The 11th Asian-Australasian Conference on Precision Agriculture (ACPA 11)
October 14-16, 2025, Chiayi, Taiwan

HOW DO DIFFERENT DATA INTERVALS IN EXPONENTIAL SINE MODEL AFFECT PREDICTION OF STRAWBERRY FLOWERING DYNAMICS?

Shintaro Ono[1, *], Daisuke Yasutake[2, 3], Tadashige Iwao[3], Kota Hidaka[1], Gaku Yokoyama[2], Tomoyoshi Hirota[2]

[1] NARO, Tsukuba, Japan. [2] Kyushu University, Fukuoka, Japan. [3] Kochi University, Kochi, Japan.

*Corresponding Author: ono.shintaro609@naro.go.jp

ABSTRACT

In strawberry cultivation, where harvests occur periodically, predicting flowering dynamics is crucial for optimizing yield. This study aimed to organize fundamental information on the exponential sine model, which could play a central role in developing prediction processes for strawberry flowering dynamics. To achieve this, the model was applied to flowering data, and the impacts of different data intervals on predictive performance (trends and accuracy) were evaluate. Over three cultivating seasons, we collected visually the daily data on changes in the number of flowers, fruits, and cumulative harvests and extracted each data at different interval (*Int*) ranging from 1 to 7 days. Furthermore, we calculated the changes in number of flowerings (*FL*) over different *Int.* The exponential sine model was then fitted to each *FL* dataset, and parameters representing the flowering dynamics patterns were obtained for each *Int* to compare predictive trends. Additionally, the predictive accuracy of the exponential sine model for each *Int* was evaluated using the root mean square error (RMSE). The model parameters for *Int* = 1 (original *FL*) and *Int* = 2–7 were generally consistent, confirming that the impact of different *Int* values on predictive trends was minimal. As *Int* increased, the RMSE decreased and remained relatively constant for *Int* ≥ 4. Balancing accuracy and practicality, an *Int* of 4 was suggested as reasonable for *FL* prediction using exponential sine model. This study provides key information on applying the exponential sine model to strawberry *FL* dynamics and suggests a clear direction for developing *FL* prediction software.

Keywords: *Fragaria × ananassa*, number of flowers, flowering rate, yield prediction, yield forecasting

INTRODUCTION

In strawberry cultivation, optimizing flowering (*FL*) dynamics is beneficial for stable production. A promising approach is using mathematical models to predict *FL* dynamics. *FL* patterns are often represented as waves, *e.g.*, Gaussian mixture models. However, these models have the drawback that overall wave characteristics are difficult to grasp solely from model parameters. To address this, the exponential sine model (Malo, 2002; hereafter Malo model) has gained attention, as all parameters correspond to specific wave features. It has been applied to tree *FL* dynamics, often observed with relatively coarse data intervals (*Int*). In contrast, horticultural analyses use various *Int*, possibly influencing predictive performance (trends and accuracy).
In this study, we evaluate the impact of different *Int* on the predictive performance of the Malo model in modeling strawberry *FL* dynamics.

MATERIALS AND METHODS

Strawberry plants (*Fragaria* × *ananassa* Duch. cv. Fukuoka S6) grown in the greenhouse were used over three cropping seasons (number of plants: 212 in 2019, 89 in 2020, and 57 in 2021). The number of flowers (*NFL*), fruits (*NFR*), and cumulative harvests (*NH*) were visually counted every morning throughout each season. From these, daily datasets were extracted at different *Int* (from 1 to 7 days), and new datasets were reconstructed for each *Int*. *FL* was calculated as follows: $FL_{n*Intx} = NFL_{n*Intx} - NFL_{(n-1)*Intx} + FR_{n*Intx}$ (1), $FR_{n*Intx} = NFR_{n*Intx} - NFR_{(n-1)*Intx} + H_{n*Intx}$ (2), $H_{n*Intx} = NH_{n*Intx} - NH_{(n-1)*Intx}$ (3), where n is a time step, x (1–7) is the interval length in days, and *FR* and *H* represent the number of newly fruit settings and harvestings, respectively, between consecutive intervals. The Malo model was fitted to the *FL* dynamics for each dataset: $FL = a\{\sin[\pi((t - b)/c)d]\}e$ (4), where a, b, c, d, and e represent the maximum (d^{-1}/plant), start date (days), duration (days), waveform symmetry (-), and kurtosis (-), respectively. Finally, the waveform similarity between each *Int* and the original *FL* (Int_1), as well as the predictive accuracy (root mean square error, RMSE) of the Malo model, were calculated and compared.

RESULTS & DISCUSSION

NFL, *NFR*, and *NH* showed consistent trends across all cultivation years and *Int*, and *FL* also showed similar trends, becoming smoother with increasing *Int* (data not shown). The Malo model accurately described *FL* dynamics across years regardless of *Int*, with consistent parameters (except *b* and *c*, based on measured data; Fig. 1A). Thus, *Int* does not affect the predictive trends of Malo model. RMSE decreased from Int_1 to Int_4 and plateaued thereafter (Fig. 1B), suggesting Int_4 is optimal for balancing accuracy and practicality. Developing prediction processes based on environmental factors for Malo model parameters may lead to *FL* prediction. While further study is needed, this work marks a key step toward predicting and optimizing strawberry *FL* dynamics using the Malo model.

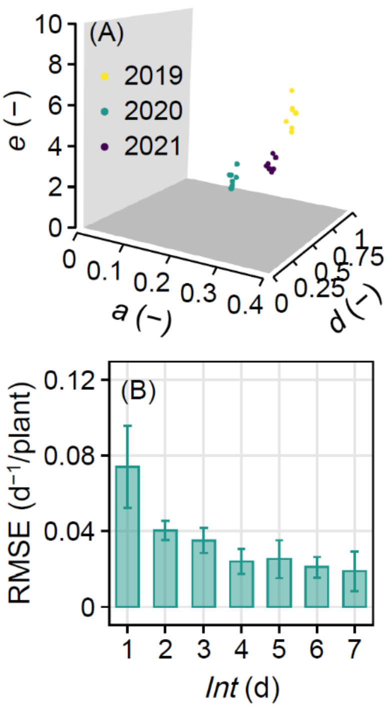

Fig. 1 Distributions of parameters *a*, *d*, and *e* for different data intervals (*Int*) in each season (A); root mean square error (RMSE) for each *Int* (B).

ACKNOWLEDGEMENTS

This research was financially supported by Grant-in-Aid for Scientific Research (JSPS KAKENHI grant number 22KJ2433) from the Japan Society for the Promotion of Science; Cabinet Office grant in aid "Evolution to Society 5.0 Agriculture Driven by IoP (Internet of Plants)," Japan; and development and improvement program of strategic smart agricultural technology grants (JPJ011397) from the Project of the Bio-oriented Technology Research Advancement Institution (BRAIN).

REFERENCES

Malo, J. E. 2002. Modeling unimodal flowering phenology with exponential sine equations. Funct. Ecol. 16: 413-418. https://doi.org/10.1046/j.1365-2435.2002.00629.x.