CHAPTER 6

RESULTS OF FIELD EXPERIMENT

6.1 Experiment results

6.1.1 Observed phenological events

Phenological events of varieties of soybean in field experiment were summarized in Table 6.1.

Table 6.1 Observed phenological events[a] of soybean varieties in field experiment.

Variety	Sowing date	Anthesis date	First pod date	First seed date	Physiological maturity date
AK06	Aug 2	245 (31)	260 (46)	265 (51)	300 (86)
	Sept 14	287 (30)	294 (37)	297 (40)	340 (83)
TN12	Aug 2	242 (28)	250 (36)	265 (51)	289 (75)
	Sept 14	284 (27)	290 (33)	297 (40)	330 (73)
DT84	Aug 2	245 (31)	256 (42)	265 (51)	296 (82)
	Sept 14	288 (31)	292 (35)	294 (37)	335 (78)
CM60	Aug 2	249 (35)	255 (41)	261 (47)	309 (100)
	Sept 14	287 (30)	287 (32)	300 (43)	347 (90)

Note: [a] in Julian days; number in parenthesis showed days after planting.

Table 6.1 showed observed anthesis, first pod, first seed and maturity dates of four soybean varieties, namely AK06, TN12, DT84, and CM60 in August and September planting dates. The observed anthesis dates ranged from 27 to 35 days after planting. The shortest duration from planting to anthesis date that was observed for TN12 soybean variety in September planting date while the longest duration was found for CM60 in August planting date.

The first pod dates ranged from 32 to 46 days after planting, the shortest duration from planting to first pod for CM60 occurred in September planting date, and longest for DT84 in August planting date.

Days to first seed dates ranged from 37 to 51, the shortest duration from planting to first seed was 37 days for DT84 in September planting date and the longest duration from planting to first seed were found for AK06 in August planting date.

The observed days from planting to physiological maturity date ranged from 73 to 100 days. In soybean varieties used in field experiment, TN12 had the shortest growing period (73 days), while CM60 had the longest growing period (about 100 days).

6.1.2 Growth analysis

Leaf area index

In general, trend of LAI for all soybean varieties in August planting date were higher than those did in September planting date. These were displayed in Figure 6.1 (a), (b), (c) and (d).

Figure 6.1 (a) illustrated the difference between two planting dates in terms of LAI of AK06. LAI_{max} was obtained at around 65 and 54 DAP, and were 3.2 m^2 m^{-2} and 2.5m^2 m^{-2} in August and September planting dates, respectively. It was found that there was not much difference in LAI between two planting dates during the 15 to 27 DAP period. The LAI_{min} was attained at 80 DAP (0.5m^2m^{-2}) in PD2.

Figure 6.1(b) presented LAI of TN12 through two planting dates, similar to AK06, there is difference between LAI of PD_1 and PD_2 occurred, however, peak value of LAI for PD_1 was attained on 54 DAP, while the figure of PD_2 did at 45 DAP. Slight difference was appeared from 15 DAP to 27 DAP, and larger discrepancy occurred in remain growing season.

Figure 6.1 (c) illustrated the LAI of DT 84 in two planting dates. There was not much difference from 15 to 31 DAP and bigger difference occurred with the remaining period. The peak value most occurred the same time of 63 DAP of two planting dates but value of LAI was different (3.6m^2 m^{-2} and 2.5m^2 m^{-2} respecting to PD1 and PD2).

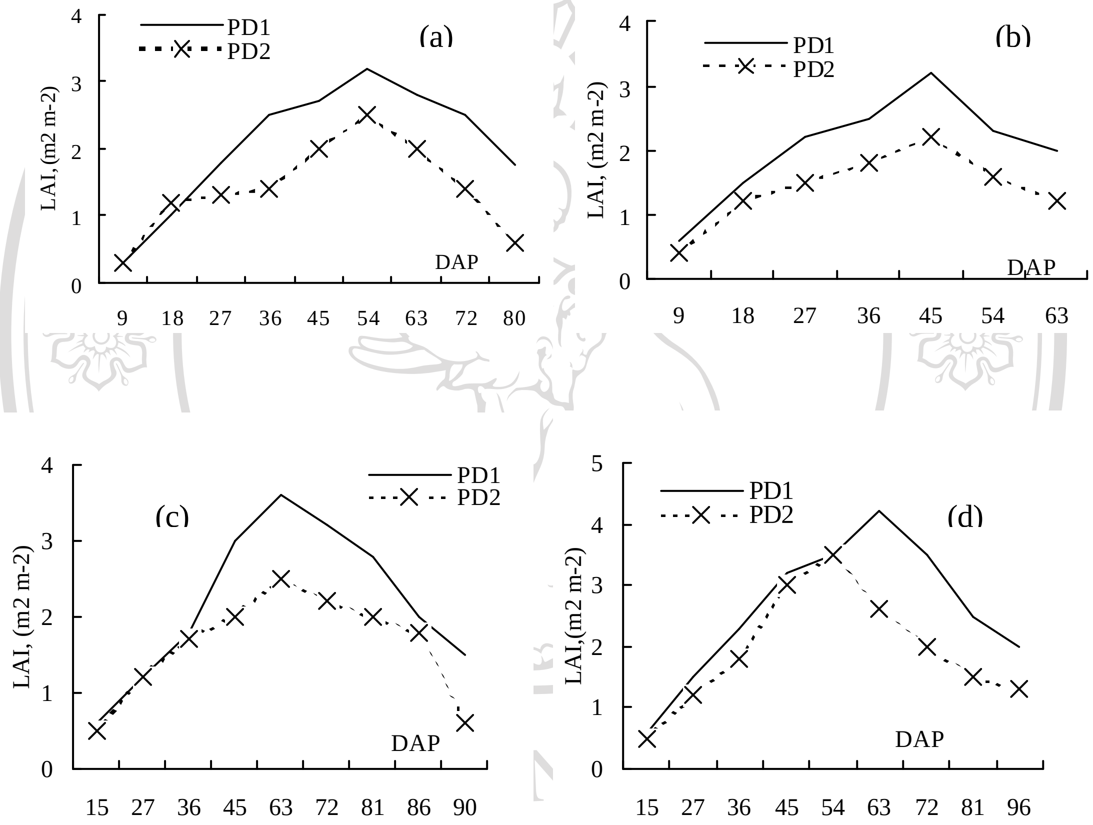

Figure 6.1 Comparisons of LAI of soybean variety between Aug. and Sept. planting dates (a) AK06, (b) TN12, (c) DT 84 and (d) CM 60.

Figure 6.1(d) showed the deviation between LAI of CM60 of PD_1 and PD_2 through season. The measured data supposed that LAI at PD_2 increased rapidly and attained the peak value of 3.5 m^2 m^{-2} on 48 DAP for PD2, when LAI of CM 60 at PD_1 attained the maximum value of 4.5 m^2 m^{-2} at 57 DAP, then decreased trend of LAI occurred after 48 DAP at PD_2 and 58 DAP at PD_1.

Maximum leaf area index (LAI $_{max}$)

Table 6.2 indicated that there was significant difference of maximum leaf area index of soybean varieties for all planting date and varieties ($P<0.01$). The coefficient of variation (CV) equals to 3.5 % implied that data collection in experiment is good in terms of LAI_{max}. The results also revealed that difference between planting dates and varieties of LAI was statistically significant at the 0.05 level.

Table 6.2 Analysis of variance for LAI_{max}.

Source of variation	F test
Replication (A)	NS
Planting date (B)	**
Variety (C)	**
B x C	NS
CV%	3.5

** Significance at 0.01 level ; * Significance at 0.05 level ;NS No significance

LAImax were calculated by fitting curves based on experimental data, ANOVA results indicated that there was no significant difference from one another among replications (appendix Fig.C1). These values were represented in Table 6.3.

Table 6.3 LAI_{max} of soybean varieties across two planting dates.

Varieties	August planting date (PD1)		September planting date (PD2)	
	LAI_{max}	DAP	LAI_{max}	DAP
AK06	2.8	62	1.7	62
TN12	2.7	50	1.7	47
DT84	3.0	62	2.2	60
CM60	3.8	62	2.9	50

LSD 0.05 of LAImax = 0.2239; LSD 0.01 of LAI_{max} = 0.5065

In general, LAI_{max} of four soybean varieties (AK06, TN12, DT84 and CM60) in August planting date were higher than those did in September planting date. It can estimate averages of LAI_{max} of them were more than 30% than that at PD2. In which, CM60 variety was achieved the highest value (3.8 m^2 m^{-2}) as compare to others varieties did in both planting dates.

In August planting date, LAI of AK06, DT84, CM60 all reached the maximum at the same time of 62 DAP, which were 2.8 m^2m^{-2}, 3.0 m^2m^{-2}, and 3.8 m^2m^{-2}, respectively, particularly, LAI of TN12 attained the peak value as earlier than other varieties and at 50 DAP, but maximum LAI $_{max}$ only was 2.7 m^2m^{-2}. At September planting date, LAI_{max} of AK06, TN12, DT84, CM60 get at various times of growing period, which were 1.7, 1.7, 2.2 and 2.9 m^2m^{-2}, respectively.

Yield, yield components and above ground biomass.

In analysis of variance for all trials, large effects of sowing date, their interaction were found for variety and planting date in trial ($P<0.01$ and $P<0.05$ in all case; Table 6.4).

Table 6.4 Analysis of variance for the final harvest.

Source of variation	F- test					
	Seed/pod (*# pod^{-1}*)	Seed number (*# m^{-2}*)	Weight pod $^{-1}$ (*g; dry*)	Pod yield (*kg ha^{-1}*)	Seed yield (*kg ha^{-1}*)	Above ground biomass (*kg ha^{-1}*)
Replication (A)	NS	NS	NS	NS	NS	NS
Planting date (B)	**	*	NS	**	**	*
Variety (C)	**	**	*	**	**	**
B x C	*	**	NS	**	**	**
CV%	14.9	9.2	6.4	3.2	10.6	10.7
$LSD_{0.05}$	0.1925	137.06	0.233	221.76	49.636	311.26
$LSD_{0.01}$	0.4439	316.15	0.538	511.53	114.49	717.99

** Significance at 0.01 level, * Significance at 0.05 level and NS non significance

These results confirmed the strong effects of sowing date on growth and yield and support the hypothesis that difference types of germplasm vary in their responses to conditions in the Chiang Mai University. CV% mostly were less than 20 percent which illustrated the difference of replications occurred but slightly. The planting dates and variety are interacted with significant of one percent levels in both maximum point and final harvest with CV% of 10.7%. In this trial, seed yield, seed weight, seed number, seed per pod and biomass decreased responding to sowing date was displayed (Table 6.5).

Table 6.5 Change of yields and yield components of four soybean varieties across two planting dates.

	Seed yield *(kg ha^{-1})*	1000-seed weight *(g;dry)*	Seed number *(# / m^{-2})*	Seed per pod *(# / pod $^{-1}$)*	Above ground biomass *(kg ha^{-1})*
AK06					
PD1 (a)	1,656	159	950	1.8	3,000
PD2 (b)	1,156	150	867	1.5	2,200
Difference (a-b)	500	9.0	83.0	0.3	800
TN12					
PD1 (a)	1,527	162	800	1.9	2,500
PD2 (b)	1,200	160	704	1.6	1,823
Difference (a-b)	327	2.0	96.0	0.3	677
DT84					
PD1 (a)	1,804	158	1,058	2.0	4,250
PD2 (b)	1,209	155	958	1.6	2,828
Difference (a-b)	595	3.0	100	0.4	1,422
CM60					
PD1 (a)	1,560	140	1,477	1.8	4,800
PD2 (b)	1,368	138	1,077	1.6	3,717
Difference (a-b)	192	2.0	400	0.2	1,083

In September planting date, grain yield, seed number and biomass decreased more than others indicators as compared to those did in August plating date. Implying that the greatest effect was on overall growth rather than on partitioning for seed growth (Table 6.5). There were differences in seed yield between two planting dates, ranged 192 kg - 595 kg ha $^{-1}$, minimum for CM60, and maximum difference for DT

84. In regard with others, weight per seed difference was no occurred. Differences of seed numbers between two planting dates of varieties ranged from 83 to 400 seed m^{-2}, the least appeared with AK06.

Above ground biomass ranged from 2,500 to 4,800 kg ha $^{-1}$ at PD1 and from 1,823 to 3,717 kg ha $^{-1}$ at September planting date (PD2), in which, CM 60 variety attained the highest value while TN12 had the lowest in August planting date. These results implied that biomass was affected by planting date and had big gap between two planting dates.

6.2 Results of the Bragg (7) coefficients

6.2.1 Phenological events

Figure 6.2(a), 6.2 (b), 6.2 (c) and 6.2 (d) illustrated phenological events of four varieties in August and September planting dates. In general, there were agreements between observed and simulated data of phenological events for AK06, TN12, and DT84. It was proved that points denoted as pairs of observed and simulated events of all soybean varieties, except CM60, closed with line 1:1.

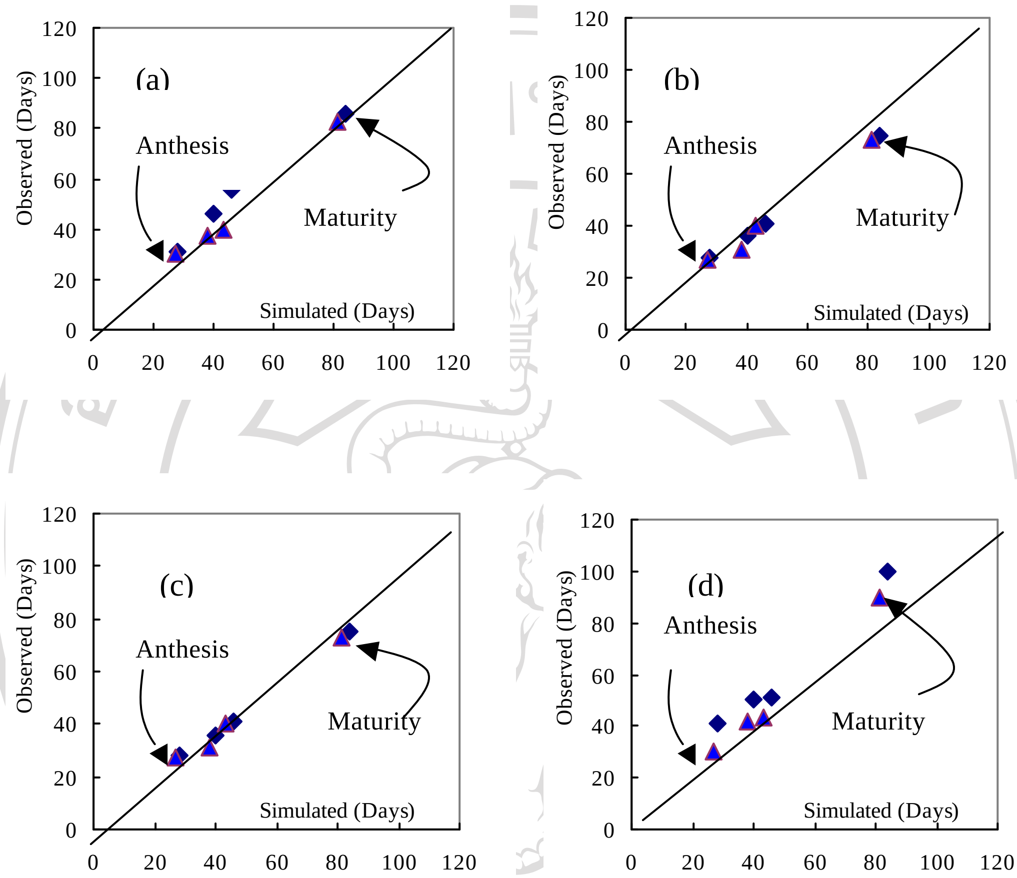

Figure 6.2 Comparisons between observed and simulated days to anthesis, first pod, first seed and maturity of AK06 (a), TN12 (b), DT84 (c) and CM60 (d) using Bragg (7) genetic coefficients. Note: August (◆) and September (▲) planting dates.

Table 6.6 indicated that Bias and RMSE in AK06, TN12 and DT84 in anthesis were slightly different but much different in CM60 (RMSE = 9.5 days for both planting dates). Number of days to first pod, first seed and maturity of four varieties were slightly different. To obtain the good agreement between observed and simulated phenological events, modified genetic coefficients need to be conducted. This was because RMSEs of comparison between observed and simulated data of remaining phenological events were not acceptable. It was illustrated that, for first pod date of all varieties, RMSE =4.3, 5.7, 4.0 and 8.5 days for AK06, TN12, DT84 and CM60, respectively. First seed needed adjust for all of them. Maturity date can be done by adjust for TN12 and CM60 with purpose to minimize RMSE.

Table 6.6 Bias and RMSE of comparisons between simulated and observed days to anthesis, first pod, first seed and maturity date.

Variety	Statistic indicators	Anthesis	First pod	First seed	Maturity
AK06	Bias	-3.0	-2.5	-3.5	-2.0
	RMSE	3.0	4.3	7.4	2.0
TN12	Bias	2.0	5.5	4.0	8.5
	RMSE	2.0	5.7	4.2	8.5
DT84	Bias	-3.5	-1.5	0.5	2.5
	RMSE	3.6	4.0	5.6	2.6
CM60	Bias	-8.0	6.0	-2.5	-12.5
	RMSE	9.5	8.5	3.6	13.0

In summary, model run based on genetic coefficient of Bragg (7) CM60 has greater RMSE than other soybean varieties at anthesis, first pod and maturity date. It means that we should consider and adjust much genetic coefficients concerning phenology of it until RMSE became the smallest to be accepted.

6.2.2 Growth parameters and yield components.

Growth parameters such as grain yield, pod yield, biomass and maximum LAI are considered before calibrating. Table 6.7 showed results of them in terms of bias and root mean square error. It reported that there was slightly difference in term of grain yield with RMSE = 86.7 kg ha $^{-1}$ for TN12. It has the highest RMSE for CM60 in terms of grain yield, pod yield, biomass and maximum LAI than other varieties. Although DT84 soybean variety also get RMSE = 1674.6 kg ha $^{-1}$ and 1.6 m^2 m $^{-2}$ for biomass and LAI_{max}, respectively. It implied that need strong adjusted for DT84 and CM60 in terms of pod yield, biomass at harvest and LAI_{max}.

Table 6.7 Bias and RMSE of comparisons between simulated and observed grain yield, pod weight, biomass and LAI $_{max}$.

Variety	Statistics indicators	Grain yield (kg ha $^{-1}$)	Pod yield (kg ha $^{-1}$)	Biomass (kg ha $^{-1}$)	LAI_{max} (m^2 m^{-2})
AK06	Bias	-194.0	-22.0	-670.5	-1.2
	RMSE	165.9	28.4	678.0	1.3
TN12	Bias	-6.0	188.5	-232.0	-0.1
	RMSE	86.7	197.4	248.9	1.0
DT84	Bias	-187.0	-622.5	-1,609	1.6
	RMSE	261.7	629.2	1,674	1.6
CM60	Bias	-478.0	-1,173	-2,329	5.1
	RMSE	478.1	1,178	2,347	2.3

From Figure 6.2, Tables 6.6 and 6.7, genetic coefficients concerning phenological events and growth of four soybean varieties should be adjusted more or less, but with CM60 these coefficients should adjust more. Calibrating genetic coefficients could be done for these varieties. Bragg (7) default was initial coefficients to start the adjustment until to match simulated and observed data from experiment. That method and results would be discussed further in next section.

6.3 Results of modified coefficients.

The CROGRO-Soybean model was calibrated against measured data for phenological, growth, yield and yield components of four soybean varieties in both planting dates. The calibration process would be started from the initial genetic coefficients of BRAGG (7). Based on principle best fit of simulated from the model and observed data from experiment, the calibrated genetic coefficients were obtained from program GENCAL that was embedded in DSSATv.3.5. The end-point used to show simulated and observed data. Whichever parameters in terms of phenological, growth and yield components are not fitted or have high RMSE that would be adjusted by modifying the genetic coefficients of BRAGG (7). Each genetic coefficient of BRAGG (7) was adjusted until RMSEs of phenology, growth, yield and yield components for both planting dates were minimized. Measurements from varieties and planting dates treatments of 2002 experiment were used for this purpose.

Crop life cycle: The first step in any model calibration it should be concentrated on crop development (flowering date and maturity date). A start should be made by selecting the starting parameter values from initial Bragg (7) variety, assuming the critical daylength and photoperiod sensitivity values are correct, and adjusting the duration of the period between germination or emergence and flower appearance until flowering date is simulated correctly. Then, the period between first seed and physiological maturity should be adjusted until maturity date is correct. Four soybeans' phenological genetic coefficients were adjusted by modifying genetic coefficients of Bragg (7) including EM – FL (3) to adjust days to flowering, FL – SD (5) to adjust days to seed addition, SD – PM (6) to adjust days to maturity.

Dry matter accumulation: The next step involves a comparison of simulated and measured biomass value. If simulated dry matter accumulation is too rapid or too slow, parameters that affect leaf and canopy photosynthesis will need to be adjusted. Some genetic coefficients are used in this term as LFMAX (8) to adjust biomass.

Leaf area index and specific leaf area: Several 'cultivars' parameters can impact somewhat on dry matter accumulation via their effect on leaf area index and light interception. These include specific leaf area, time to cessation of leaf area expansion, early leaf area expansion, and the timing of pod and seed growth. Of these characteristics, specific leaf area was adjusted first then the simulated leaf area curve was compared with real data and the other parameters adjusted to achieve a reasonable match. Genetic coefficients are be adjust as FL – LF (7) and SLAVAR (9) adjust leaf area index.

Yield and yield components: These values are adjusted by changing values of genetic coefficient Bragg (7) initial as WTPSD (12) to adjust weight per seed, SFDUR (13) to adjust yield. The rate of specific leaf area (SLA) was calibrated by changing value of SLAVAR (9). SLAVAR were adjusted such that simulated peak

SLA matched observed SLA values. Rate of pod per square meter was altering pod addition rate, PODUR (15). Seed growth was calibrated by changing values of seed growth rate coefficient (SDVAR). Finally, the simulated harvest index was matched with actual harvest index by changing XFRT (11) and PODUR (15). To calibrate the cultivars for photoperiod sensitivity for pod addition and pod growth rate, CSDVAR and PPSEN were set at 13 and 20 h of night length, respectively.

Table 6.8 Genetic coefficients of AK06, TN12, DT84 and CM60 estimated from experiment data.

Genetic coefficients	Unit	BRAGG (7)	AK06	TN12	DT84	CM60
CSDL (1)	*h*	12.33	12.33	12.33	12.37	12.34
PPSEN (2)	*1/h*	0.32	0.32	0.32	0.33	0.32
EM-FL (3)	*p-t-d*	19.50	19.50	19.50	20.50	20.50
FL-SH (4)	*p-t-d*	10.00	10.50	9.00	9.50	10.00
FL-SD (5)	*p-t-d*	15.00	16.00	13.50	14.00	11.00
SD-PM (6)	*p-t-d*	36.80	36.80	35.80	36.80	38.00
FL-LF (7)	*p-t-d*	19.00	26.00	25.80	26.00	26.00
LFMAX (8)	CO_2/m^2s	1.00	1.30	1.15	1.40	1.40
SLAVR (9)	cm^2/g	355.0	400.0	400.0	400.0	400.0
SIZLF (10)	$cm^2/leaf$	170.0	170.0	170.0	170.0	170.0
XFRT (11)		1.00	1.00	1.00	1.00	1.00
WTPSD (12)	*g*	0.17	0.16	0.17	0.16	0.17
SFDUR (13)	*p-t-d*	23.50	20.00	26.00	21.50	24.50
SDPDV (14)	*seed*	2.05	1.90	2.10	1.95	2.10
PODUR (15)	*pod/day*	10.00	9.00	10.00	9.50	10.00

Note: p-t-d, photothermal days.

Table 6.8 indicated that 15 genetic coefficients of four soybean varieties in August and September planting dates are accepted. There were 11 coefficients out of 15 genetic coefficients being adjusted more or less, in order to obtain the agreement between simulated and observed data. The calibrated model needs to be tested in term of phenological like anthesis, first pod, first seed and physiological maturity date. The growth parameters such as above ground biomass, pod weight, seed weight, leaf area index and grain yield also were involved in the testing process. Finally yield and yield components are tested in terms of biomass at final harvesting, seed per pod, pod per square meter, and 1000 seeds weight, and harvest index. The process of testing the agreement of simulated and observed values was described in next section.

6.4 Testing the modified coefficient

6.4.1 Phenological events

New set of genetic coefficient (Table 6.8) was obtained by calibrating the set of genetic coefficients Bragg (7) by running GENCAL. By graphical method, results showed that the simulated and observed anthesis, first pod, first seed and physical maturity dates matched well for most varieties, except for CM60 (Figure 6.2, 6.3, 6.4, and 6.5). As be seen in the graph, the points represented for anthesis, first pod, first seed and maturity were relatively close one –to-one line for almost varieties. Therefore, it was concluded that genetic coefficients were adjusted to acceptable values. The obtained genetic coefficient once EM-FL (3) was not changed for AK06, TN12, and increased one photothermal day for DT84 and CM60 (Table 6.3), most FL – SH were not adjusted, FL – SD (5) was not changed for AK06, TN12, but decreased 1 photothermal day for DT84, and 4 photothermal days for CM60. SD – PM (6) was not adjusted for AK06, TN12 and DT84 but changed 2 photothermal days for CM60.

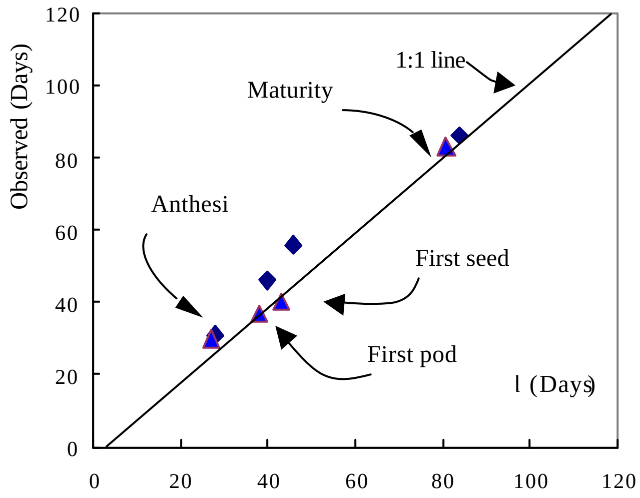

Figure 6.3 Comparisons between observed and simulated number of days to anthesis, first pod, first seed and maturity of AK06. Genetic coefficients determined from experiment data in August (◆) and September (▲) planting dates.

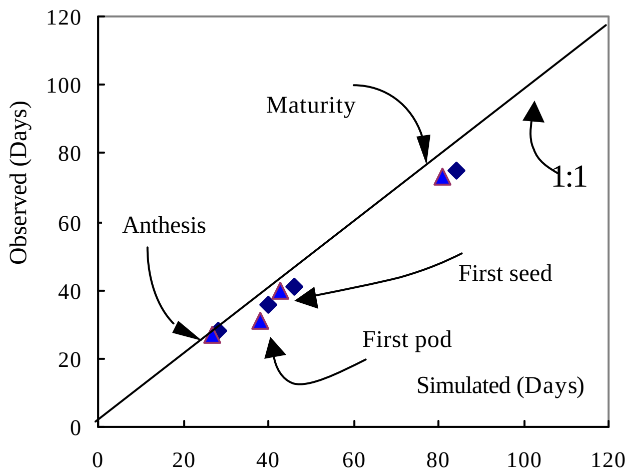

Figure 6.4 Comparisons between observed and simulated number of days to anthesis, first pod, first seed and maturity of TN12. Genetic coefficients determined from experiment data in August (◆) and September (▲) planting dates.

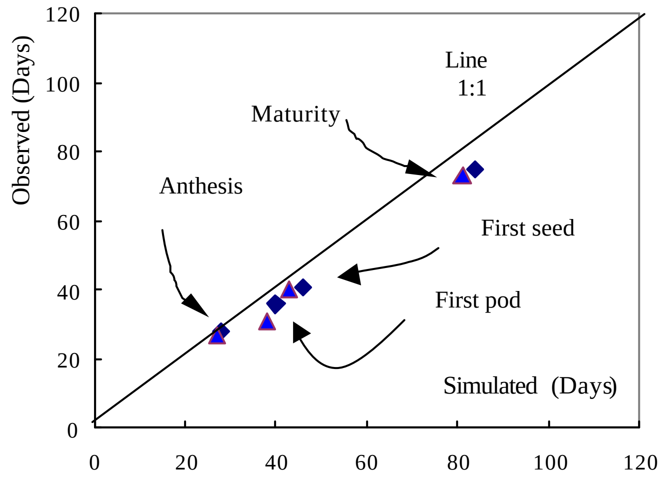

Figure 6.5 Comparisons between observed and simulated number of days to anthesis, first pod, first seed and maturity of DT84. Genetic coefficients determined from experiment data in August (◆) and September (▲) planting dates.

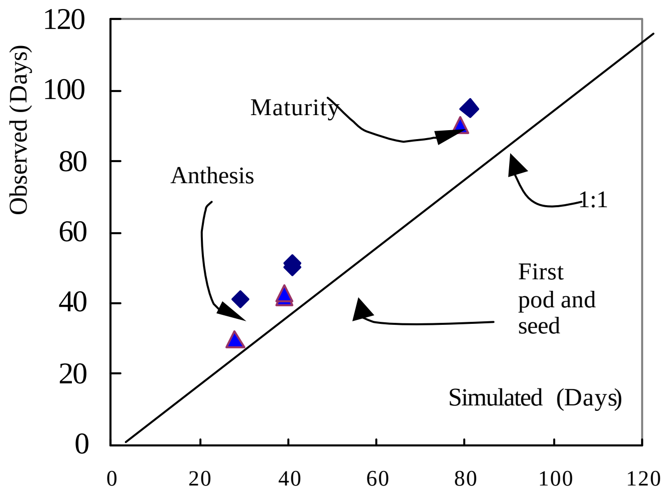

Figure 6.6 Comparisons between observed and simulated number of days to anthesis, first pod, first seed and maturity of CM60. Genetic coefficients determined from experiment data in August (◆) and September (▲) planting dates.

Accompanied the graphical method, the phenological events were also tested by using statistical method (Bias, RMSE). The results were as follows:

Anthesis date

Table 6.9 demonstrated that the model simulate days to anthesis date of all four varieties of soybean satisfactory.

Table 6.9 Bias and RMSE of comparisons between simulated and observed days to anthesis date.

Varieties	Planting dates	Modified coefficient			Bragg (7) coefficient
		Simulated	Observed	Difference	Difference
AK06	August 2 (214)	28	31	-3	-3
	September 14 (257)	27	30	-3	-3
	Bias			*-3*	*-3.0*
	RMSE			*3.00*	*3.0*
TN12	August 2 (214)	28	28	0	2.0
	September 14 (257)	27	27	0	2.0
	Bias			*0*	*2.0*
	RMSE			*0.00*	*2.0*
DT84	August 2 (214)	28	31	-3	-3
	September 14 (257)	28	31	-3	-4
	Bias			*-3*	*-3.5*
	RMSE			*3.00*	*3.6*
CM60	August 2 (214)	29	35	-6	-13
	September 14 (257)	28	30	-2	-3
	Bias			*-4.0*	*-8.0*
	RMSE			*4.47*	*9.5*

It was found that the model well estimated anthesis date of TN12 for both planting dates (RMSE=0). However, the model trend to underestimate anthesis date of the other three varieties, namely AK06, DT84, and CM60.

The greatest difference between observed and simulated anthesis date was found in CM60 in August planting date, which was 6 days. After calibrated model most of RMSE reduced except AK06. CM60 strongly decreased (9.5 down to 4.47), while slightly reduced in DT84 (3.6 down to 3.0).

First pod date

Table 6.10 Bias and RMSE of comparisons between simulated and observed days to first pod of four soybean varieties.

Varieties	Planting dates	Modified coefficient			Bragg (7) coefficient
		Simulated	Observed	Difference	Difference
AK06	August 2 (214)	40	46	-6	-6
	September 14 (257)	37	37	0	1
	Bias			*-3.00*	*-2.5*
	RMSE			*3.0*	*4.3*
TN12	August 2 (214)	40	36	4	4
	September 14 (257)	38	33	5	7
	Bias			*4.50*	*5.5*
	RMSE			*4.52*	*5.7*
DT84	August 2 (214)	41	42	-1	2
	September 14 (257)	39	35	4	-5
	Bias			*1.50*	*-1.5*
	RMSE			*2.92*	*3.8*
CM60	August 2 (214)	31	41	-10	12
	September 14 (257)	32	32	0	0
	Bias			*-5.00*	*6.0*
	RMSE			*7.07*	*8.5*

Table 6.10 indicated that the model overestimated the observed first pod date for TN12 and DT84. In constrast, trend of model was underestimated the observed value for AK06, CM60 in both planting dates. In which, the calibration occurred with better accuracy for CM60, since RMSE was reduced from 8.5 days to 7.0 days. Modified coefficients achieved lower RMSE than Bragg (7) coefficients but it not much.

First seed date

Table 6.11 represented that the model simulated first seed date of all four varieties of soybean acceptable.

Table 6.11 Bias and RMSE of comparisons between simulated and observed days to first seed date of four soybean varieties.

Varieties	Planting dates	Modified coefficient			Bragg (7) coefficient
		Simulated	Observed	Difference	Difference
AK06	August 2 (214)	260 (46)	265 (51)	-5	-10
	September 14 (257)	300 (43)	297 (40)	3	3
	Bias			*-1.00*	*-3.50*
	RMSE			*4.12*	*7.40*
TN12	August 2 (214)	260 (46)	265 (51)	5	5
	September 14 (257)	399 (42)	297 (40)	2	3
	Bias			*3.50*	*4.00*
	RMSE			*3.80*	*4.20*
DT84	August 2 (214)	261 (47)	265 (51)	-4	-5
	September 14 (257)	397 (42)	294 (39)	3	6
	Bias			*-1.0*	*0.5*
	RMSE			*3.53*	*5.60*
CM60	August 2 (214)	258 (44)	261 (47)	-3	-5
	September 14 (257)	297 (40)	300 (43)	-3	0
	Bias			*-3.00*	*-2.5*
	RMSE			*3.00*	*3.60*

RMSEs responding to varieties were slightly different with range 3.0- 4.12. The highest value occurred in AK06 and the smallest were for CM60. The model underestimated the days to first seed for AK06, DT84 and CM60 but overestimated the value for TN12 in August and September planting dates. RMSE of all soybean varieties are reduced less or much due to calibration process. AK 06 variety strong decreased from 7.4 to 4.12 days in August and September planting dates.

Physiological maturity date

Table 6.12 Bias and RMSE of comparisons between simulated and observed days to physiological maturity date of four soybean varieties.

Varieties	Planting dates	Modified coefficient			Bragg (7) coefficient
		Simulated	Observed	Difference	Difference
AK06	August 2 (214)	298 (84)	300 (86)	-2	-2
	September 14 (257)	338 (81)	340 (83)	-2	-2
	Bias			*-2.00*	*-2.0*
	RMSE			*2.00*	*2.0*
TN12	August 2 (214)	294 (80)	289 (75)	5	9
	September 14 (257)	335 (78)	330 (73)	5	8
	Bias			*5.00*	*8.5*
	RMSE			*5.00*	*8.5*
DT84	August 2 (214)	297 (83)	296 (82)	1	2
	September 14 (257)	337 (80)	335 (78)	2	3
	Bias			*1.50*	*2.5*
	RMSE			*1.58*	*2.6*
CM60	August 2 (214)	301 (92)	309 (100)	-8	-16
	September 14 (257)	347 (90)	347 (90)	0	-9
	Bias			*-4.00*	*-12.5*
	RMSE			*5.65*	*13.0*

Table 6.12 showed that simulated and observed days to physiological maturity date were well matched for AK06 and DT84 with RMSE ranged from 1.58 to 2.0 days, and close agreement of the values for TN12, CM60 with RMSE varied between 5.0 and 5.7 days. The genetic coefficient SD - PM (6) was adjusted to be obtained at 35.8 photothermal days for TN12 and 38.8 photothermal days for CM60. RMSE days to physiological maturity was 8.5 and 13.0 days for TN12 and CM60 experiments, respectively (Table 6.6). Now RMSE were decreased to be 5.0 and 5.7 days for TN12 and CM60, respectively. Coefficients of CM 60 were adjusted more than others (RMSE declined from 13 to 5.65 days).

The overall results indicated that the calibrated model predicted phenological events relatively accurate in terms of anthesis, first pod, first seed and maturity dates, it also means that genetic coefficients controlling phenological events were completely acceptable.

6.4.2 Model testing for growth and yield components

Leaf area index

Figures 6.7 (a), (b), (c), and (d) shows the observed and simulated LAI of AK06, TN12, DT84 and CM60. Generally, the trend of model illustrated relatively good agreement of simulated and measured of LAI across two planting dates for all of them. The model underestimated LAI of four varieties in both planting dates, Excepted at 58 and 46 days in both planting dates in TN12 and at 46 DAP in DT84 and CM60 in September planting date, and at most part of growing season for CM60, except at 62 DAP.

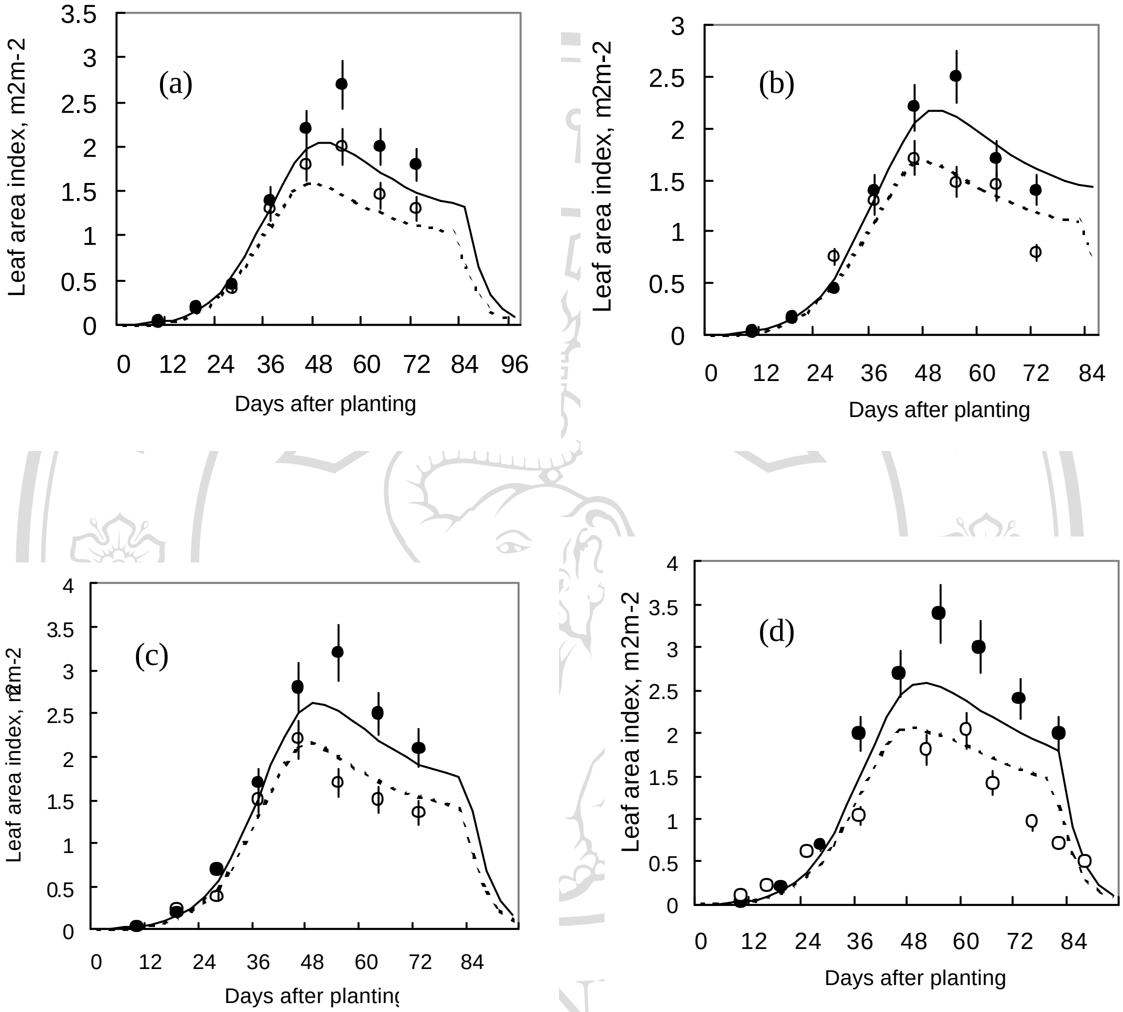

Figure 6.7 Comparisons between simulated and observed data of LAI of four varieties (a) AK06, (b) TN12, (c) DT 84, and (d) CM60 in planting dates. Note: (—) presented the simulated and (●) observed LAI in Aug. planting date; (----)presented simulated and (○) observed in Sept. planting date. Vertical bar showed error 10% of mean.

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Maximum leaf area index (LAI_{max})

Figure 6.8 illustrated simulated and observed LAI_{max} for 4 soybean varieties in August and September planting dates together with models of Bragg (7) coefficient and modified by equation and squared-R between simulated and observed data.

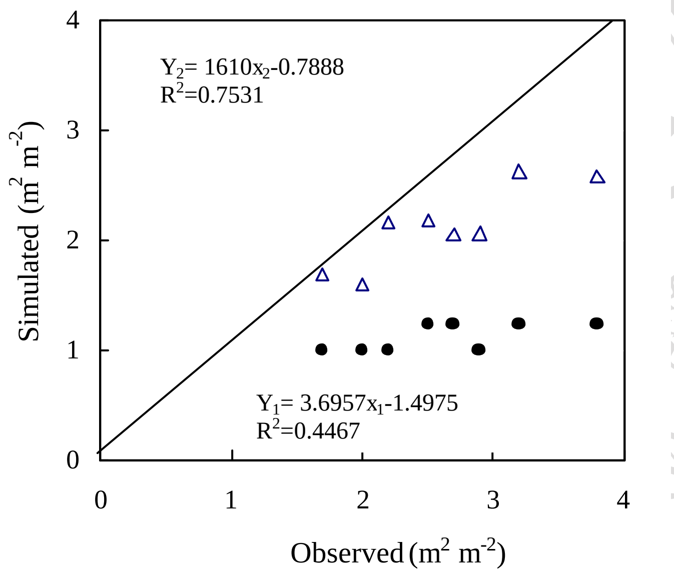

Figure 6.8 Comparisons between observed and simulated LAI_{max} by the Bragg (7) coefficient(●) and modified coefficient (Δ) of four varieties in August and September planting. Each point represents the mean of three replicates.

All of points of both Bragg (7) coefficient and modified coefficients were underestimated for four varieties in August and September planting dates. The model estimated LAI_{max} satisfactorily for four soybean varieties. The agreement between simulated and observed was examined by squared-R, it was found the correlation coefficient changed from 0.45 to 0.75, in other words, the model estimated better than before. Furthermore, need to compare simulated and observed data by considering difference, bias, and RMSE for four soybean varieties in both planting dates.

RMSE computed indicated the agreement between simulated and observed LAImax of four soybean varieties across planting dates (Table 6.13). In general, both models underestimated due to bias of negative value for August and September planting dates in the range of 0.17m^2 m^{-2} (TN12) to 1.03m^2 m^{-2} (CM60) in modified coefficient. The range for Bragg (7) coefficient was between 0.99 - 2.24 m^2 m^{-2}.

Table 6.13. Bias and RMSE of comparisons between simulated and observed LAI_{max} by modified and Bragg (7) coefficients.

Varieties	Planting dates	Modified coefficient			Bragg (7) coefficient	
		Simulated	Observed	Difference	Simulated	Difference
AK06	August	2.05	2.70	-0.65	1.23	-1.47
	September	1.60	2.00	-0.40	1.00	-1.00
	Bias			-0.53		-1.24
	RMSE			0.54		1.26
TN12	August	2.18	2.50	-0.32	1.23	-1.27
	September	1.69	1.70	-0.01	1.00	-0.70
	Bias			-0.17		-0.99
	RMSE			0.23		1.03
DT84	August	2.63	3.20	-0.57	1.23	-1.97
	September	2.16	2.20	-0.04	1.00	-1.20
	Bias			-0.31		-1.59
	RMSE			0.40		1.63
CM60	August	2.58	3.80	-1.22	1.23	-2.57
	September	2.07	2.90	-0.83	1.00	-1.90
	Bias			-1.03		-2.24
	RMSE			1.04		2.26

The consideration was also based on RMSE, it considered that most of RMSE were lower than this run with model Bragg (7) (1.26 to 0.54, 1.03 to 0.23, 1.63 to 0.4, 2.26 to 1.04 m^2 m^{-2} in respect to AK06, TN12, DT84 and CM60. It was concluded that parameter in genetic component have been adjusted acceptably in terms of prediction of LAI_{max}.

Above ground biomass

Figure 6.9(a), (b), (c) and (d) show above ground biomass of soybean varieties in both planting dates. The model underestimates biomass of DT84 and CM60 in both planting dates and AK06 in August planting, while overestimated the value for TN12 in both planting dates and AK06 in September planting date.

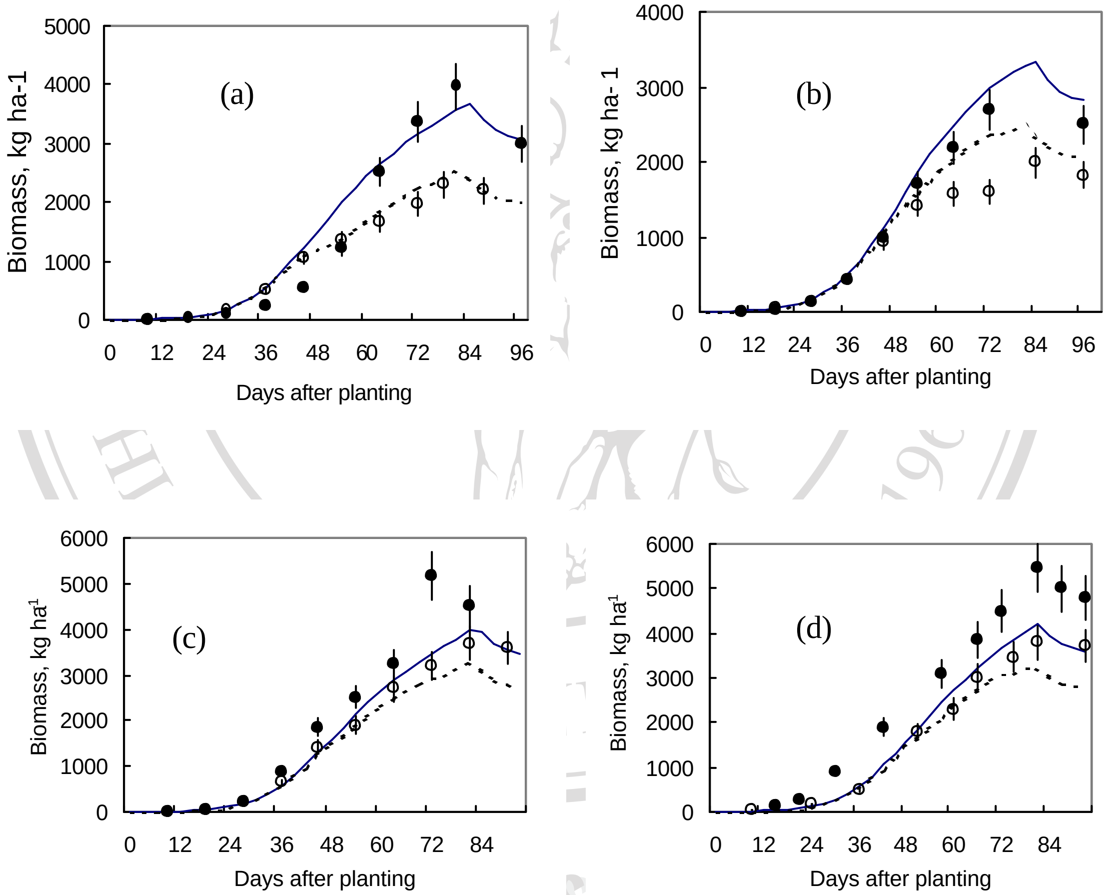

Figure 6.9 Simulated and observed above ground biomass of four varieties (a) AK06, (b) TN12, (c) DT 84, and (d) CM60 in planting dates. (─) presented simulated, and (●) observed in Aug. planting date; (---) simulated and (○) observed in Sept. planting date. Vertical bar showed error 10% of mean.

In general, the model gave good agreement between simulated and observed above ground biomass; it was illustrated accurate level for DT84, and larger difference occurred for the remaining varieties. However, in which, for AK06, the match also was demonstrated accurately in PD2. Regarding the accumulation of biomass, the model predicted accurately the parameter in early growing season, while relative accurately in the remaining growing season of all varieties. This may be since in the late growing season, or the duration of strongest uptake nutrient from soil, soybean growth was affected by environmental conditions such as varied temperature and rainfall levels.

Above ground biomass at harvest

In regard with above ground biomass at harvest, based on linear regression analysis for correlation between simulated and observed the growth parameters, indicating that simulated value followed close the observed data (squared–R increased from 0.27 in bragg7 model up to 0.82 in the modified coefficient). Figure 6.10 provided comparison of simulated aboveground biomass corresponding field data.

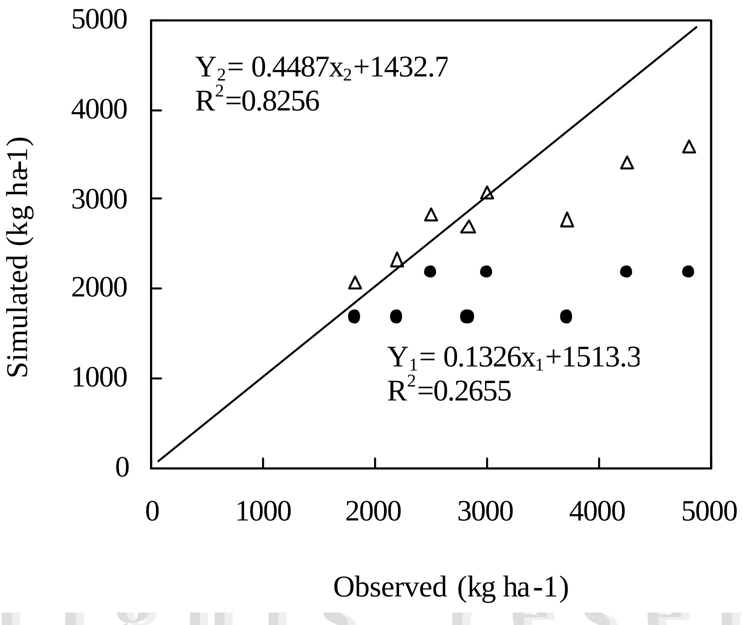

Figure 6.10 Comparisons between observed and simulated above ground biomass by Bragg (7) coefficient (●) and modified coefficient (∆) of four varieties in August and September planting dates (Each point represents the mean of three replicates).

Table 6.14 showed that Bias and RMSE were changed in all soybean varieties; Bias values in Bragg (7) coefficient were negative in all soybean varieties in both planting dates. Highest value was recorded for CM60, (Bias = –2,329 kg ha $^{-1}$) while lowest in TN12 (Bias = –232.0 kg ha $^{-1}$). Bias values in modified coefficient were positive for AK06 and TN12. In contrast, negative value occurred in DT84 (Bias = –490.5 kg ha $^{-1}$) and CM60 (Bias = 1,084 kg ha $^{-1}$).

Table 6.14 Bias and RMSE of comparisons between simulated and observed above ground biomass by modified and Bragg (7) coefficient.

Variety	Planting dates	Modified coefficient			Bragg (7) coefficient	
		Simulated	Observed	Difference	Simulated	Difference
AK06	August	3,069	3,000	69.0	2,178	-822.0
	September	2,324	2,200	124.0	1,681	-519.0
	Bias			96.5		-670.5
	RMSE			100.3		687.4
TN12	August	2,826	2,500	326.0	2,178	-322.0
	September	2,067	1,823	244.0	1,681	-142.0
	Bias			285.0		-232.0
	RMSE			287.9		248.9
DT84	August	3,408	4,250	-842.0	2,178	-2,072
	September	2,689	2,828	-139.0	1,681	-1,147
	Bias			-490.5		-1,610
	RMSE			603.4		1,675
CM60	August	3,584	4,800	-1,216	2,178	-2,622
	September	2,766	3,717	-951.0	1,681	-2,036
	Bias			-1,084		-2,329
	RMSE			1,092		2,347

The difference and bias changed after calibration, as a result, root mean square error of all soybean varieties changed too. All values were reduced in AK06, TN12, DT84 and CM60, in which, root mean square error of CM60 rapidly reduced from 2,347 to 1,092 kg ha $^{-1}$

Pod growth

Figure 6.11a, (b), (c) and (d) showed the comparison of simulated and observed pod weight of AK06, TN12, DT84 and CM60. Visually, in August planting date, model overestimated the observed pod weight for AK06, TN12 and DT84, while it underestimated for CM60 in both planting dates.

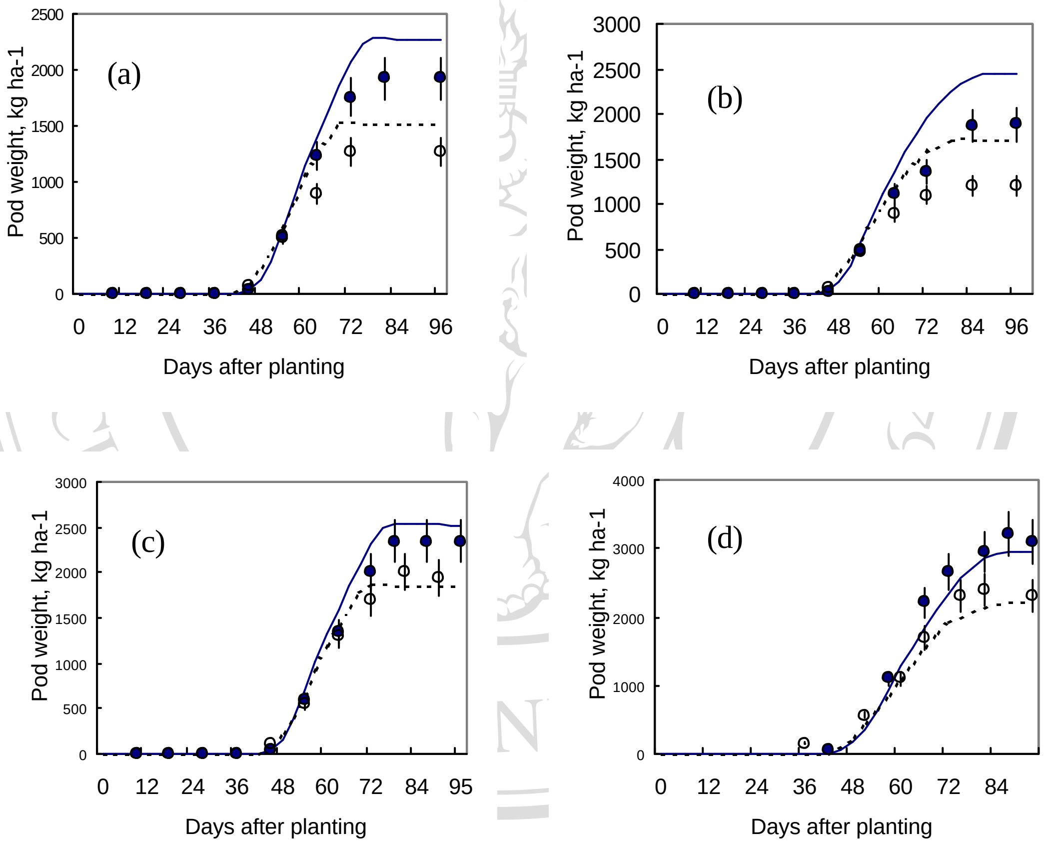

Figure 6.11 Simulated and observed pod weight of four varieties (a) AK06, (b) TN12, (c) DT 84, and (d) CM60 in planting dates. (—) presented simulated, (●) presented observed pod weight in Aug. planting date. (--) simulated for September planting date and ○) presented observed pod weight in Sept. planting date. Vertical bar showed error 10% of mean.

Pod weight at harvest

Pod weight at final harvest for four soybean varieties in August and September planting dates of Bragg (7) coefficient and modified coefficient are presented in Figure 6.12. It was observed that R^2 increased from 0.7156 to 0.7256 after modified coefficient of Bragg (7). It implies that relationship between simulated and observed became slightly stronger than before. Most of points in modified coefficient illustrated overestimation as compared to underestimated in Bragg (7) coefficient.

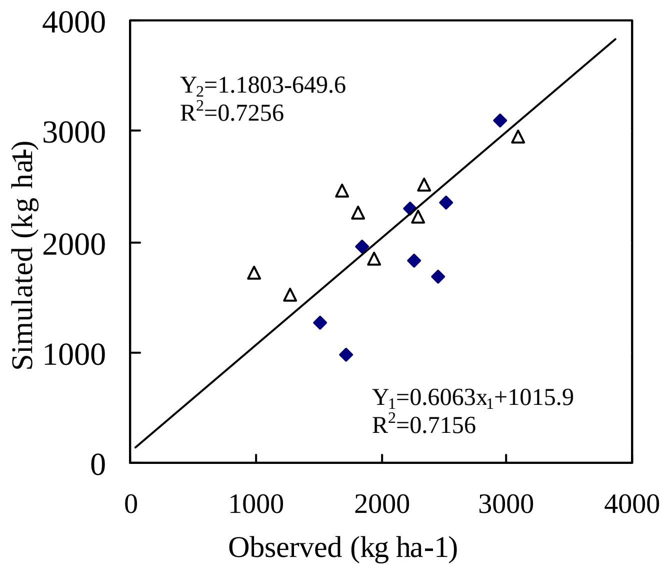

Figure 6.12 Comparisons between observed and simulated pod weight by Bragg (7) coefficient (●) and modified coefficient (∆) of four varieties in August and September planting dates (Each point represents the mean of three replicates).

To determine coefficients controlling the pod weight to be adjusted acceptably or not, Bragg (7) coefficient and calibrated models was compared based on deviation between simulated and observed pod weight at harvest. There was a change from almost underestimation of pod weight at harvest in Bragg (7) coefficient model to under- or overestimation of this parameter in modified model.

Table 6.15. Bias and RMSE of comparisons between simulated and observed pod weight at final harvest by modified and Bragg (7) coefficients.

Variety	Planting dates	Modified coefficient			Bragg (7) coefficient	
		Simulated	Observed	Difference	Simulated	Difference
AK06	August	2,012	1,820	192.0	1,816	-4.0
	September	1,412	1,273	139.0	1,033	-240.0
	Bias			165.5		-122.0
	RMSE			167.6		169.7
TN12	August	1,912	1,686	226.0	1,816	130.0
	September	1,058	986	72.0	1,233	247.0
	Bias			149.0		188.5
	RMSE			167.7		197.4
DT84	August	2,524	2,347	177.0	1,816	-531.0
	September	1,846	1,947	-101.0	1,233	-714.0
	Bias			38.0		-622.5
	RMSE			144.1		629.2
CM60	August	2,955	3,098	-143.0	1,816	-1,282
	September	2,225	2,298	-73.0	1,233	-1,065
	Bias			-108.0		-1,174
	RMSE			113.5		1,179

It was found that the modified coefficients help model simulate pod weight more accurately than it run with coefficients of Bragg (7), in particular, for DT84 and CM60 (RMSE declined from 629.2 to 144 kg ha^{-1}, and 1,178 to 113 kg ha^{-1}, respectively). The remain varieties AK06, TN12 showed that their coefficients nearly similar to Bragg (7), there fore, the adjustment was not conducted much for adjusting coefficients of Bragg (7) to model attain the pod weight close to experiment data.

Grain yield

Figure 6.13a, 6.13b, 6.13c and 6.13d illustrated the simulated and observed grain yield of soybean varieties across two planting dates. Visually, the model overestimated the observed grain yield for AK06, TN12, and DT84, but underestimated for CM60 in both planting dates.

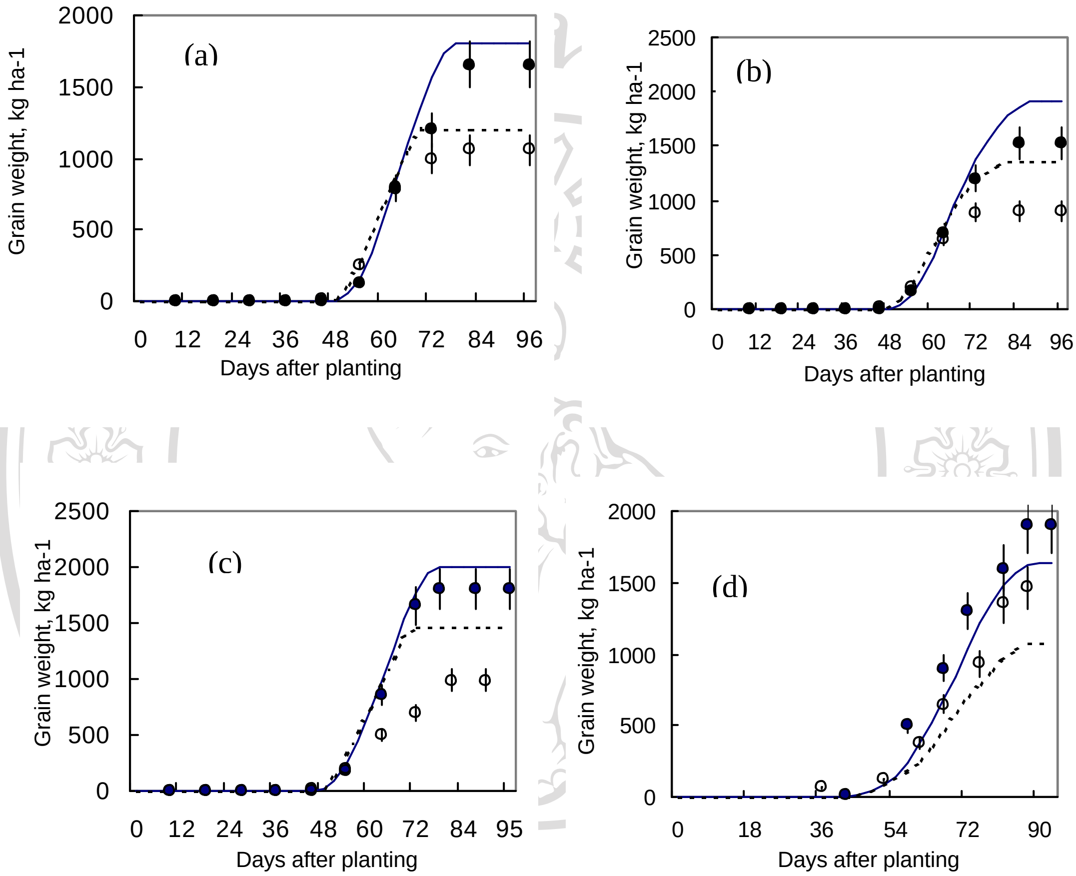

Figure 6.13 Comparisons between simulated and observed grain yield of four varieties (a) AK06, (b) TN12, (c) DT 84, and (d) CM60 in planting dates. Solid lne (–) presented simulated (●) presented observed in Aug. planting date, (---) simulated for September planting date and (○) presented observed grain yield in Sept. planting date. Vertical bar showed error 10% of mean.

Table 6.16 shown that the largest deviation between simulated and observed grain yield occurred for DT84 starting from 62 DAP until end of growing season in September planting date, whereas, the difference was slight in other varieties in both planting dates. Bias and RMSE of grain yield were indicated that reducing RMSE value that occurred in four varieties in two planting date, strong reduced from 478.1 to 332.9 $kgha^{-1}$in CM60.

Table 6.16 Bias and RMSE of comparisons between simulated and observed grain yield at final harvest by modified and Bragg (7) coefficients.

Variety	Planting dates	Modified coefficient			Bragg (7) coefficient	
		Simulated	Observed	Difference	Simulated	Difference
AK06	August	1,799	1,656	143.0	1,434	-222.0
	September	1,207	1,056	151.0	980	-76.0
	Bias			*147.0*		*-149.0*
	RMSE			*147.1*		*165.9*
TN12	August	1,658	1,527	131.0	1,334	-193.0
	September	1,100	900	200.0	1,059	159.0
	Bias			*165.5*		*-17.0*
	RMSE			*169.1*		*176.8*
DT84	August	1,900	1,804	96.0	1,434	-370.0
	September	1,300	984	316.0	980	-4.0
	Bias			*206.0*		*-187.0*
	RMSE			*233.5*		*261.6*
CM60	August	1,631	1,902	-271.0	1,434	-468.0
	September	1,083	1,468	-385.0	980	-488.0
	Bias			*-328.0*		*-478.0*
	RMSE			*332.9*		*478.1*

Yield and yield components at harvest

Figure 6.14 (a) and 6.14 (d) presented seed m^{-2} and grain yield at harvest. The points illustrated that seed m^{-2} and grain yield for four varieties at two planting dates were more scattered than seed pod^{-1} and 1000 seeds weight. It implies that simulated and observed data in two planting dates were not quite different for seed pod^{-1} and 1000 seeds weight but were much different for seed m^{-2} and grain yield. As a consequence, bias and root mean square error were also different in each figure. These were presented in Table 6.17.

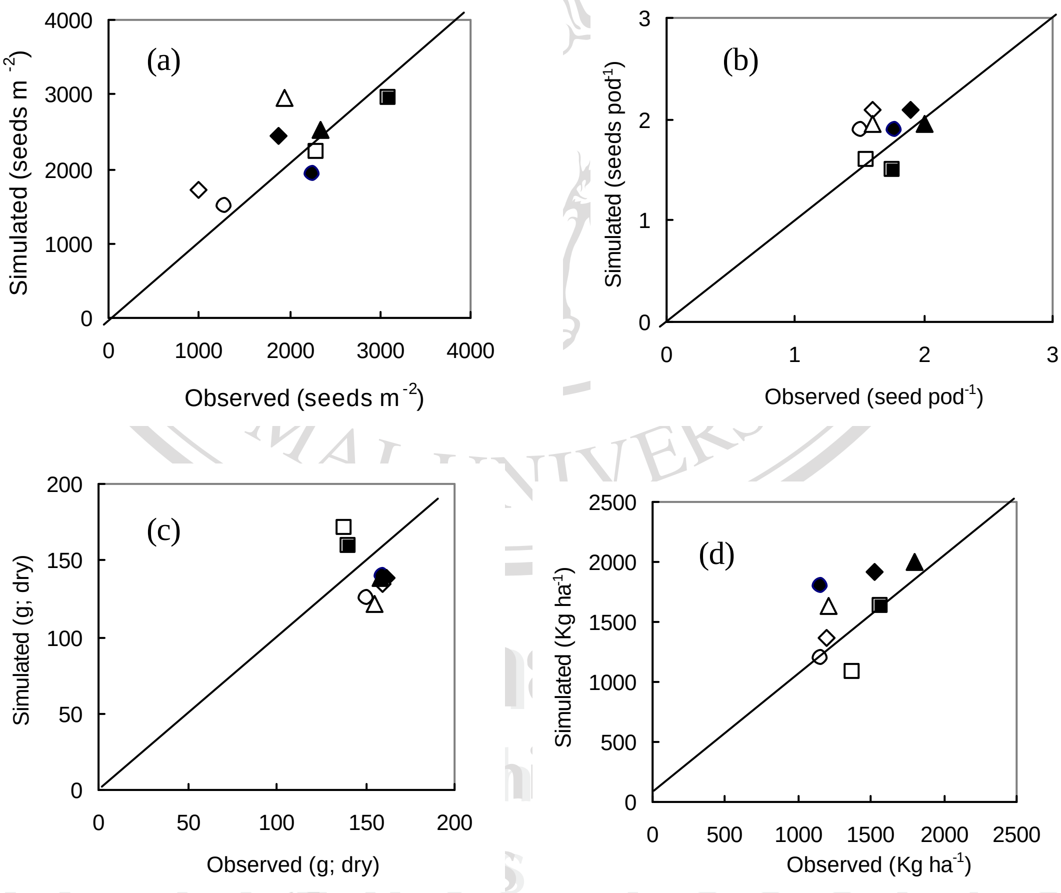

Figure 6.14 Comparisons between simulated and observed of yield components for AK06 (●), TN12 (◆), DT84 (▲), and CM60 (■) in August (Black) and September (white). Seed per square meter (a), seeds per pod (b), 1000 seeds weight (c) and grain yield (d).

Table 6.17 was reported that positive bias values of seed yield; seed number, and seed per pod were noticed in AK06, TN12 and DT84. However, model underestimated seed yield for CM60 with standardized bias (R) =0.19. Standardized mean square errors (V) ranged from 0.01 (AK06) to highest 0.04 (CM60). It implied that more accuracy occurred for AK06 after running calibrated model.

Table 6.17 Bias, RMSE, standardized bias, and standardizes of comparisons between simulated and observed yield and yield components in August and September plating dates.

Variety	Statistics Indicators	Seed yield (kg ha^{-1})	Seed number (# m^{-2})	Seeds per pod (# pod^{-1})	1000- seed weight (g;dry)
AK06	Bias	147.0	213.5	0.27	-21.5
	RMSE	147.1	247.1	0.28	21.6
	R	0.11	0.24	0.16	0.14
	V	0.01	0.11	0.03	0.02
TN12	Bias	165.5	443.5	0.35	-24.5
	RMSE	169.1	463.4	0.38	24.5
	R	0.14	0.59	0.20	-0.15
	V	0.02	0.38	0.05	0.02
DT84	Bias	206.0	325.0	0.15	-27.0
	RMSE	233.5	331.4	0.25	27.9
	R	0.15	0.32	0.08	-0.17
	V	0.03	0.11	0.02	0.03
CM60	Bias	-328.0	-447.5	-0.10	26.0
	RMSE	332.9	447.0	0.18	26.9
	R	-0.19	-0.35	-0.06	0.19
	V	0.04	0.12	0.01	0.04

Seed number m^{-2} and seed pod^{-1} were underestimated in AK06, TN12 and DT84 but overestimated in CM60. The standardized mean error is lowest (V=0.11) for AK06 and DT84 and highest (V=0.38) for TN12 in term of seed number m^{-2}. This indicated more accurateness for AK06 and DT84 and less for TN12. The standardized mean square error of seed pod^{-1} had highest value for TN12 (V=0.05), while the lowest for CM60 (V=0.01).

1000 seeds weight were overestimated for AK06, TN12 and DT84 due to negative bias value occurring, but underestimated for CM60. Similarly, standardized mean square error had slightly difference and the highest value was for CM60 (V=0.04) and lowest for AK06 (V=0.02).

6.5 To utilize CROPGRO-soybean model in Hoa Binh province.

This part addresses the third objective of the study. An analysis was conducted to demonstrate how changes of major climate variables (temperature, precipitation, and radiation) would affect soybean yield in Hoa Binh province (Table 6.18). Changes in climate were produced for the analysis by changing daily values of maximum, minimum temperatures and precipitation on each day of the 8-year weather data sets in the Chi Ne Meteorology Station, Hoa Binh province. In addition, farm management practices were set up for model simulation such as plant density (25 plant m^{-2}), fertilizer applications (40N). The management of soybean animation was referenced from survey data and observed farm practice of soybean growers in the Than Ha Farm (Figure 6.14).

Simulation started on January 15th of each year with an assumed initial soil profile in Than Ha, Hoa Binh province. Twelve planting dates (time interval of 30 days) were used in a trial run. This study was done in order to explore possibility of prediction as well as to obtain strategic management scenarios. Simulated results were analyzed by averaging yields for each combination of temperature, radiation, and precipitation varied over the 8-year weather records, in turn, for each variety (AK06, TN12, DT84 and CM60) in twelve sowing dates.

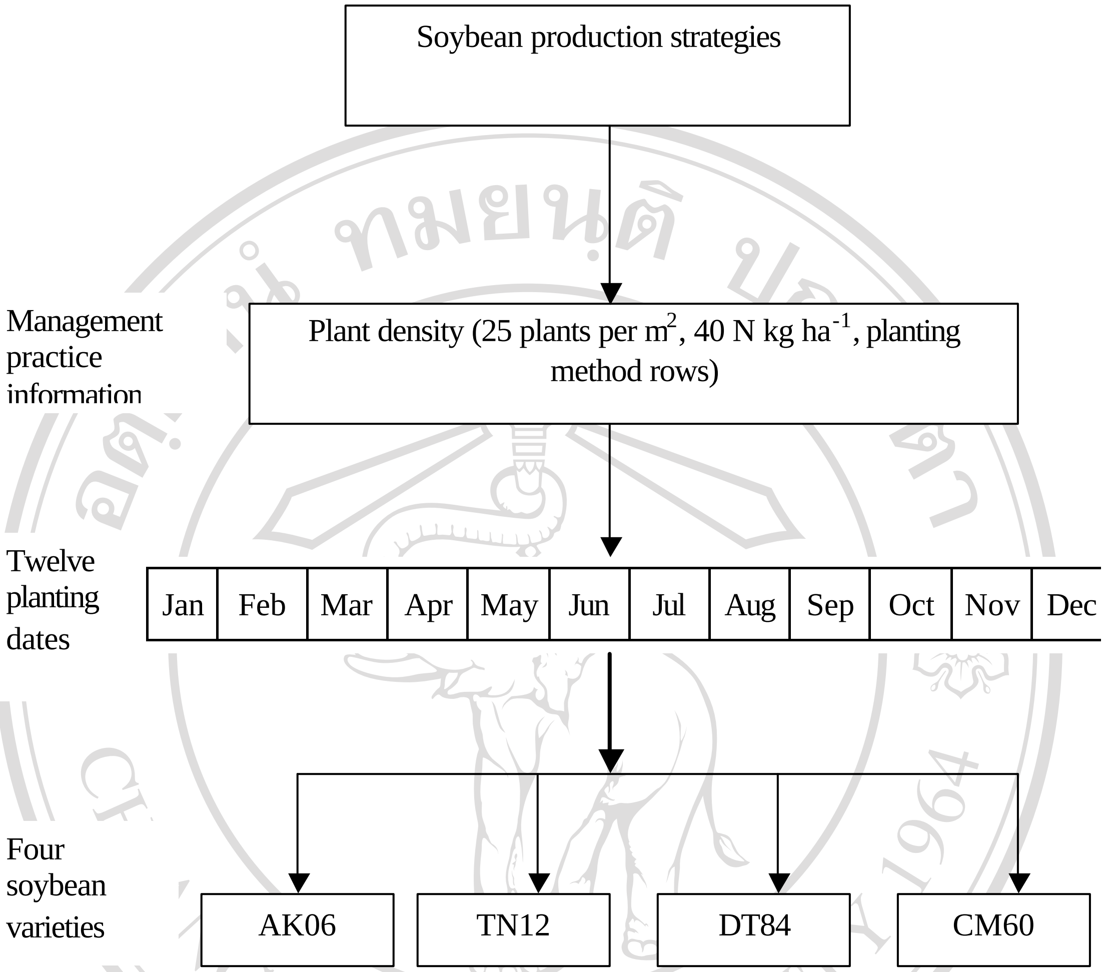

Figure 6.15 Soybean strategies simulation for 8 years using Hoa Binh weather data and soil data.

Table 6.18 shows the means and standard deviations of grain yields of the 48 strategies run for eight consecutive years as influenced by planting dates and varieties. In general, in the May 15th planting date, four varieties, namely AK06, TN12, DT84 and CM60 produced higher grain yields than other planting dates. In contrast, the lowest grain yield was found on January 15th planting date.

Table 6.18 Mean and SD of simulated grain yield (kg ha^{-1}) of four soybean varieties in twelve planting dates in the Thanh Ha farm, Hoa Binh Province.

Planting date	AK06		TN12		DT84		CM60	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Jan 15	394	199	387	200	426	225	476	274
Feb 15	720	519	696	542	757	592	942	712
March 15	1,249	699	1,244	665	1,310	810	1,642	975
Apr15	2,113	1,065	2,102	932	2,150	1,081	2,601	1,202
May 15	2,901	739	2,972	611	3,015	728	3,298	835
Jun 15	2,605	546	2,741	563	2,682	553	3,058	682
July 15	2,106	327	2,213	350	2,203	334	2,594	406
Aug 15	1,342	233	1,332	178	1,390	196	1,637	212
Sept 15	948	239	892	191	1,014	268	1,193	226
Oct 15	758	183	735	120	837	186	939	136
Nov 15	746	190	707	156	827	213	916	243
Dec 15	874	324	828	292	945	352	1,112	373

The variation of grain yields was affected by varied weather in a year, in which, major climate parameters such as rainfall, radiation and temperature were considered. This was because they affected vividly soybean growth, especially rainfall. The study emphasized the phenomena because soybean system in Hoa Binh province was mainly under rain-fed condition. Besides, temperature also affected the growth and development of soybean. Variation of rainfall and average temperature was depicted in Figure 5.2 in Chapter 5. As discussion in results of field survey, rainfall during May and August takes an account of 80 percent of total annual rainfall. Peak precipitation is in the months of August and September. Commonly, the lowest temperature of 12^{o}C occurs in December and January. As simulated, the lowest soybean grain yield was found in January planting date for all four varieties.

The results indicated that CM60 variety achieved the highest grain yield as compare to other varieties in twelve planting dates. For instance in May 15th CM60 achieved 3298 kg ha^{-1} while AK06, TN12 and DT84 achieved 2901, 2972, 3015 kg ha^{-1}, respectively. The largest of standard deviation occurred in April 15th. It means that great variation of grain yields of all varieties occurs in April planting date when eight –year weather data is varied.

In conclusion, the results of this research confirm the insight of the way farmers operate and also suggest new opportunities for research, which may be of value to farmers. Under Hoa Binh conditions, farmers experience marked yield reduction when planting is delayed from June to monthly in end of year. But they did not know at May planting date, which may be achieving highest grain yield for rainfall season. This proved changing weather condition that will be strong effect on soybean's grain yield. In further, on-farm trial needs to undertake in Hoa Binh province then give accuracy results, then giving recommendations to farmers who attended in soybean production.