Bearing of Tree Crops

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Abstract– This paper presents a comparative study of three recent models, i. e. the original Isagi's model [1] and two recent models by Ye and Sakai [2,3], for modeling the alternate bearing of tree crops. The theories, definitions and performance of these models are discussed. All of these models are based on theoretical assumptions of resource allocation and budgeting in plant body. Simulations indicate that the new models may be more suitable for modeling the alternate bearing phenomenon in evergreen tree crops such as citrus plants.

1. Introduction

Alternate bearing or masting is commonly found in tree crops. Scientists have proposed several hypotheses for explaining the phenomenon from the perspective of internal resource allocation and budgeting in plant. Isagi et al. (1997) first proposed the resource budget model and tested it with experimental data for F. crenata [1]. Recently, Ye and Sakai have developed two new models based on Isagi's model by incorporating vegetative growth component and introducing new equations for describing the relationship between vegetative and reproductive growths [2,3]. This paper attempts to explain the theories and definitions of these models for a better understanding of the models for this phenomenon.

2. Model theories and definitions

The Isagi's model [1] describes a deterministic process of energy storage due to photosynthesis, and energy depletion due to flower and fruit production in the plant. It hypothesizes that each crop accumulates photosynthate every year, producing flowers when energy reserves exceed a threshold level, and sets fruits at a rate limited by the ratio between costs for flowering and fruiting in individual plants.

Ye and Sakai (2016) assume that the growth of new leaves (C_l) in early season constitutes a major part of energy consumption, which is determined by a ratio (r) of the potential resource accumulation capacity that depends on the reproductive threshold (L_T), the energy reserve (I) and the new resources accumulated by photosynthesis (P_s) in the year:

$$C_l(t) = r(L_T + P_s - I(t)) \qquad (1)$$

Further, to add nonlinearity to the model, a Ricker-type equation is used to describe the relationship between flowering (C_f) and fruiting (C_a) events in the model:

$$C_a(t) = R_k C_f(t) e^{a\left(1-\frac{C_f(t)}{K}\right)} \qquad (2)$$

where a represents the fruiting coefficient; K represents the optimal cost of flowering.

In another new model [3], the inter-dependent phenological relationships between vegetative and reproductive growths are highlighted. The plant growth dynamics is described by two equations:

$$C_a(t) = \frac{cP_s}{1 + e^{(bC_l(t)-a)}} \qquad (3)$$

$$C_l(t+1) = \frac{C_l(t)^2}{C_l(t) + d} + kC_a(t) \qquad (4)$$

where a, b, c, d, k are constants, and $0<k<1$. Natural defoliation is determined by d, and new leaf growth is k times preceding cost for fruiting. k represents the degree of enhancing effect of fruiting ($C_a(t)$) on subsequent new leave growth ($C_l(t+1)$).

3. Conclusion

This paper presents a comparative study of three recent models developed for alternate bearing of tree crops. All of these models are based on theoretical assumptions of resource allocation and budgeting in plant body and can model the alternate bearing or masting in tree crops. Simulations indicate that the new models may be more suitable for evergreen tree crops such as citrus plants.

References

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