CHAPTER 4

RESULTS AND DISCUSSION

Experiment data

Planting to Emergence

Percent of emergence of all varieties were higher than 89% in both experiments, except U-Thong2 variety in the second experiment where its emergence rate was only 40 percent. Duration from planting to emergence of each variety in both experiments were measured as number of days (#day), summation of growing degree day above 8, 10 and 16°C ($SUMGDD_8$, $SUMGDD_{10}$, and $SUMGDD_{16}$). Comparisons of the duration at each scale of each variety between experiment (Table 4-1) showed that $SUMGDD_8$ and $SUMGDD_{10}$ since planting to emergence of CP78-1628 and K84-200 variety were not significantly different between experiments. It imply that the growing degree day concept with the base temperature of 8 and 10 °C can be used to predict the duration from planting to emergence of CP78-1628 and K84-200 sugarcane varieties. This result is agreed with Yang and Chen (1980) finding that the base temperature was 8 °C for planting to emergence interval (Robertson et al., 1998). The difference of the duration in number of days and in GDD at all three base temperatures between experiments for U-Thong might be the result of its low percent of emergence in the first experiment. For K88-92, it might be that its optimal temperature for emergence is narrow. Additional study is needed for the issue.

Table 4-1 Comparisons of the number of day, $SUMGDD_8$, $SUMGDD_{10}$, and $SUMGDD_{16}$ since planting to emergence between experiment of each variety.

Variety	Planting to emergence interval			
	$SUMGDD_8$	$SUMGDD_{10}$	$SUMGDD_{16}$	#day
CP78-1628	ns	ns	ns	**
K84-200	ns	ns	*	**
K88-92	**	**	**	ns
U-Thong2	**	**	**	**

However, the analysis of variance of $SUMGDD_8$ from planting to emergence of four varieties in both experiments (Table 4–2) showed that $SUMGDD_8$ were not significantly different, but it was significant between varieties. The fastest development variety was CP78-1628, the slowest was K84-200 and U-Thong2. The average $SUMGDD_8$ of both experiments is 209.66 °Cd.

Table 4-2 $SUMGDD_8$ since planting to emergence of all four varieties

Experiment	Sugarcane variety				
	CP78-1628	K84-200	K88-92	U-Thong2	mean
1^{st}	145.90	250.48	218.33	269.92	221.16 ns
2^{nd}	148.13	247.08	190.69	206.70	198.15 ns
mean	147.02 a	248.78 c	204.51 b	238.31 c	209.66

Leaf development

Both leaf tip and ligule appearance dates were observed in this study. Cumulative growing degree day above the base temperature 16 °C since emergence (CUMGDD) was more linearly related to number of total expanded leaves ($r^2 = 0.99$) than total visible leaves ($r^2 = 0.98$). Slope of the linear relationship between CUMGDD and number of total expanded leaves is leaf development rate and in unit of leaf per degree-days, which its inversion is the growing degree days required for a leaf production, call phyllochron.

First experiment

Analysis of variance of the slope of all treatments in the first experiment shown that the higher development rate varieties were K88-92 and CP78-1628 experiment (Table 4–3). Their rates of leaf development were not significantly different and equal to 0.0121and 0.0120 leaf $°Cd^{-1}$, respectively. The following varieties were K84-200 and U-Thong2, which both variety rates were equal to 0.0116 and 0.0115 leaf $°Cd^{-1}$ and not significantly different but differ with the rates of the first two varieties.

Second Experiment

Table 4–4 showed the slope of all treatments in the second experiment. The highest leaf development rate variety was K88-92, with the rate of 0.0126 leaf $°Cd^{-1}$. The second variety is CP78-1628, with the rate of 0.0118 leaf $°Cd^{-1}$. The following varieties are K84-200 and U-Thong2, with rate of 0.0107 and 0.0104 leaf $°Cd^{-1}$, respectively.

The inverses of the slope of all treatment in both experiments give GDD per leaf and were shown in Table 4–3. This study gave similar results as the study of phenology of these four cane varieties results at experimental fields in Suphan Buri, Khon Kean (Siri et al., 1997) and Chiang Mai (Chanmueng, 1997), which show that the fastest leaf development variety was K88-92 and the average phyllochron was between 122-149 °Cd above 10 °C. The average phyllochron of all treatment in this study would be 112-136°Cd, if the GDD were calculated base on the base temperature of 10°C.

Table 4-3 The average leaf development rate and phyllochron of all leaf of four sugarcane varieties in both experiment (Tbase =16°C)

Experiment		Sugarcane variety			
		CP78-1628	K84-200	K88-92	U-Thong2
1st	Leaf development rat	0.0120 a	0.0116 b	0.0121 a	0.0115 b
2nd	(leaf°Cd^{-1})	0.0118	0.0107	0.0126	0.0104
1st	phyllochron	83.33	86.21	82.64	86.96
2nd	(°Cd leaf^{-1})	84.74	93.46	79.36	96.15

Table 4-4 Slope of the relationship between CUMGDD and number of fully expanded leaf of all treatments in the second experiment.

Varieties	Types	Photoperiod Treatments				mean ±SE
		Natural	14-hour	15-hour	16-hour	
		---------------Leaf °Cd^{-1}---------------				
CP78-1628	Plant	0.0118	0.0120	0.0121	0.0119	0.0118
	1^{st} ratooned	0.0110	0.0124	0.0122	0.0112	$\pm 1.04\times10^{-4}$
K84-200	Plant	0.0111	0.0111	0.0104	0.0104	0.0107
	1^{s} ratooned	0.0099	0.0114	0.0106	0.0109	$\pm 1.34\times10^{-4}$
K88-92	Plant	0.0128	0.0130	0.0127	0.0128	0.0126
	1^{s} ratooned	0.0127	0.0130	0.0116	0.0118	$\pm 1.33\times10^{-4}$
U-Thong2	Plant	0.0105	0.0105	0.0110	0.0106	0.0104
	1^{s} ratooned	0.0098	0.0108	0.0098	0.0101	$\pm 1.07\times10^{-4}$

Tiller and visible leaf position

Tillering and tiller mortality rates was well correlated with leaf numbers in all four varieties (Figure 4–1). The result shown that tillering of all four plant cane varieties begun during the 9^{th}–12^{th} visible leaf stage in all photoperiod treatments. The maximum tiller number per plant of CP78-1628 and K88-92 was observed at 17^{th} – 18^{th} visible leaf positions in all photoperiod treatments. The maximum tiller number per plant of K84-200 and U-Thong2 was observed at 20^{th} – 21^{st} visible leaf position in all photoperiod treatments, which similar to Nasuriwong's (1997) results. Thereafter, declining to a stable stalk number of CP78-1628, K84-200, K88-92, and U-Thong2 at 27^{th}-29^{th}, 25^{th}-26^{th}, 28^{th}-30^{th}, and 25^{th}-27^{th} visible leaf position stage, respectively. The beginning of tiller and tiller mortality is a predictable phenological stage and related to leaf numbers. However, the number of live shoot or stalk might be related with radiation, which demonstrated by tiller number per plant of K84-200, and U-Thong2 were higher than other daylength at 15-h and natural daylength, where they were not shaded by the first ratooned plant in 15-h light treatment and natural daylength treatment as others plot. This evidence was similar with Inman-Bamber's (1994) result.

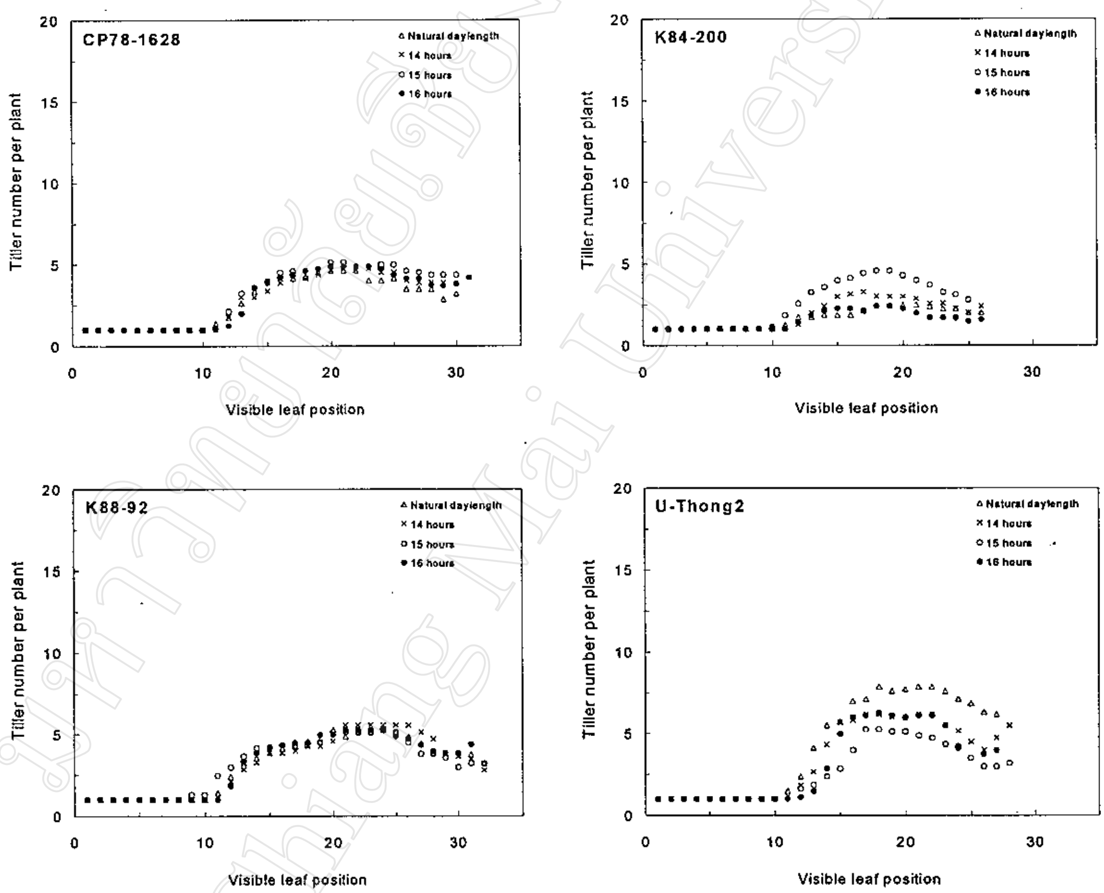


Figure 4-1 Tiller numbers per plant at each visible leaf position of four sugarcane varieties from four photoperiod treatments, Chiang Mai.

Panicle Initiation

All sugarcane plants in this study did not initiate panicle in any extended photoperiod treatments. This was unexpected since studies in blossoming time of a native *S. spontaneum* at Pingtung Taiwan shown that the 9- and 15- hour photoperiod delayed blossoming (Clements, 1975).

In natural photoperiod, U-Thong2 variety initiated panicle in both experiments and both plant cane and first ratooned cane, K84-200 variety initiated panicle only first ratooned cane in the second experiment and plant cane in the first planting date. Others varieties had never initiated their panicles in both experiments (Figure 4–2).

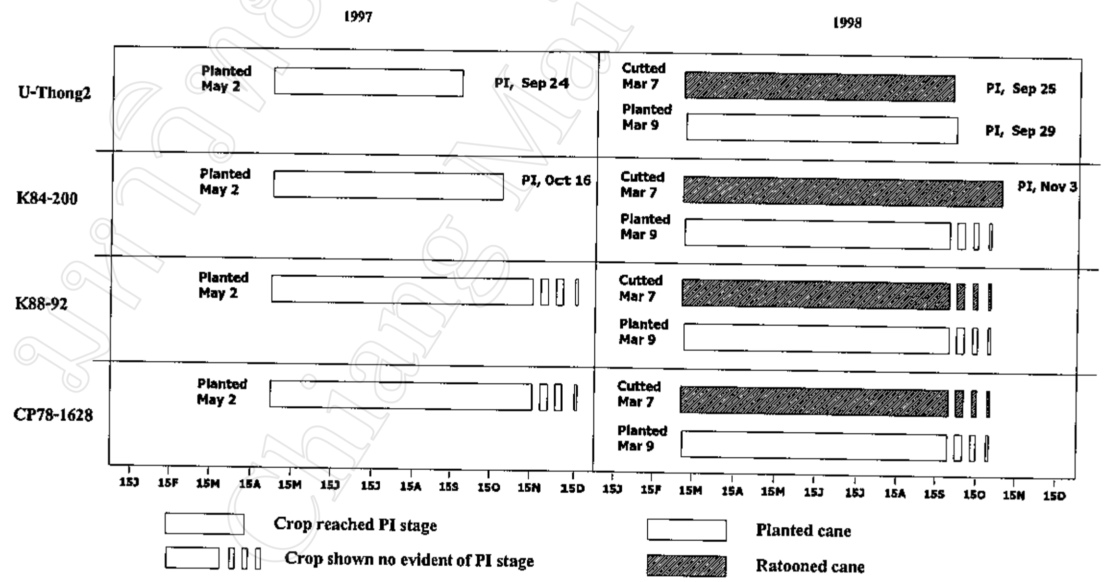


Figure 4-2 Panicle initiation of four varieties under natural photoperiod treatment.

First Experiment

In the first experiment, plant cane of U-Thong2 variety reached 50% of its panicle initiation on September 24, 1997, and plant cane of K84-200 variety reach 50% of panicle initiation stage on October 16, 1997. Their panicle initiations stages were very consistency.

Second Experiment

In the second experiment, initiation of the plant cane of K84-200 variety was not found, but in its first ratooned cane, the initiation was first found on November 3, 1998, however, it never reached 50% of panicle initiation. For U-Thong2 variety, the first ratooned and plant cane reached 50% of panicle initiation on September 25 and 29, 1998. The initiation of first ratooned cane of U-Thong2 variety was more consistency and higher percentage than its plant cane (Table 4–5).

The initiation seems to be delayed and had high percentage of variation as sampling date progressed (Figure 4–3). The errors of the used reference for estimation of initiation could be effect on delaying of panicle initiation, if the development of the initiated panicle in the reference (Clements, 1975) was slower than the development of initiated panicle in this study. However, the delaying was great as about and over 30 days in the plant cane of U-Thong2 and first ratooned cane of K84-200 variety, so it should not be the reason of the delay.

Table 4-5 Percent of the initiated panicle and the date of initiation in average on each sampling date.

Variety	type	Sampling date	% initiation	average initiation date	SE
U-Thong2	plant	September 28, 1998	–	–	–
		October 2, 1998	66.7	September 29, 1998	1.00
		October 21, 1998	–	–	–
		November 4, 1998	80.0	October 20, 1998	1.00
		November 18, 1998	20.0	October 28, 1998	8.00
U-Thong2	first ratooned	September 28, 1998	33.3	September 28, 1998	–
		October 2, 1998	66.7	September 25, 1998	0.00
		October 21, 1998	33.3	September 28, 1998	–
		November 4, 1998	100.0	October 12, 1998	1.04
		November 18, 1998	100.0	October 19, 1998	2.39
K84-200	first ratooned	November 18, 1998	25.0	November 10, 1998	–
		December 2, 1998	25.0	November 3, 1998	–
		December 21, 1998	30.0	December 10, 1998	6.08

Note: - means that panicle initiation was not observed on the sampling date.

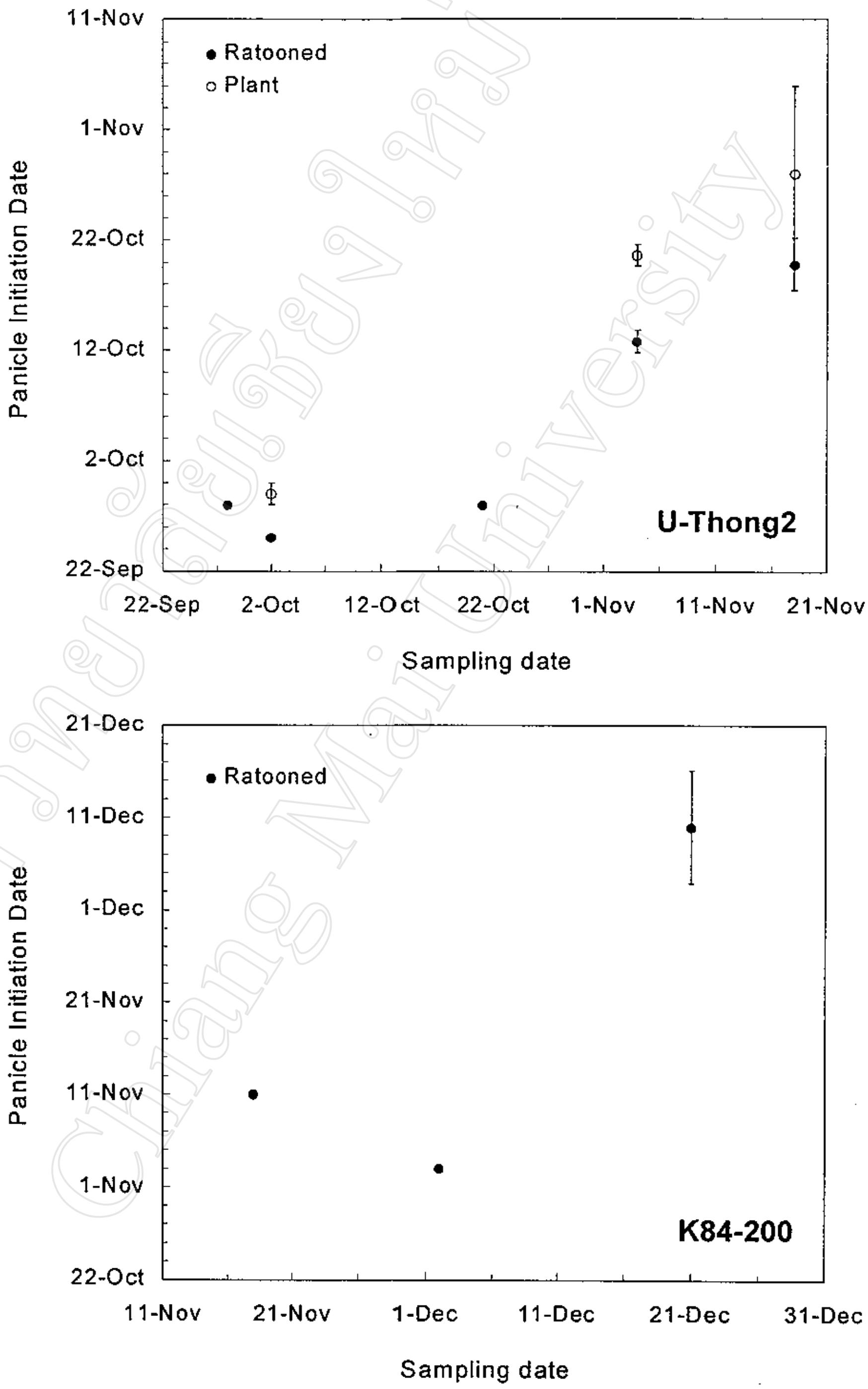


Figure 4-3 The panicle initiation delayed and was more variation as sampling dates.

Panicle Emergence

First Experiment

Panicle emergence event was found only in U-Thong2 variety in the first experiment. On the average initiated panicles of U-Thong2 variety emerged on December 1, 1997. The final panicle plants were 79.3 percent of the plot. The averaged summation of GDD since panicle initiation to panicle emergence was 720.8 °Cd above 16 °C (Table 4–6). The initiated panicles of plant cane of K84-200 variety in the first experiment had never emerged until the end of December 1997.

Second Experiment

The initiated panicles of both plant and first ratooned cane of U-Thong2 variety and first ratooned cane of K84-200 variety had also never emerged unit the end of December 1998 of the second experiment.

Table 4-6 Number of days and growing degree day since panicle initiation to emergence in average of U-Thong2 variety in the first experiment.

	Panicle initiation to panicle emergence interval		
	panicle emergence date	number of days	GDD_{16}
mean	December 1, 1997	68.3	720.8
SD	5.6	5.6	53.2

Sugarcane Flowering Model (ScFM 1.0)

Introducing Sugarcane Flowering Model (ScFM 1.0)

Welcome to Sugarcane Flowering Model (ScFM 1.0)

- ScFM 1.0 is a crop phenological simulation model – it provides a simple way to simulate sugarcane phenological development and display the simulation results in both graphic format and data file.
- ScFM 1.0 has two optional methods for daylength simulation and three optional methods for floral initiation simulation.

Requirements

System Requirements:

- ScFM 1.0 is an application that generated by using Visual Basic 5.0. It runs under Windows 95 and 98 operating systems.

Hardware Requirements:

- An IBM PC or compatible computer with a 486 DX processor (or higher) and a minimum of 8 MB of RAM

Installation

1. Make sure no other applications are running.
2. Insert the ScFM 1.0 CD into you CD-ROM drive or diskette into you floppy drive.
3. Choose Run from the Start menu, type "d:\setup" (use the drive letter appropriate to the drive containing the installation disk) and press Enter.
4. Setup installs ScFM 1.0 into the C:\Program Files\ScFM1 directory.
5. Follow setup's instructions to complete the installation.

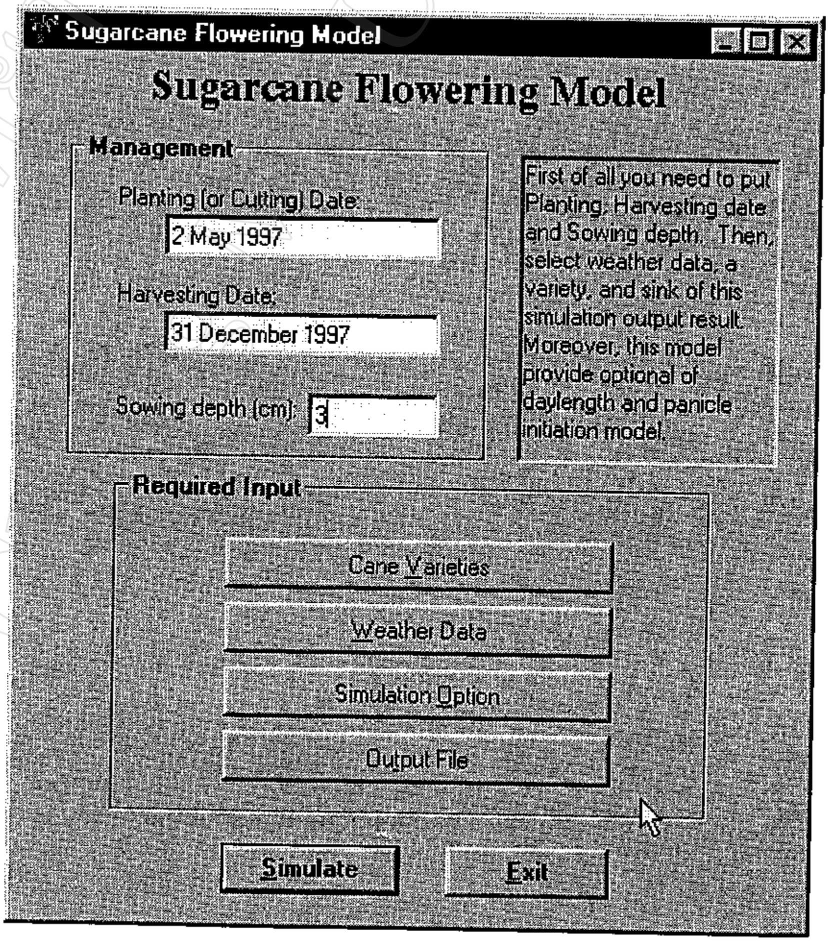
Sugarcane Flowering Model Interface

Main Form

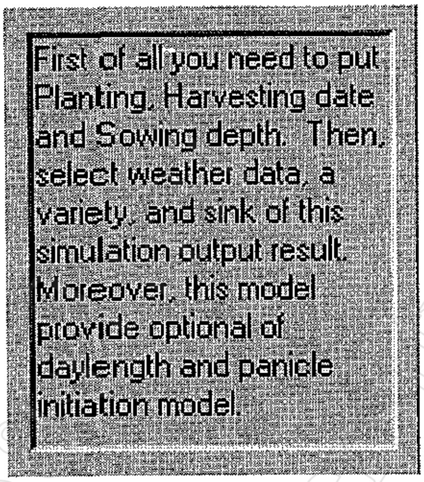
The main form (Screen 1) consists of three main parts;

- Management Information
- Required Input
- Operation

Furthermore, there is a description box (Screen 1A), which explains steps of using the program, then shows the description of each part of the main form, when move mouse on it.



Screen 1: Main form of the Sugarcane Flowering Model 1.0



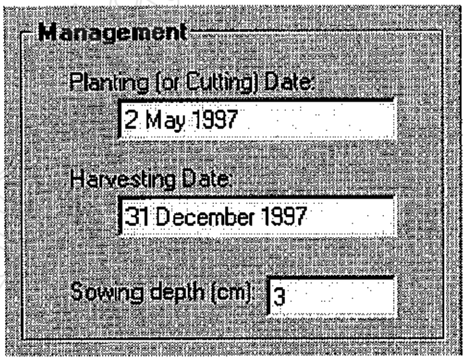
Screen 1A: Description of each part in the main form

Management Information

The model needs two management information; planting date and harvesting date. Model starts running at planting date and stops at harvesting date. Run time of the model is equal to number of day since planting to harvesting. This part is needed to put before other required information. Another management information required for plant cane is sowing depth (Screen 1B).

After user enters these management dates, the dates will be change to be long format of date in order to prevent calculation error.

There are a message box to inform the user, if the input is not in the date format.



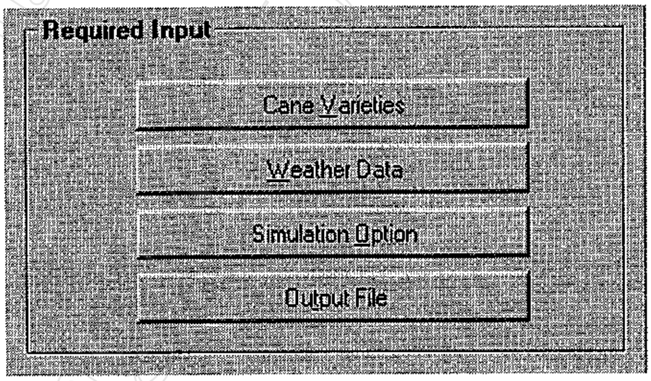
Screen 1B: The required management input

Required input

The ScFM 1.0 required genetic coefficients of the variety in the genotype file (*.cul) and daily maximum and minimum temperature, and position of the weather station in the weather file (*.wth), which are in DSSAT 3.5 system file format (Screen 1C).

The ScFM 1.0 provides two optional daylength calculation models and two type of sugarcane plant in the simulation option button.

User can also select or create a file name to be their sink of the simulation result at output file button.



Screen 1C: The required input files, and simulation options

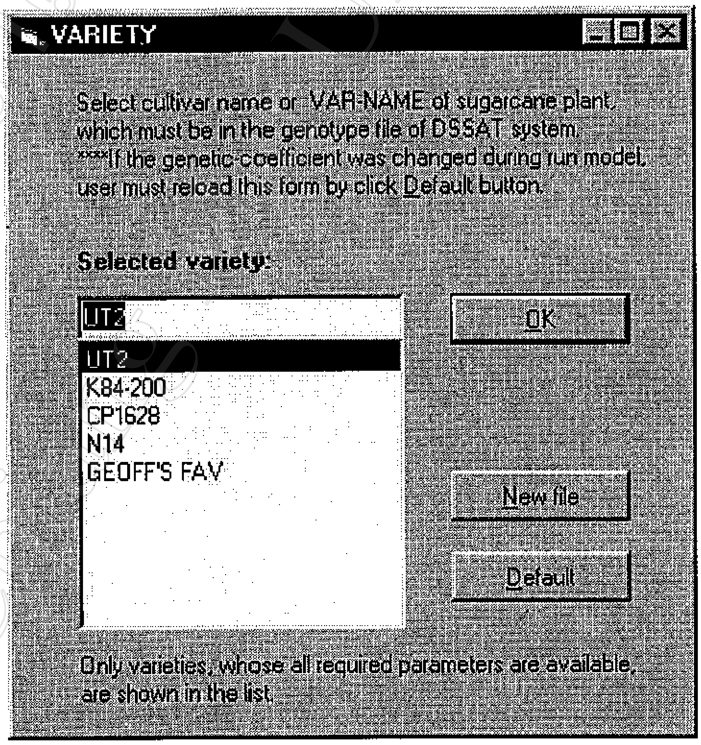
Cane Variety

This section allows the user to select a variety that has all required parameter for the simulation.

Genotype specific parameters of sugarcane is kept in the genotype file of DSSAT 3.5 file system, which its default path is in the first line of a specific file named as "FilePath.txt" in the application path.

User can select one of those varieties by clicking on it.

Alternatively, user can open another genotype file (*.cul) by clicking on "New File" button and reopen the default file by click on "Default" button.



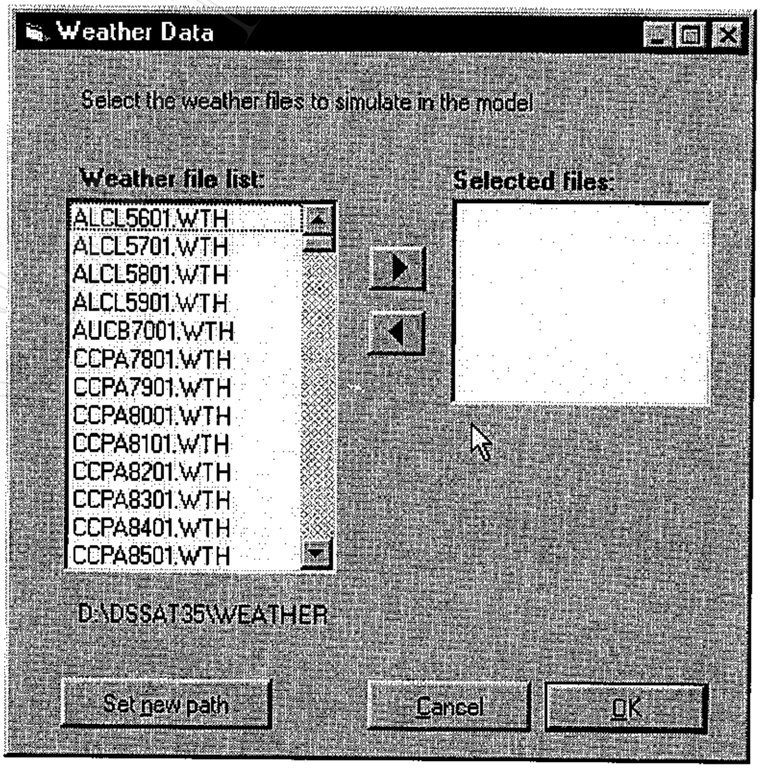
Screen 2: Selection of a variety in the selected genotype file.

Weather file

In DSSAT 3.5 system, daily maximum and minimum temperature, and location of the weather station (latitude in degree) are kept as specific format in weather file (*.wth), which is under specific name system of DSSAT 3.5.

These weather files are kept in weather directory of DSSAT 3.5 program, which its default path is in the second line of a specific file named as "FilePath.txt" in application path, and shown in the weather file list box.

User has to select the weather file (Screen 3), which match the crop location and duration, to simulate the phenological stages of sugarcane by click on the file and click the arrow button, or double click on the file. If the selected weather file is not match with the crop duration or has not some required value, a warning message will pop-up.



Screen 3: Selection of the relevant weather file.

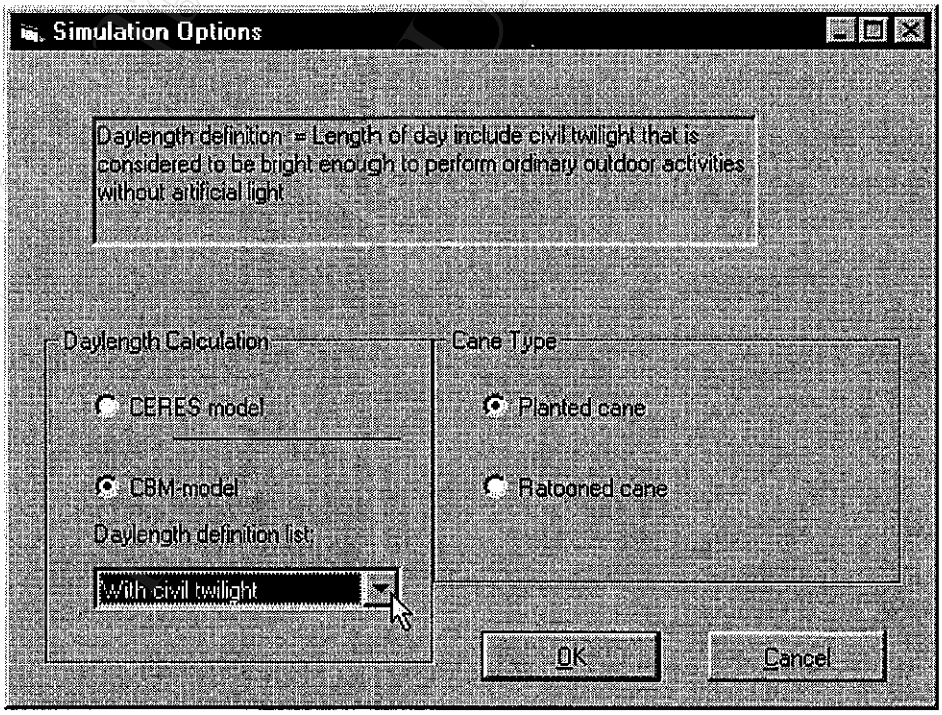
Simulation Option

This form consists of two main parts; daylength model, and cane type (Screen 4).

Daylength calculation part consists of CERES model and CBM model options. If user select the CBM model, the model will remind user to select a daylength definition.

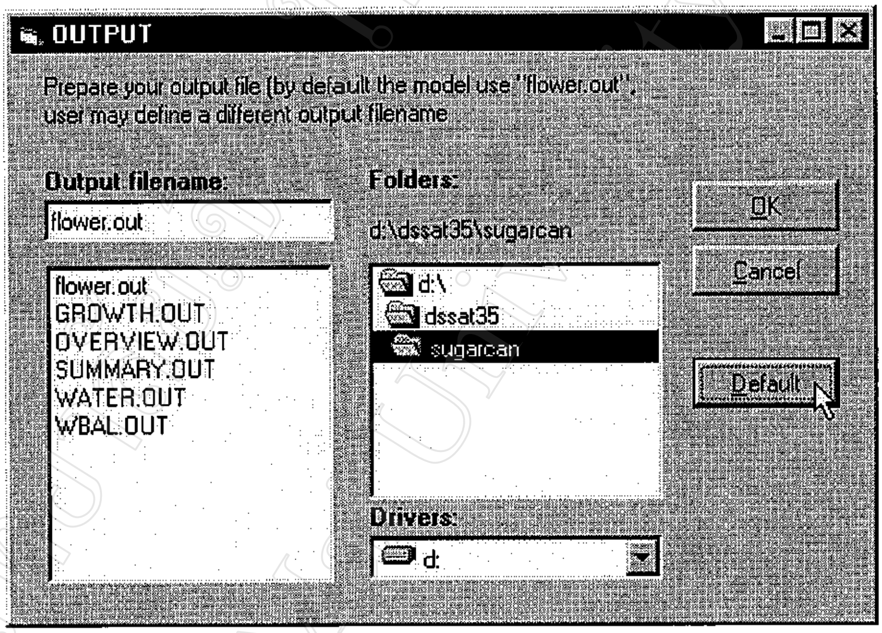
The ScFM 1.0 also provide two types of sugarcane crop: plant and ratooned canes.

User can view the explanation of each option and each daylength definition in the description box by move and click mouse on it.



Screen 4: Options for simulation in the ScFM 1.0

Output file The default path and name of the output file, where the simulation result will be stored, is stored in the third line of the "FilePath.txt" file in the application path. However, user can select or create another path and give a different file name (Screen 5).



Screen 5: Create the output file name and its position.

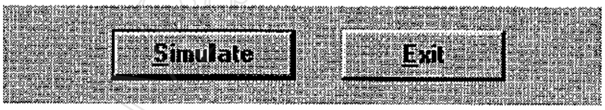
Operation

The previous parts are the preparation of the required information for simulation run. After all required information is defined, user can simulate the development stages of sugarcane by click on simulation button (Screen 1D).

If some required information is not provided, there are message box inform user the missing information.

After simulation process, the user-selected path and file of the required inputs become the default path and file for the next time of running program.

The exit button is used to end the program.



Screen 1D: The operation part of the main form.

Simulation Result

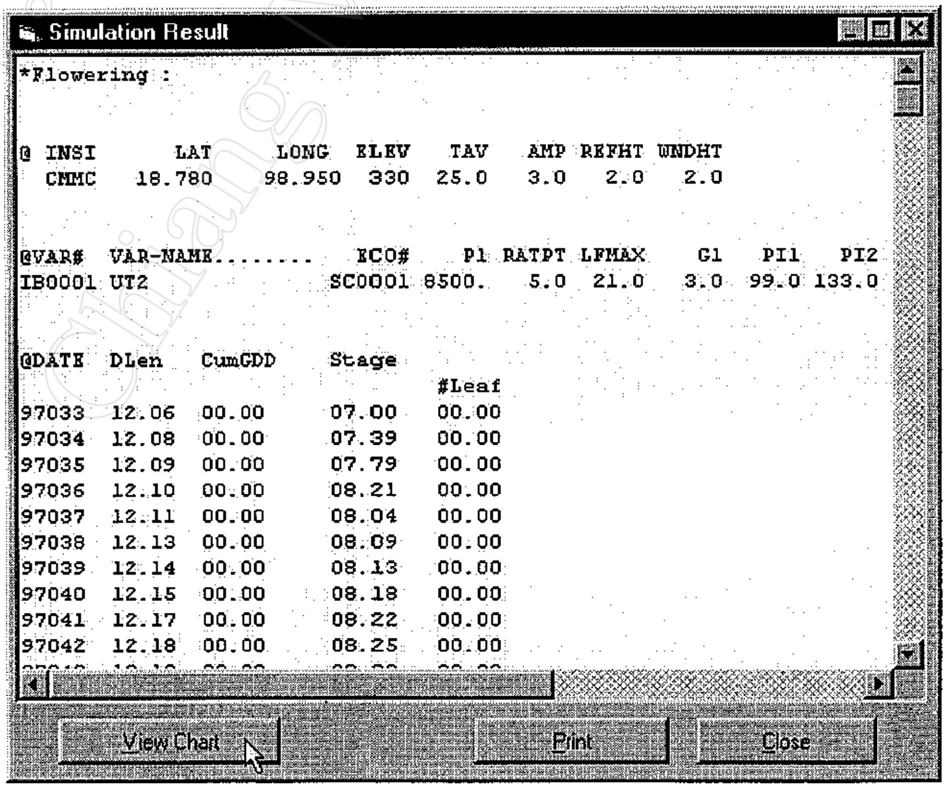
Text

This form (Screen 6) shows up after simulation has completed by open the outputs file as a text file.

The simulation results file contains title of the file, information of the weather station, information of genetic coefficient of the selected variety, and the simulated results.

- The information of weather station and genetic coefficient of the selected variety are similar with information part of the read files.
- The simulation result consists of date of year, daylength, CUMGDD, development stage, and leaf development.

User can print out the output file by clicking on print button and view the result in graphic made by clicking on the view chart button.



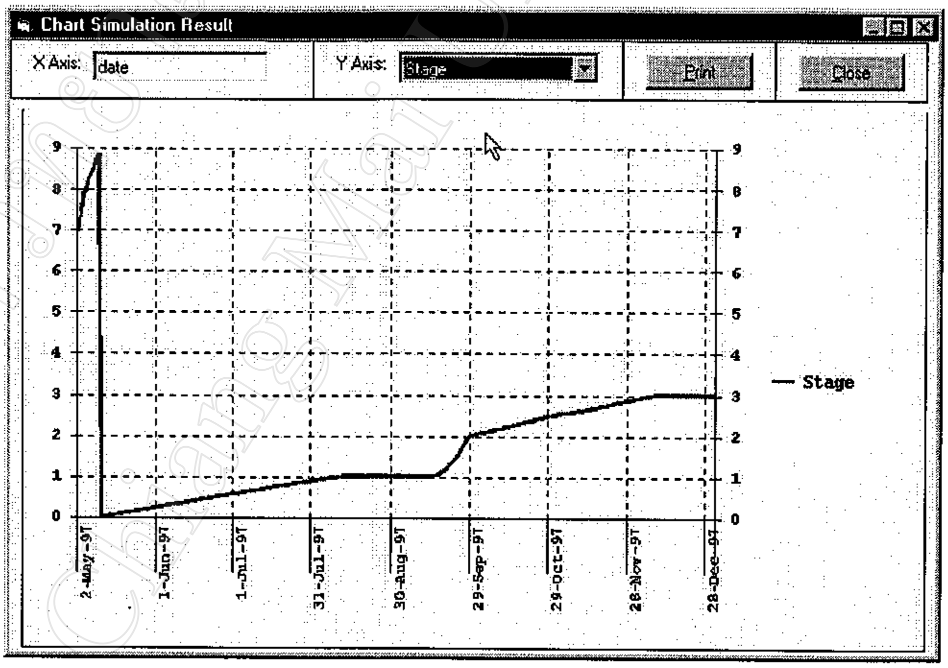
Screen 6: The stored simulation results in the output file.

Graphic

After clicking the view chart button, this form (Screen 7) shows the chart of all simulation result variables, which all variables is on Y-axis and date since planting to harvesting date is on X-axis.

The chart allows user to select one of all variables to plot on Y-axis, but X-axis is fixed as date. Date interval on X-axis scale is 30 day. Y-axis scale is automatically adjusted depend on the selected variable value.

User can print out the chart by clicking on the print button.



Screen 7: Graphical view of the simulation results.

CBM and CERES model daylength simulation

The daylength definition may be specified in the CBM model. Thus, we first establish the accuracy of CBM model by compared the calculated daylength with the published table of Meteorological Department at Chiang Mai latitude during 1998 and then compare the CERES daylength model to the CBM model, using the civil twilight definition (definition 4).

CBM model

Results from the CBM model were compared to the published data. The CBM model was set to use the same definition of daylength. Figure 4–4 shows the differences between the daylength calculated from the published data and the output of the CBM model. The errors of daylength simulation of CBM model compared to the published was as low as 0.02866 hour (1.72 minute) at sunrise to sunset definition, 0.01159 hour (0.69 minute) at including civil twilight definition, and 0.01129 hour (0.68 minute) at including nautical twilight definition.

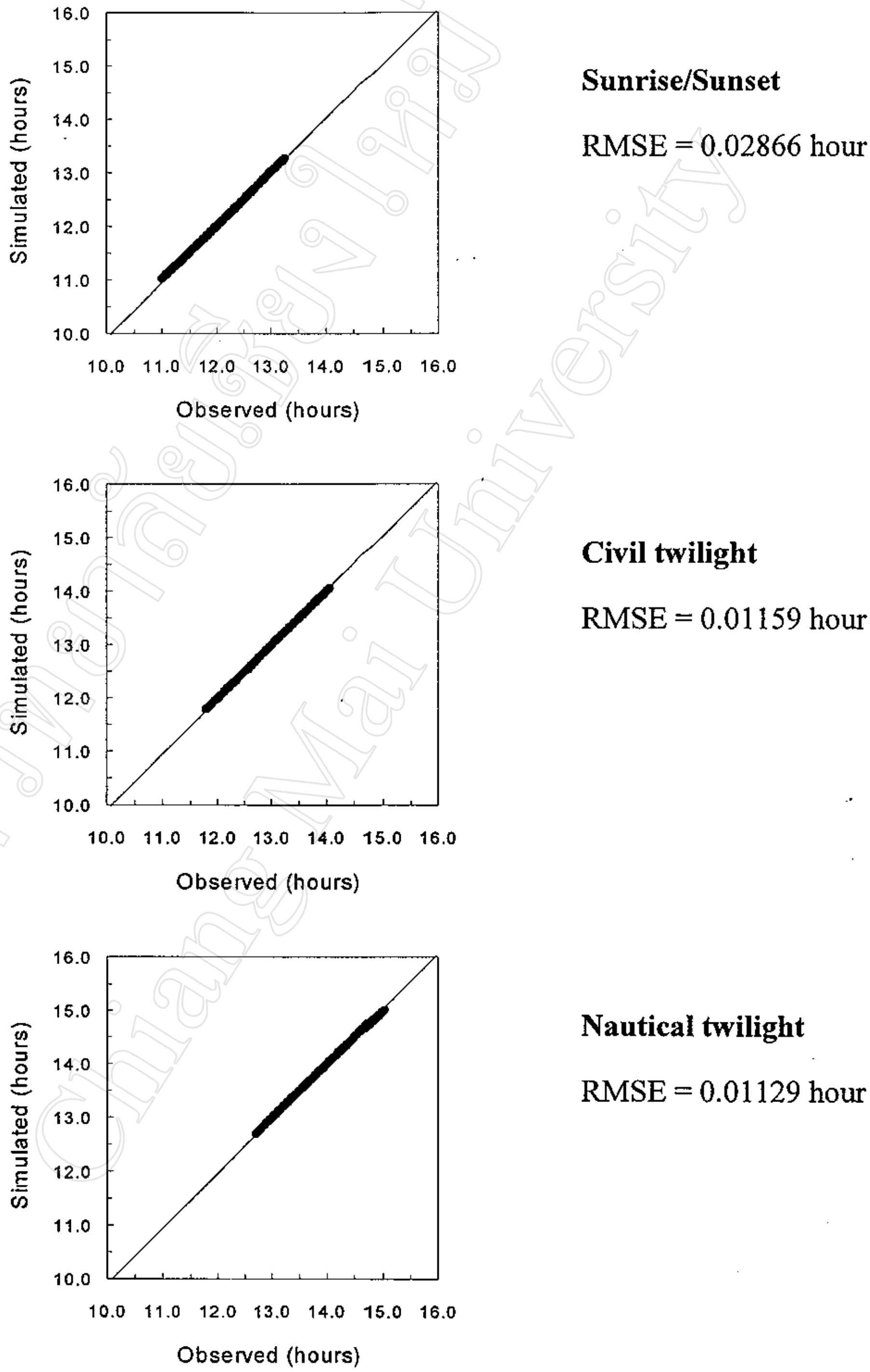


Figure 4-4 Comparison of the simulated daylength from the CBM model and published daylength data by Meteorological Department at Chiang Mai latitude (1998).

CERES model

The output from CERES model was compared to the published data. The errors of daylength simulation of CERES model compared to the published, which is the including civil twilight definition, RMSE was 0.02549 hour (1.53 minute) (Table 4–7). The errors of civil twilight calculation by the CERES model was higher than the CBM model, V values of 3.96×10^{-6} and 8.04×10^{-7}, respectively..

However, both models have good predictive capacity. The average of the difference between simulated and observed daylength during 1998 (Table 4–7) showed that the simulated daylength from CBM model are longer than the published as 0.02487 (1.49 minute), 0.00041 (0.025 minute), and 8.27×10^{-17} hour (4.96×10^{-15} minute) at sunrise to sunset, including civil twilight, and nautical twilight, respectively. For CERES model, the simulated daylength are shorter than the published as 0.01625 hour (0.097 minute) in average.

The error of simulated daylength from CERES model compared to CBM model using the corresponding definitions (Figure 4–5) showed that the simulated daylength of CERES model was lower than CBM model and the difference was lower than 3 minutes at Chiang Mai latitude.

Table 4-7 Calculated statistics testing model

Model	Statistical Testing			
	Bias (hour)	RMSE (hour)	R	V
CBM model				
Sunrise/sunset	0.02487	0.02866	0.00204	5.55×10^{-6}
Civil twilight	0.00041	0.01159	3.18×10^{-5}	8.04×10^{-7}
Nautical twilight	8.27×10^{-17}	0.01129	0.6×10^{-8}	6.68×10^{-7}
CERES model				
Civil twilight	-0.01625	0.02549	-0.00126	3.89×10^{-6}

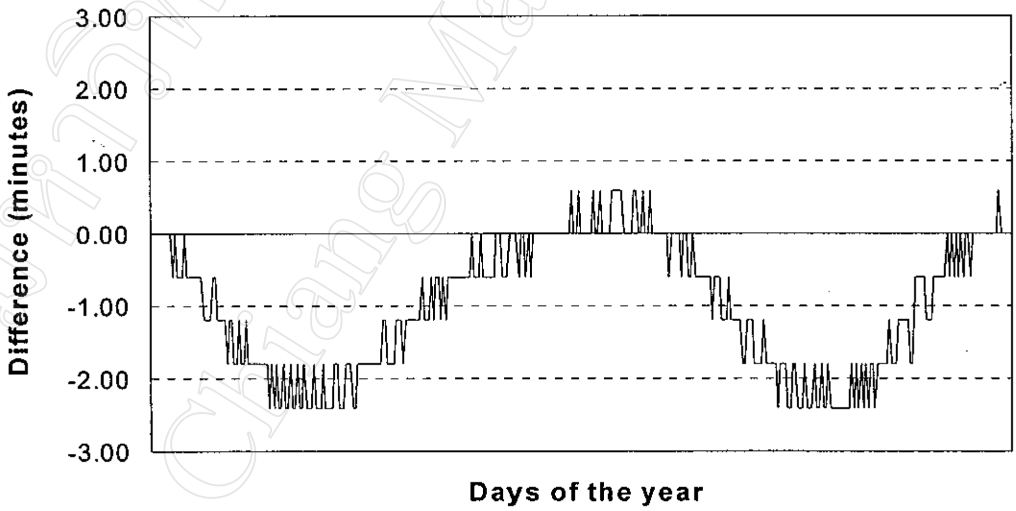


Figure 4-5 Errors of CERES daylength model compared to CBM model at Chiang Mai latitude during 1998.

Estimation of Coefficients

Thermal threshold

Planting to Emergence

Three out of five developmental phases were used to describe sugarcane development are depends only on temperature (Figure 4–6). A base temperature of 8 °C appears to be a practical value for root germination to emergence interval. Results from both experiments have shown that there was an average of 209.6 °Cd in the interval from planting to emergence when sowing depth is three centimeters. In the model, root germination is assumed to occur one day after planting, so emergence is assumed from the result to occur 200 °Cd after root germination. There was a report suggested that sugarcane requires 1 °Cd for a millimeter of shoot elongation, so the constant for sprouting as 170 °Cd is used in the equation to calculate the developmental rate from root germination to emergence. The equation 3.2 is modified as shown in equation 4.1.

$$P9 = 170 + (10 \times SDEPTH) \quad \text{.......... (4.1)}$$

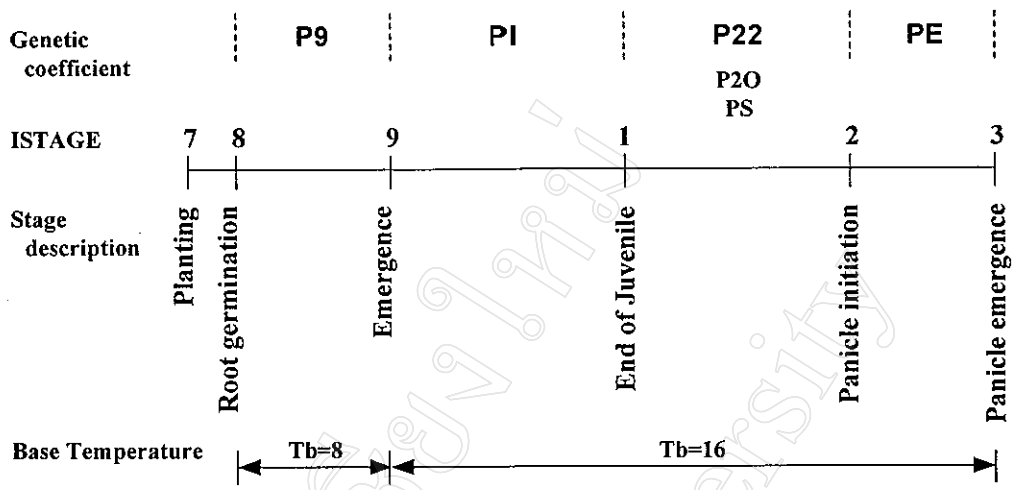


Figure 4-6 The required genotype specific coefficient for simulation of sugarcane development stages with the ScFM 1.0 model.

Emergence to Panicle emergence

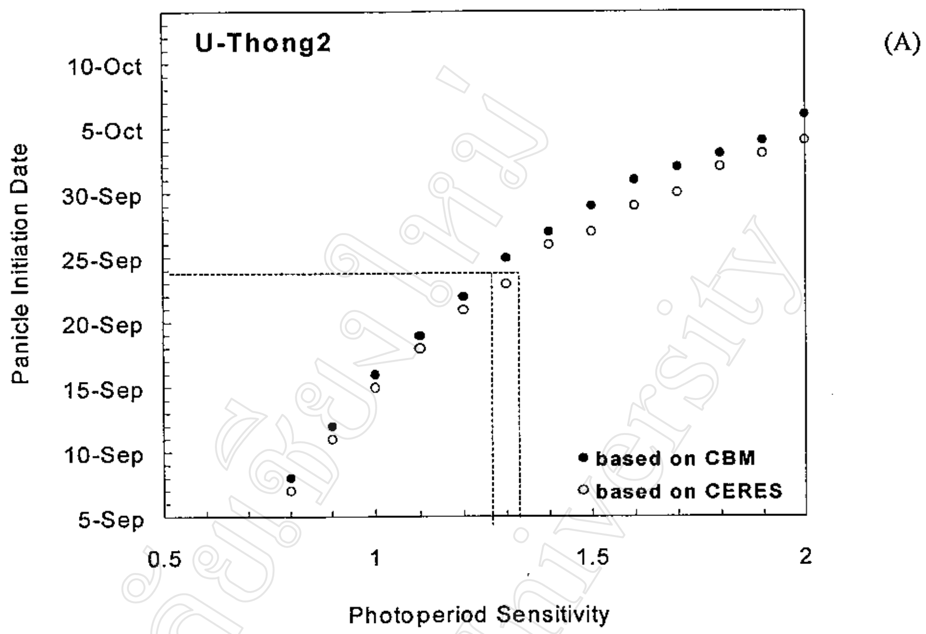
This study used a base temperature of 16 °C to calculate the growing degree requirement for leaf and panicle development. The experimental results showed that only one phyllochron value is sufficient for predicting leaf development of four sugarcane varieties. So, both the first and the second phyllochron intervals have a similar value in all phase. The duration from emergence to end of juvenile is assumed to be growing degree day required for the first 14 leaves development, which depends on phyllochron value of each variety, in the first experiment due to more plant samples. The first experimental results showed that the averaged growing degree day from panicle initiation to panicle emergence stage of U-Thong2 was 720.8 °Cd, which is then used as the growing degree day requirement for the phase of all four varieties.

The base temperature of 16 °C also was used for panicle induction stage. Under optimal photoperiod condition, the growing degree day requirement for panicle induction (P22) is assumed to equal to the growing degree day required for a leaf production (PI) of the variety, which its value was from the experiment.

Photoperiod Sensitivity Coefficient (PS)

The experimental results showed that all varieties did not initiate panicle at 14, 15, and 16-hour photoperiod treatments, so the threshold photoperiod (P2O) and photoperiod sensitivity (PS) could not be calculated from the experimental data. P2O was assumed to be 12.5 h based on existing literature (Clements, 1975; James, 1969; James and Smith, 1969; and Levi, 1985). Simulation of panicle initiation of the first experiment with the ScFM 1.0 model, based on both CBM and CERES models at P2O 12.5 hours and various PS, showed that the difference of simulated panicle initiation date using CBM and CERES model was during zero to three days (Figure 4–7A and 4–7B). The difference seems to increase as increasing of the photoperiod sensitivity increased.

The simulation of panicle initiation based on the CBM model, which had more predictive capacity for daylength than CERES-model, showed that the simulated panicle initiation date of U-Thong2 variety was the same as observed date, when PS was 1.3 $hour^{-1}$ at P2O 12.5 hours (Figure 4–7A). For K84-200 variety, PS value was 6.0 $hour^{-1}$ gave the simulated panicle initiation date similar to the observed date (Figure 4–7B). The simulated initiation date of U-Thong2 and K84-200 varieties was the same, except at the value of PS less than 1.0 (Figure 4–8).



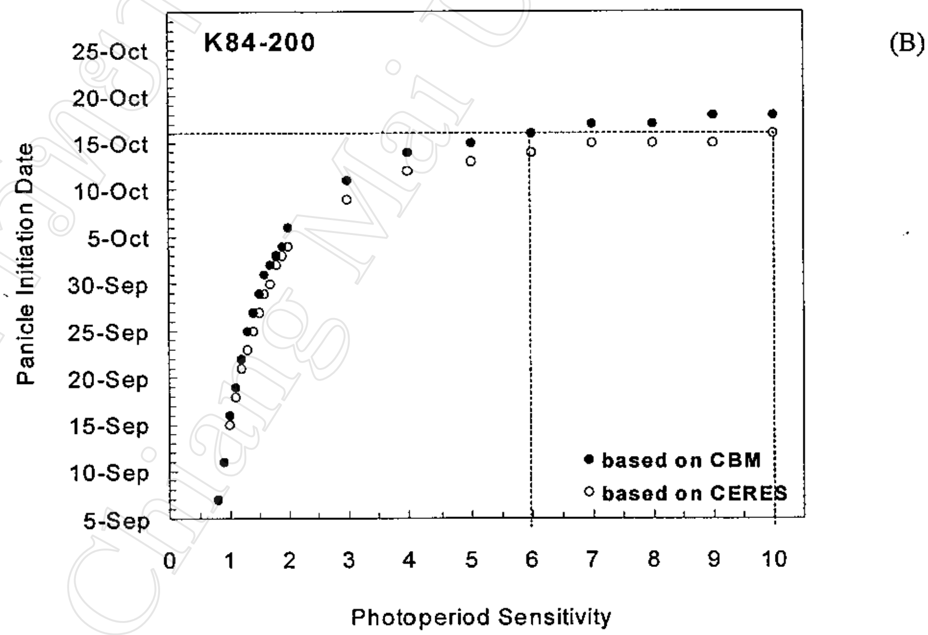


Figure 4-7 Simulation of panicle initiation of U-Thong2 (A) and K84-200 (B) variety with the ScFM 1.0 based on CBM and CERES-model.

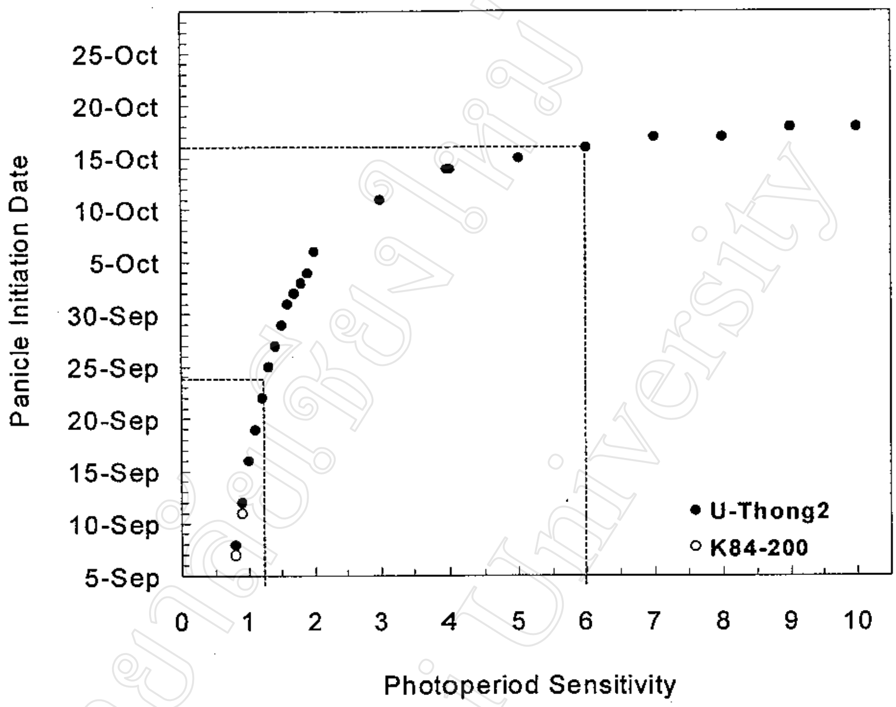


Figure 4-8 Simulated panicle initiation date at various PS of U-Thong2 and K84-200 variety with 12.5-hour P2O.

From the relationship depicted in Figure 2–1C (page 11), if P2O and PS of U-Thong2 variety were 12.5 hours and 1.3 $hour^{-1}$, respectively, then its critical photoperiod (CP) would be 13.27 hours (or 13 hours 16 minutes). The estimated CP value was nearly with CP value of a Hawaii clone, H37-1933, which its CP value was 13 hours 2 minutes (Clements, 1967). For K84-200 variety, if P2O and PS were 12.5 hours and 6 $hour^{-1}$, respectively, then its critical photoperiod (CP) would be 12.67 hours (or 12 hours 40 minutes).

All required genotype specific coefficients for simulation of sugarcane development, which was estimated in this section and was be used for model testing in the following sections, is presented in Table 4–8.

Table 4-8 The genotype specific coefficient, which were estimated from the first experiment data set.

Variety	Value of genetic coefficient				
	PI (1 and 2) (°Cd)	P2O (hours)	PS ($hour^{-1}$)	P22 (°Cd)	PE (°Cd)
CP78-1628	83.3	-99.0	0.0	83.3	721
K84-200	86.2	12.5	6.0	86.2	721
K88-92	82.6	-99.0	0.0	82.6	721
U-Thong2	86.9	12.5	1.3	86.9	721

Note: -99.0 value was used for non-sensitive to photoperiod variety.

Model Testing

Prediction of phenological development of sugarcane was tested for the dates of emergence, leaf ligule appearance, panicle initiation, and panicle emergence. Testing for the emergence date was done on all varieties in both planting dates using the calibrated equation 4.1. Testing for others events were done on all treatments in both experiments using the estimated genotype specific values in previous section.

Emergence Date

Tests on the emergence date were done with both experimental data sets, which was used to estimate coefficients. Table 4–9 summarizes the differences between simulated and observed emergence date of both planting dates. The mean error was 0.9 days and the SD was 2.1 days. The greatest error of the emergence date was found in CP78-1628 and K88-92 varieties. These errors were the result of the difference of the planting to emergence interval between varieties.

Table 4-9 The difference between simulated and observed emergence date

Variety	Planting date	Emergence date		Differences (days)
		Simulated	Observed	
CP78-1628	May 2, 1997	May 12, 1997	May 9, 1997	3
	March 9, 1998	March 21, 1998	March 17, 1998	4
K84-200	May 2, 1997	May 12, 1997	May 13, 1997	–1
	March 9, 1998	March 21, 1998	March 22, 1998	–1
K88-92	May 2, 1997	May 12, 1997	May 12, 1997	0
	March 9, 1998	March 21, 1998	March 19, 1998	3
U-Thong2	May 2, 1997	May 12, 1997	May 14, 1997	–2
	March 9, 1998	March 21, 1998	March 20, 1998	1
mean				0.9
SD				2.1

Leaf development

The errors of simulation of leaf number, as compared to the observed data sets, (RMSE) was greatest in K84-200 variety, which the error was 1.616 leaf. The lowest errors was found in U-Thong2 variety, with an errors of 0.898 leaf (Figure 4–9).

The simulated leaf number of U-Thong2 and K84-200 varieties were higher than the observed leaf number by 0.23 and 0.89 leaf, whereas the simulated leaf number of CP78-1628 and K88-92 varieties were less than the observed leaf number by 0.78 and 0.69 (Table 4–10).

However, the number of leaves on the main stem of each variety were not equal, so the R and V were used to compare the predictive capacity between varieties. The lowest error (V) or the best predicting of leaf number was found in U-Thong2 variety and the greatest error was found in K84-200 variety. The most over-estimated (R) was found in K84-200 variety and the most under-estimated was found in CP78-1628 variety.

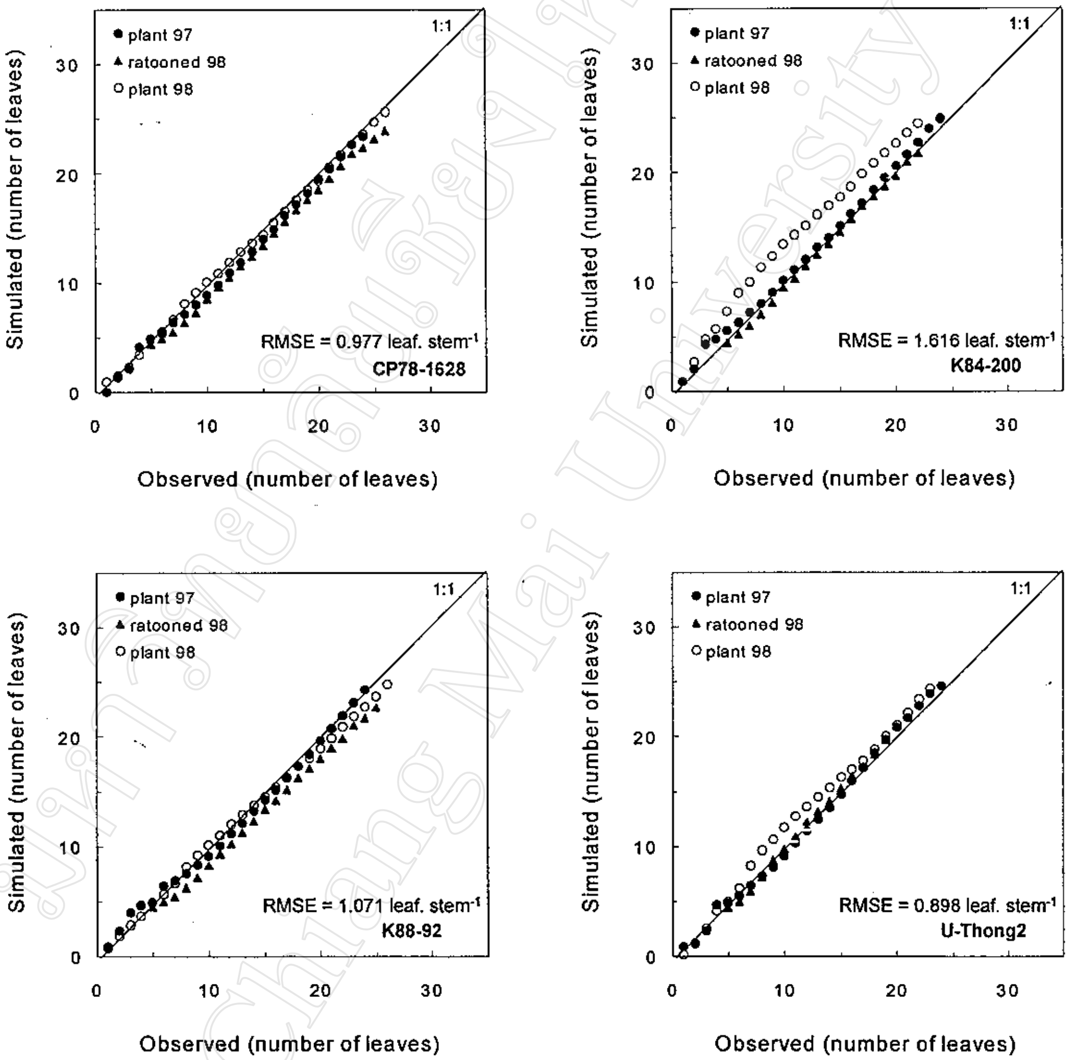


Figure 4-9 One-to-one line comparison of simulated and observed leaf number of four sugarcane varieties in both experiments in 1997 and 1998.

Table 4-10 Calculated statistics for the leaf number prediction

Variety	Statistical Testing			
	Bias leaf. $stem^{-1}$	RMSE leaf. $stem^{-1}$	R	V
CP78-1628	-0.785	0.977	-0.0570	0.00398
K84-200	0.887	1.616	0.0646	0.01074
K88-92	-0.699	1.071	-0.0469	0.00405
U-Thong2	0.230	0.898	0.0171	0.00349

Panicle initiation

Tests on the panicle initiation dates was done with two varieties, which initiated panicles in this study, by using PS 1.3 $hour^{-1}$ for U-Thong2 variety, PS 6.0 $hour^{-1}$ for K84-200 variety, P22 as the phyllochron value of the varieties and the P2O as 12.5 hours for both varieties. Table 4–11 summarizes the differences between the predicted and the observed panicle initiation dates of those varieties. The overall mean different was –4.8 days and the SD was 7.39 days. The error of the simulated panicle initiation of U-Thong2 variety was much lower than K84-200 variety. Furthermore, the simulated panicle initiation dates of plant cane K84-200 variety in the second experiment is on October 15, 1998, but the event was not observed in the experiment. It may be the result of other factors, which were not included in the model, or the interaction between temperature and photoperiod, which was found in other plants (Bernier et al., 1985). Additional panicle initiation data sets are required to improve the ScFM 1.0 model.

Table 4-11 Comparison between simulated and observed panicle initiation date using ScFM 1.0 based on CBM daylength model

Start Simulation	Variety	Emergence date		Difference (days)
		Simulated	Observed	
May 2, 1997 (Planted)	U-Thong2	September 25, 1997	September 24, 1997	1
	K84-200	October 16, 1997	October 16, 1997	0
March 9, 1998 (Planted)	U-Thong2	September 24, 1998	September 29, 1998	–5
	K84-200	October 15, 1998	–	–
March 7, 1998 (First ratooned)	U-Thong2	September 24, 1998	September 25, 1998	–1
	K84-200	October 15, 1998	November 3, 1998	–19
mean				– 4.8
SD				7.39

Note: the panicle initiation of first ratooned cane of K84-200 variety never reach 50%, so the first date of initiation was use as observed initiation date.

Panicle emergence

The observation of panicle emergence event was monitored until 31 December in both experiments. The observed panicle emergence date of both plant and first ratooned cane of K84-200 variety was not found in both experiments, so the GDD required for panicle initiation to panicle emergence interval (PE) could not be calculated. The PE value of plant U-Thong2 variety was 721 GDD, which is the only one for all treatments that found the panicle emergence event, is also used as the PE value of the K84-200 variety. Tests on the panicle emergence date were done with the initiated panicle treatment in both experiments. Table 4–12 summarizes the differences between simulated and observed panicle emergence date for the initiated variety in both experiments. The simulated panicle emergence dates of plant and first ratooned K84-200 variety in both experiments showed that the panicle emergence event was not observed in the field, which was similar with the observed. The simulated panicle emergence date of plant U-Thong2 variety in the first experiment is only two days over-predicted. However, the simulated panicle emergence date of plant and first ratooned U-Thong2 variety of the second experiment were on November 29, 1998, but the event was not found in the field observations.

Table 4-12 Comparison of the simulated and the observed panicle emergence date.

Start Simulation	Variety	Emergence date		Difference (days)
		Simulated	Observed	
May 2, 1997 (Planted)	U-Thong2	December 3, 1997	December 1, 1997	2
	K84-200	–	–	–
March 9, 1998 (Planted)	U-Thong2	November 29, 1998	–	–
	K84-200	–	–	–
March 7, 1998 (First ratooned)	U-Thong2	November 29, 1998	–	–
	K84-200	–	–	–

Sensitivity Analyses

Sensitivity test of crop parameters

Sensitivity analysis is a post-model development testing in which the model was further tested by changing a crop parameter input at a time while all others were held constant. Variables were changed by ±10% and ±50% of their standard values. The standard values for the tested parameter were presented in Table 4–13. The environmental variables were also held constant between comparative simulations. However, the planting dates are different. Simulations were made with May 2, 1997 and March 9, 1998 planting dates. The simulation results were shown as number of day changed from the standard simulation. Standard simulation values were shown in Table 4–14. The result of these tests, in simulated panicle initiation date was presented in Table 4–15.

The response to change in P22 was monotonic and almost symmetrical. A large increase in P22, up to 50% slightly delayed panicle induction time. The response to change in PS was monotonic, but not symmetrical at high change. That is, a 50% increase of PS value increased the induction time by only 11 days while 50% decrease of PS value decreased the induction time by 25 and 47 days for May 2 and March 9 planting date of U-Thong2 variety. For K84-200 variety, a 50% increase of PS value increased the induction time by two days while 50% decrease decreased by five days.

Table 4-13 Standard values of crop parameter used

Variable	Sugarcane Variety	
	U-Thong2	K84-200
P22	86.9	86.9
PS	1.3	6.0
P2O	12.5	12.5

Table 4-14 Standard simulated panicle initiation date by ScFM 1.0 at Chiang Mai latitude.

Start Simulation	Panicle initiation date	
	U-Thong2	K84-200
May 2, 1997	September 24, 1997	October 16, 1997
March 9, 1998	September 25, 1998	October 15, 1998

Table 4-15 Panicle initiation dates as affected by changing P22, PS, and P2O sugarcane genetic coefficients.

Variety	Start Simulation	% Change of parameter	Number of days changed from the standard		
			P22	PS	P2O
U-Thong2	May 2, 1997	+50	6	11	–34
		+10	1	2	–34
		–10	–1	–3	–
		–50	–7	–25	–
	March 9, 1998	+50	6	11	–87
		+10	2	2	–84
		–10	–1	–2	–
		–50	–7	–47	–
K84-200	May 2, 1997	+50	4	2	–55
		+10	1	1	–55
		–10	–1	0	–
		–50	–4	–5	–
	March 9, 1998	+50	4	2	–108
		+10	1	1	–79
		–10	0	0	–
		–50	–2	–4	–

The response of the model to changes in P2O values was reversing the sign but the magnitude was the same effect (Table 4–16). The simulated panicle initiation events were most sensitive to change in P2O parameter in the model. The larger increases in P2O values further decreased the induction time, but not symmetrical at a high change. The non-symmetrical response to change in PS and P2O value was the result of changing of daylength overtime (Figure 4–10). The effects of PS and P2O on induction rate, both are related to the daylength.

Table 4-16 Effect of changing the threshold photoperiod (P2O) on simulated panicle initiation date by ScFM 1.0 model.

Start Simulation	% Change of P2O	Number of days changed from the standard	
		U-Thong2	K84-200
May 2, 1997	+50	–34	–55
	+10	–34	–55
	+8	–34	–55
	+6	–30	–39
	+4	–25	–29
	+2	–16	–17
	–2	17	21
	–4	28	34
	–6	44	55
	–8	66	–
	–10	–	–
	–50	–	–
March 9, 1998	+50	–87	–108
	+10	–81	–70
	+8	–70	–57
	+6	–42	–39
	+4	–29	–28
	+2	–16	–17
	–2	18	20
	–4	29	36
	–6	43	54
	–8	67	–
	–10	–	–
	–50	–	–

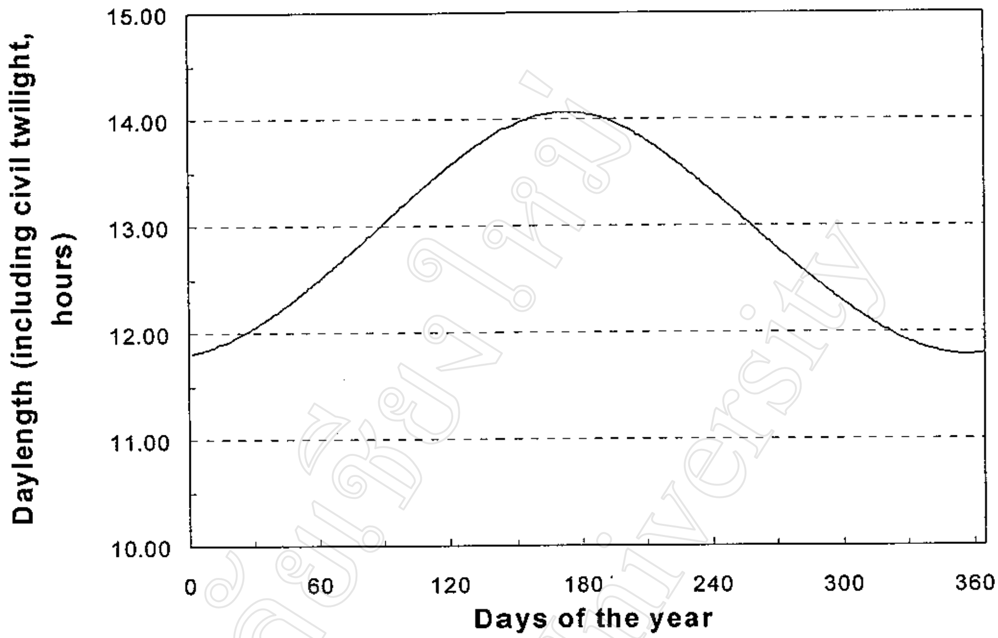


Figure 4-10 Simulated daylength from CBM model at Chiang Mai latitude during 1998.

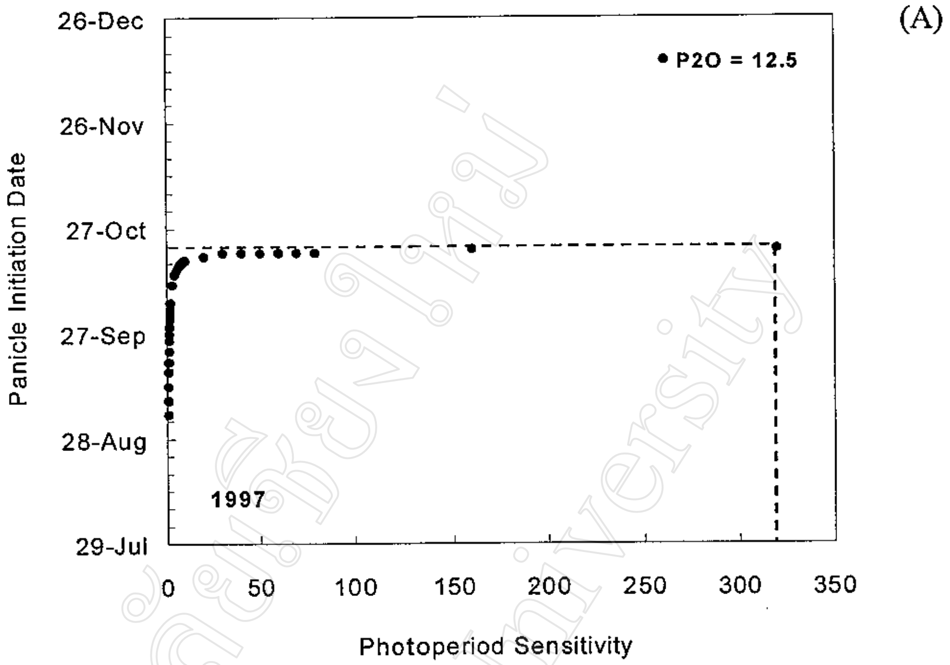
The responses of the model to a large decrease of PS value and increase P2O value were different with planting dates (Tables 4–15 and 4–16). The difference was the result of the different in starting time of respond to daylength of planting dates.

At a fixed P2O value, a low PS value is the result of its high CP value (see Figure 2–1, page 12), which is the photoperiod that an ended juvenile plant was start to be induced to initiate panicle. U-Thong2 variety, which its low PS value resulted from high CP Value, in May 2 planting date they ended their juvenile stage at daylength below the CP value whereas in March 9 planting date they ended their juvenile stage at the daylength above the CP value. This result in lower magnitude of response of May 2 planting date than March 9 planting date to the low PS value.

At fix PS, a high P2O value results in high CP value. Both cane varieties in May 2 planting date ends their juvenile stage at daylength below the CP value of 6% increase P2O whereas in March 9 planting date they end their juvenile stage at daylength above the CP value of 10% increase P2O. This result in lower magnitude of response of May 2 planting date than Mar 9 planting date to the high P2O value and result in indifference magnitude of response of May 2 planting date to 8%, 10% and 50% increase in P2O.

The model was further tested by changing 0.1-unit interval of PS and P2O while all others were held constant. The respond to P2O changes was greater than PS. Panicle initiations were also highly sensitive to change of PS parameter, but only at a low PS. The sensitivity to change of PS decreased as PS increased. Large increase of PS values caused the maximum simulated initiation date changed only 27 days from the standard date (Figure 4–11A). Whereas an hour change of the P2O, the simulated panicle initiation date changed as about 60 days (Figure 4–11B). Therefore, the difference in flowering time of early and late flowering variety, which more than one month, was possible to be the result of their different in P2O further than PS.

If the PS value of K84-200 variety was the same as value of U-Thong2, then simulating the panicle initiation date at various P2O. The P2O that gave the same panicle initiation date as observed was 12.1 hours (12 hours 6 minutes). However, new experimental data sets needs to be generated to test the hypothesis.



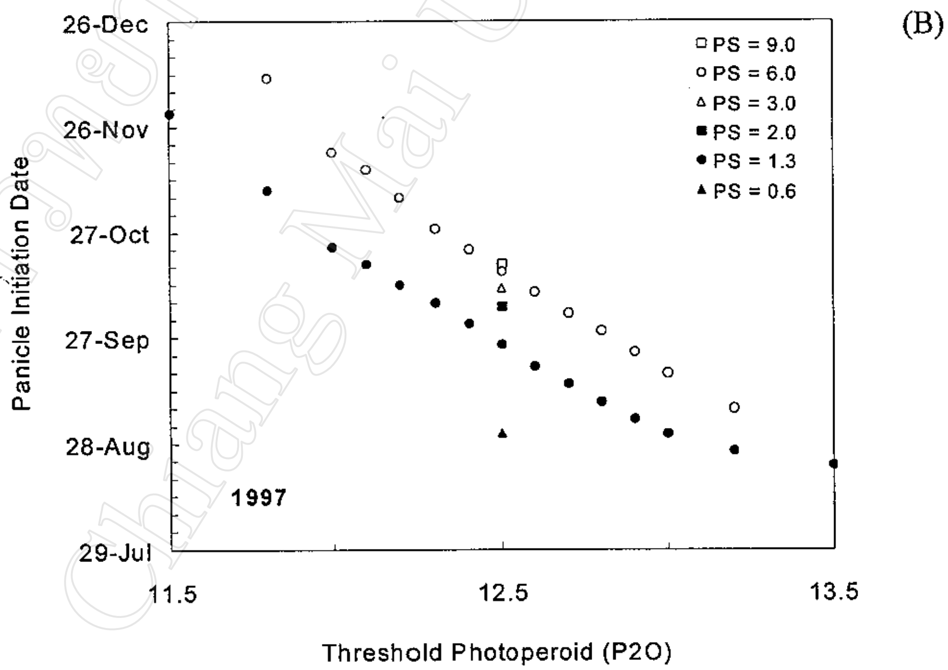


Figure 4-11 Simulated panicle initiation date at P2O 12.5 hours and various PS (A), and at 6 PS values and various P2O (B).

Sensitivity of Planting Dates

Using the standard value of crop parameters in Table 16, the simulation at monthly planting date interval since January 1995 to December 1996, which cover the planting dates of experiment of Chanmueng (1997) and Jintrawet et al. (1997a), gave the simulation result as shown in Figure 4–12.

The simulated panicle initiation date at planting date between January 1995 to May 1995 was on September 26, 1995 and at June 1995 to August 1995 planting date was on beginning of October to middle of December 1995, whereas planting date between September 1995 to May 1996 was on September 24, 1996. The simulation result agree with the observed flowering time in experiments conducted by Chanmueng (1997) and Jintrawet et al. (1997a).

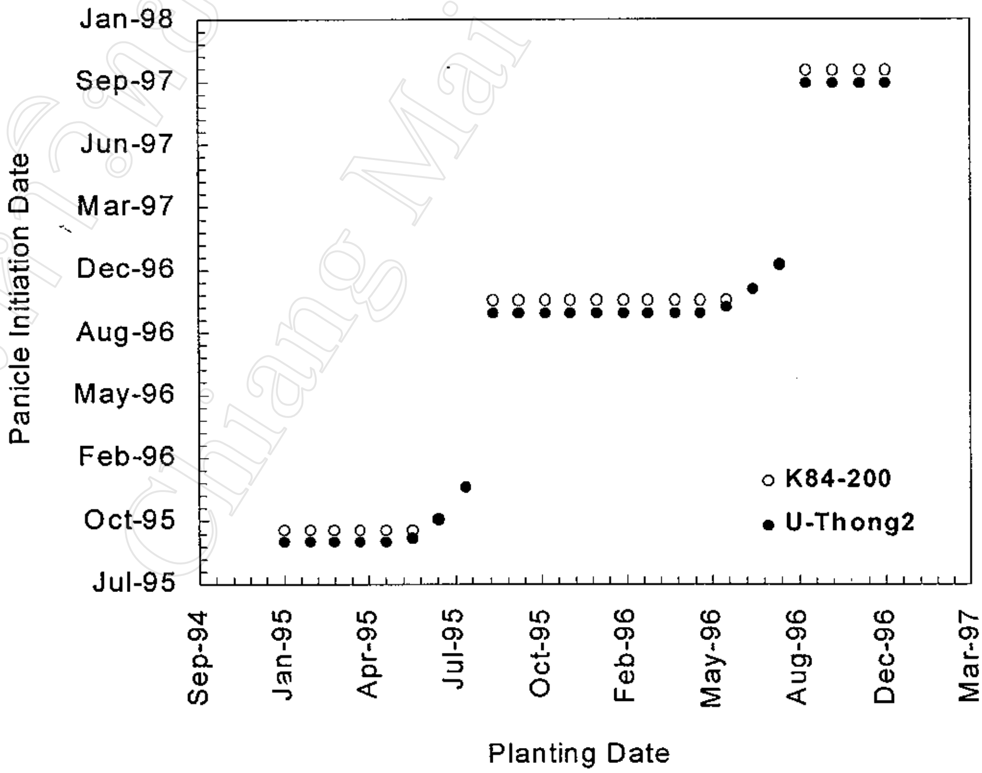


Figure 4-12 Simulated panicle initiation date of U-Thong2 and K84-200 variety at a monthly planting date interval.