A WWW Application for Pear Fruit Growth Prediction

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[Introduction]

With the wide popularity of WWW (the World Wide Web), many kinds of WWW application systems have been developed and utilized in business. In agriculture, if more systems to support crop production are open on WWW, they will be available for more farmers, extension officers, and researchers.

The work reported here was aimed at establishing a WWW application to predict pear fruit growth and harvest time using temperature data and a simple growth model. To model pear fruit growth, the analysis method of "the number of days transformed to standard temperature (DTS)" (Konno and Sugihara, 1986) using the theory regarding chemical reaction rate, and the fruit growth model applying it (Ono et al., 1989) was used. It is relatively easy to calibrate fruit growth with DTS model because the only required input variable is temperature. The data for modeling were the time-series records of pear fruit growth and daily air temperature for ten years at Aomori Pref. Kennan Fruit Tree Research Center. I am grateful to the researchers there for contributing the data.

[Materials and Methods]

Research on pear growth was carried out at the orchard in Aomori Pref. Kennan Fruit Tree Research Center. The data in pear cultivar 'General Le Clark' from 1987 to 1996 was used to model fruit growth, since the cultivar is mainly cultivated in Aomori Pref. and means to predict its fruit growth correctly have been required.

First, the parameters of DTS model for fruit growth were calibrated using time-series temperature and fruit size over the five years from 1992 to 1996. Daily DTS was calculated from daily average air temperature (T) and constant standard temperature (Te) with function(1), and DTS in fruit growth period was calculated with accumulating daily DTS from full flowering day.

$$DTS = \exp (Ea (T - Te) / (8.314 \, T \, Te)) \qquad \text{DTS model function} \qquad (1)$$

Ea: apparent activation energy T: absolute temperature Te: standard temperature

A physiological turning point temperature (Tc=Te) which Ea changes on was set, because pear fruit growth tends to be suppressed by high temperatures in summer.

Next, a time series of fruit volume (V) was estimated from fruit length (L) and width (W) measurements with $V=?LW^2/6$. Fig.1 shows the increase of estimated fruit volume. The data of fruit volume and accumulated DTS was fitted on the growth curve of function(2).

$$V = A / (1 + B \exp (- C \, t)) \qquad \text{growth curve (logistic) function} \qquad (2)$$

V: fruit volume t: accumulated DTS as time scale A, B, C: constants

The "Solver" tool of the spreadsheet software, Microsoft Excel 97 was used to calculate the parameters of the model using the least squares method.

Next, the correspondence between accumulated DTS from full flowering and pear fruit states was examined. The data used were fruit base colors and taste test results every seven

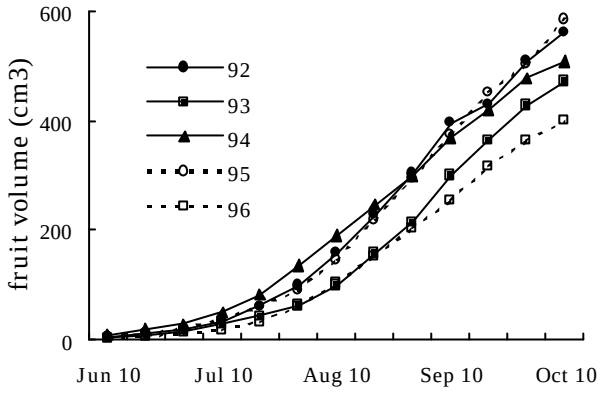

Fig.1. Increase of pear fruit volume estimated from fruit length and width recorded every 10 days in 1992-96.

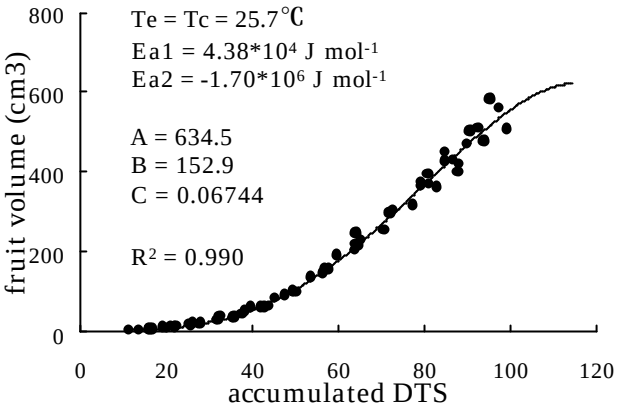

Fig.2. Growth curve of fruit volume to accumulated DTS from full flowering in 1992-96, fitting DTS model.

to ten days in September and October, and daily average temperature from 1987 to 1996. The fruit base colors were scored for ripeness with six levels (green to yellow) known as base color indices using a color chart for pear fruit. Pear fruit is usually harvested when the base color index is around 3. The fruit taste was subjectively tested by specialists after harvesting and ripening the fruit in an incubator at 20C. It was evaluated as taste indices with five levels from 1989 to 1995, or as “good” or “bad” in the other years.

[Results]

The correlation between fruit volume and accumulated DTS from full flowering was very high (Fig.2). The change of apparent activation energy (Ea of function(1)) around 26C could be observed from the result, supporting the knowledge that pear fruit growth is suppressed by high temperatures.

Fruit base color indices and DTS from full flowering were highly correlated (Fig.3). The taste indices were highest or the taste scores were “good” in the fruits harvested with

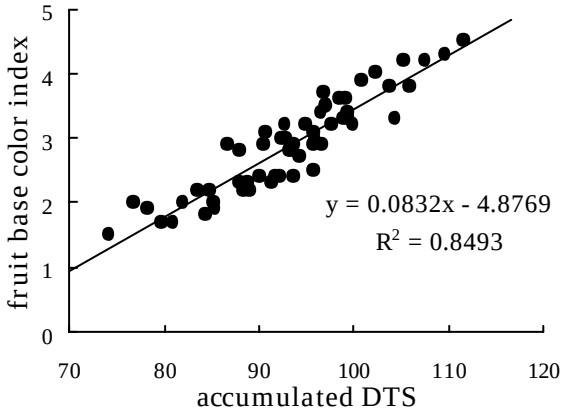

Fig.3. Relationship of accumulated DTS from full flowering and fruit base color index in 1987-96.

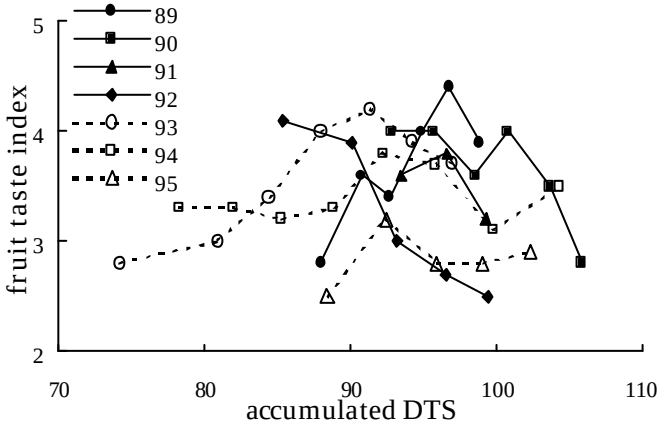

Fig.4. Relationship of accumulated DTS from full flowering and fruit taste index in 1989-1995.

accumulated DTS of 91 to 97, except in 1992 (Fig.4). However, base color indices were around 3 during the periods in all ten years. Therefore, it was found that the DTS model could correctly predict pear fruit growth and fair harvest time.

[WWW Publishing]

Using the pear fruit growth model, a WWW application page for fruit growth prediction was composed so that it would be available for more people on WWW. It was implemented by Microsoft Corporation's WWW technology. The development and operational environment of it is as follows.

Operating System : Windows NT Server 4.0
WWW Server : Internet Information Server (IIS) 4.0
Server-side Script : Active Server Pages (ASP) 2.0
Client-side Script : JavaScript 1.2
URL : http://riss.narc.affrc.go.jp/kssys/pear/growth.asp

The application lets users calculate accumulated DTS and fruit size according to time-series daily average air temperature stated in the data files (Fig.5). The temperature data at four weather stations in Aomori pref. over the twelve years from 1987 to 1998 were prepared. A user can calculate a harvesting date and fruit size, by entering a weather station, a year or forecasted temperature transition, a full flowering date, and an accumulated DTS for harvest stage into the input form. Furthermore, values of the model parameters can be easily changed.

[Discussion]

Since the DTS model for fruit growth uses only temperature as its input data, the accuracy wouldn't be high enough according to circumstances. However, it is able to calibrate and predict fruit growth and harvest time without using additional data. If the WWW application can utilize real-time or forecasted temperature data, it will be more available to predict fruit growth accurately. Furthermore, by collecting variable pear growth data from not only Aomori Pref. but also the other regions, the pear fruit growth model and the WWW application will be improved to expand applicable regions or cultivars from now on.

[References]

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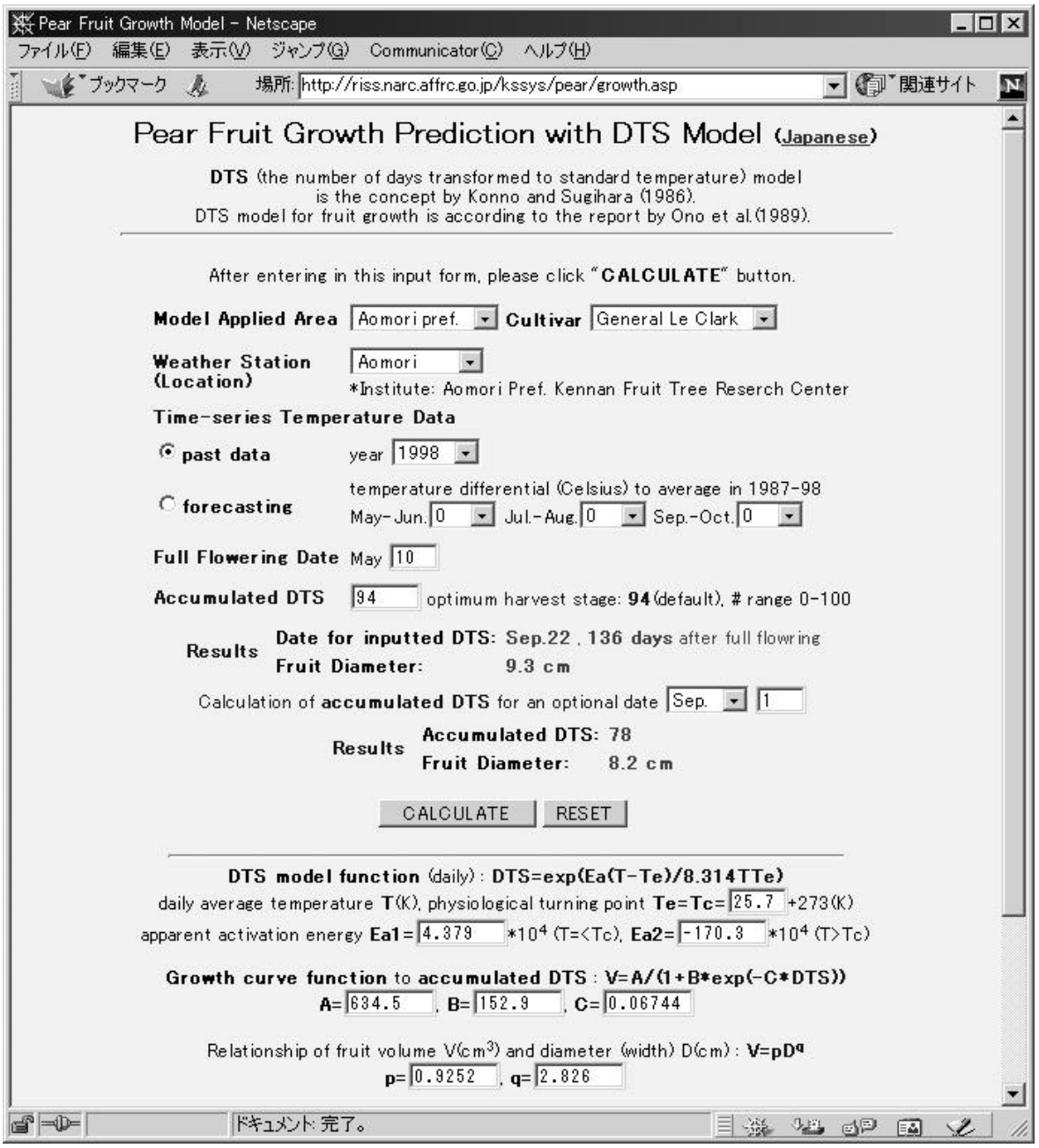

Fig.5. A screen of the WWW application for pear fruit growth prediction after calculating.
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