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MODELLING PROPORTIONATE BUD BREAK IN KIWIFRUIT

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Abstract

The amount of budbreak in kiwifruit, is a major yield component. Its prediction could be useful to help growers during winter pruning. The influence of the amount of winter chilling on bud burst as well as the effect of spring temperatures on the final proportionate budbreak is known. In this paper a model for bud burst simulation is proposed according to spring temperatures. Hydrogen cyanamide treatments were used to increase variability in bud burst pattern. The model parameters and threshold value for temperature were then estimated by fitting the model to data. The model appears to be very suitable to describe between-treatment variability.

1. Introduction

The kiwifruit (*Actinidia deliciosa* cv Hayward) is a deciduous vine which bears fruits on the current season's shoots from buds developed in leaf axils from canes from the previous season (Brundell, 1975). As all winter buds along dormant canes are potentially reproductive (Grant et al., 1982), except for flatish buds borne at the base of the cane, the amount of budbreak is a major yield component.

Winter chilling is known to be important to terminate rest and enhance the amount of budbreak on Chinese gooseberry vines (Brundell, 1976 ; Lionakis et al., 1984a ; Lawes, 1984). However, Brundell (1976) also suggested that other factors in addition to low temperature might facilitate bud burst, as buds artificially chilled to 4°C do not resume growth as quickly as other naturally chilled buds. Among these factors, spring temperatures during budburst seem to be the most influential through concentration of the budbreak pattern. Lawes (1984) showed that the more concentrated the budbreak pattern, the higher the proportion of over-wintering buds that break. The same results were obtained by McPherson et al. (1990).

On a practical side, the prediction of proportionate budbreak could be very useful to help growers during winter pruning to produce the desired number of harvestable fruits. Doyle (1989) proposed a model predicting bud break according to the amount of cold temperatures during winter. But the influence of the prevailing temperature during budbreak was not taken into account. Of course, knowledge of spring temperature could not influence winter pruning or decisions regarding hydrogen cyanamid applications; however, it seems of interest to propose a model for budbreak simulation according to spring temperatures to better understand the physiology of bud burst. In addition it will at least practically help provide a guide to flower and fruitlet thinning.

2. Material and methods

The field experiment was performed in 1991 in a commercial orchard of *Actinidia deliciosa* cv Hayward in eastern Corsica (46 Gr 98 N, 7 Gr 98 E). 10-year-old vines issued from cuttings and T-bar trained were used. Over the experimental period the vines were managed using the normal winter pruning programme, i.e. 20 to 25 canes with approximately 20 buds each.

The aim of the experiment was to increase variability in budburst pattern by using a commercially available aqueous formulation of hydrogen cyanamide containing 490 g a.i. l⁻¹.

Whole vines were treated with 2 concentrations at 3 application dates and compared to an untreated control. They were sprayed with concentrations of 4 or 6 percent hydrogen cyanamide 55, 45 or 37 days before theoretical bud burst : on 18 January, 28 January or 5 February. Treatment combinations and the untreated control were randomly allotted to three adjacent vine sub-plots within each of the four replicated blocks. Only the middle vine of each sub-plot was kept for observations.

Measurements and recordings were made on two canes from opposite sides of each treated vine. The canes selected were of average diameter and had not borne fruit in the previous year.

Nodes were numbered from the cane base to the tip and the date of bud burst was recorded individually. A bud was recorded as broken when it had swollen sufficiently to cause the bud cover to split open (Linsley-Noakes, 1989). The percentage of burst was calculated for each cane over time, so the bud burst pattern for each treatment and the untreated control could be determined.

Sheltered ambient air temperatures were monitored at a station located in the orchard. Hourly mean temperatures were recorded throughout the experimental period.

At the same time, the average state of dormancy of vines in the field was determined at fortnightly intervals using the method of isolated single-node cuttings (Mauget, 1976). The dormancy of isolated buds was measured by their growth ability, expressed as the time required for breaking on single node cuttings at 25°C. The mean budburst time (MBT) is expressed in hours and represents the arithmetic mean of budburst time for individual buds. The higher the MBT, the more dormant the buds were considered to be.

3. Modeling budburst response to high spring temperatures

Among different possible models for describing bud burst pattern, a simple logistical function was selected whose the parameters may have a biological significance:

$$Tx = K / [1 + \exp(-a(x-x_1))]$$

where

- Tx is proportionate budbreak
- x is number of hours when the temperature is above a given threshold value
- K is maximal proportionate budbreak
- a is relative budbreak rate at the beginning of budbreak
- x₁ is the value of x at maximum budbreak rate

It should be noted that the model gives final budbreak intensity as well as the delay for bud burst.

The model was fitted to data using the NLIN Procedure from the SAS package (1988). This method uses an iterative process where a starting value for the estimated value is chosen and continually improved until the error sum of squares is minimized.

In the multivariate secant method (DUD), used here, the derivatives are estimated from the history of iterations and not supplied analytically.

4. Results and discussion

4.1. Estimating the starting date for computing hours of temperature

As proportionate budbreak is described as a function of time (number of hours above a given threshold value temperature), the starting date must be known. It was estimated to be 1st February from the figures showing the Mean Budburst Time (figure 1) and the Mean Budburst Percentage (MBP) (figure 2). The 1st February is the date when MBP is the highest and MBT the lowest in the negative slope of dormancy release. This means that all the buds, when correlative inhibition has been suppressed, are no longer dormant and thus are able to growth if external conditions are favorable.

In the model, it is assumed that true dormancy release is achieved according to winter cold temperatures. After this time, it is supposed that only warm temperatures have an effect on budburst.

4.2. Fitting the temperature threshold value

In the model, the budbreak percentage is predicted from a number of hours when temperature is above a threshold value. Since some authors have shown the influence of a temperature of about 10°C on the growth ability of kiwifruit vines (Lionakis et al., 1984b ; McPherson et al., 1990), six threshold values of temperature (NH7 to NH12) from 7°C to 12°C in 1°C increments were tested.

The choice of the most convenient threshold temperature value was performed statistically by fitting the model to the untreated control data set. The non-linear regression procedure from the SAS package was applied.

The temperature of 9°C was selected because it gave the lowest residual mean square (table 1).

From a biological aspect, this means that kiwifruit vines require rather high temperatures to resume growth compared to other fruit species (Morgan et al., 1985).

4.3. Fitting the model parameters

For each of the six Hydrogen Cyanamide treatments used to create variability in budburst patterns, proportionate budbreak was expressed as a function of number of hours above 9°C. The model was fitted to each treatment data set. The same non-linear regression method was used (DUD) so that a set of three estimated parameters, K , a and x_i was obtained. Figure 3 shows the corresponding simulated curve for each treatment with the fitted parameters and actual proportionate budbreak values. In all cases variation in the data is significantly explained by the model as shown by a determination coefficient greater than 0.98. It appears that the measured bud burst pattern is well-described by the fitted pattern.

The parameters values were represented as histograms with confidence intervals for the six treatments and the untreated control (figure 4). For each parameter, K , a and x_i , the treatments are well differentiated. It is possible to rank the treatments in terms of their efficiency in function of the parameter values. There appears to be some interaction between concentration and application time. Except for the last application

date, six percent hydrogen cyanamide was significantly higher than four percent in improving total bud burst intensity. The most successful application time appeared to be 8 weeks before natural bud break, which is much longer than in New Zealand (Linsley-Noakes, 1989).

The best results in terms of total budbreak amount were obtained with a treatment applied on 18 January 1991 with a 6% dilution, as shown by K values for each treatment. The lower the relative budbreak rate at the beginning of bud burst, i.e. the significance of parameter "a", the more effective the hydrogen cyanamide application. In the same way, the smaller number of hours, at a temperature above 9°C, for maximum budbreak rate, the better the efficiency of the treatment (x_1).

The model thus appears to be very suitable to describe between-treatment variability.

5. Conclusion

A simple logistical model of bud burst simulation according to spring temperatures has been fitted to data from a one-year experiment. It is shown to be efficient to describe budbreak variability induced by different hydrogen cyanamide applications.

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Table 1 - Estimation of parameters and residual mean square value for each threshold temperature value

	K	a	Xi	Residual Mean Square
NH7	0.53	0.022	492	0.000314
NH8	0.53	0.027	412	0.000166
NH9	0.53	0.031	341	0.000154
NH10	0.53	0.035	279	0.000195
NH11	0.53	0.042	203	0.000182
NH12	0.54	0.063	106	0.000463

Figure 1 - Bud dormancy expressed by Mean Budburst Time in *Actinidia deliosa* cv Hayward.

Figure 2 - Mean Budburst Percentage of isolated single-node cuttings

Figure 3 - Bud break pattern simulation and actual values of proportionate budburst for each treatment, as a function of numbers of hours above 9°C from 1 February.

Figure 4 - Values of the model parameters for each treatment ("a" for relative budbreak rate at the beginning of budbreak : "K" for maximal proportionate budbreak : "xi" for the value of x at maximum budbreak rate)