CHAPTER 4

MATERIALS AND METHODS

The study consists of field survey, field experiment for calibration of CROPGRO- Soybean model (calibrating the genetic component by using modified method), and utilization of the CROPGRO-Soybean model for soybean varietals selection in Hoa Binh Province.

4.1 Field survey

Primary data

Field survey was conducted in Hoa Binh province from March to May 2002 in order to identify the problems of management practices in soybean production systems in study sites. Method used in survey was combination of filling questionnaire forms and semi-structured interview. Questionnaire form that was designed before field trip focused on characteristics of farmers involving to produce soybean, farm practices i.e., fertilizer application, irrigation, soybean varieties used and sowing dates. In addition, some Participatory Rapid Appraisals (PRA) tools i.e., semi-structured interview and group discussions were employed in survey as a tool for developing the necessary insights into how soybean production system operated. Three brigades in Thanh Ha Farm were selected then thirty households in each brigade were randomly sampled to interview.

Secondary data

Secondary data were collected from organizations i.e., Vietnam Agricultural Science Institute (VASI), National Institute of Planning and Projection (NIAPP), under Ministry of Agriculture and Rural Development (MARD); General Statistical

Office (GSO), Meteorological offices and Meteorological Institution, and reviewed from programs, projects, journals, and magazines which were related to research problem statement.

Climatic data were provided by meteorological office (Chine Meteorological Station in Hoa binh province). They consist of indicators such as rainfall, temperature (average, maximum, minimum), sunshine hours, and radiation energy. The long-term weather data set would be used in the model in studying the environment and practice management factors affecting soybean yield in Hoa Binh province.

Soil data were referenced from National Institute of Agricultural Planning and Projection (NIAPP), including records of soil sample analysis in Thanh Ha State Farm, Hoa Binh province. Laboratory soil analysis results include the following indicators:

Chemical features: CEC (meq/100g), Humus (%), Total content of N, P, K (%), OM (%), Ca^{++}(meq/100g), pH_{KCl}, bulk density (g/cm^3).

Physical characters of soil profile: Texture, depth of soil layers

The soil data was used in the model to evaluate the environment and soil factors affecting yield and answer the question "*What-if*" in studying soybean varieties and farm practice management in Hoa Binh province.

4.2 Field experiment

A field experiment was conducted at Multiple Cropping Center Station, Chiang Mai University, Chiang Mai province during August 2002 to January 2003 in order to get measurements to estimate the genetic coefficients of the selected soybean varieties through CROPGRO soybean model. The station is located at 18° 46' N latitude and 98 °57' E longitude (UTM47Q, X496400m N, Y20077800m E). Four soybean varieties namely AK06, DT-84, TN12 and CM60 were used in the experiments.

Experimental design

Design of field experiment was split plot design with three replications. Two planting dates were the main plots with time interval 43 days and four soybean varieties were sub plots. The treatment combinations were summarized in Table 4.1. Four soybean varieties (three of them from Vietnam and one from Thailand) were used in the experiments.

Table 4.1 Treatment combinations used in the experiment.

Variety	Planting dates	
	Aug. 2 (PD1)	Sept. 14 (PD2)
AK06 (V1)	V1 PD1	V1 PD2
TN12 (V2)	V2 PD1	V2 PD2
DT 84 (V3)	V3 PD1	V3 PD2
CM60[a] (V4)	V4 PD1	V4 PD2

Note: [a] Thai variety; V= Variety; PD = Planting date

Field management

Soybean seeds were sown by rows with the rate of three to five seeds per hill due to risk from rainfall. Two weeks after sowing only two plants per hill were kept. Thus, plant density were thirty plants per m^2. Sub plot size was 6.0 m x 2.5m.

The best conditions for soybean growth were applied in this experiment i.e., to prepare land before sowing and make furrows according to experiment design. Fertilizer dose was applied with amounts of 40N: $80P_20_5$: $60K_20$ that divided into three applications (before sowing, R2, and R4). Weed was controlled by chemical (before sowing around 10 days) and by manual after plants grew. Pesticides were sprayed three times in the stages V2, R2, and R4; and water was supplied maximum for soybean requirement.

Data collection

Weather data

Weather data required for model execution including daily rainfall, maximum and minimum air temperature, and solar radiations in 2002 were obtained from the Meteorological Station of Multiple Cropping Center, Faculty of Agriculture, Chiang Mai University.

Soil data

Soil data were obtained and referenced by San Sai series for model execution, and soil parameters were summarized in Table 4.2.

Table 4.2 Soil data for San Sai series.

SALB	SLU1	SLDR	SLRO	SLNF	SLPF	SMHB	SMPX	SMKE
0.13	23.8	0	76	1	1	IB001	IB001	IB001

SLLL	SDUL	SSAT	SBDM	SLOC	SLHW	SCEC
0.043	0.168	0.322	1.65	0.6	6.7	4.8
0.056	0.178	0.318	1.66	0.39	7.3	0.6
0.072	0.193	0.327	1.63	0.09	7	1.5
0.065	0.188	0.327	1.63	0.39	6.8	1.3
0.098	0.22	0.339	1.59	0.08	5.5	3.6

Source: Soil Agronomy Division

Note:

SLLL- Lower limit of plant-available soil water
SDUL- Drained upper limit.
SSAT- Saturation water content for soil layer
SLOC-Organic carbon content of layer.
SDBM- Bulk density of soil layer
SCEC – Cation exchanged capacity
SLHW – pH 1:2 H_20

Crop data

Experiment data were recorded with indicators such as phenology events, crop growth, yields and yields components. Data would be set up following DSSAT requirements (IBSNAT, 1990).

Crop phenology events i.e., CSDL (1), EM-LF, FL-SH and SD-PM were recorded (abbreviated name was shown in Table 4.3). Dates for phenology events were established when 50% of the plants in each treatment had reached that stage of development. The reproductive stages observed were flowering, pod initiation, beginning of seed growth, and full seed and physiological maturity.

Growth data include biomass, leaf area index, pod weight and seed weight that were collected in stages i.e., V4, R1, R3, R4, R5, R6, R7, and final harvest. The day data were collected was also recorded. In which, V4 and R1 were flowering stage, R3 and R4 for pod development, R5 and R6 for seed development, and R7 and R8 for maturation. Thereafter, the samples were taken each stages and with sample area of 0.4 m^2 per treatment. After taking the samples each part of plants was separated into leaf, stem, pod and seed to determine the distribution of dry matter in difference treatments at 70^0C to constant weight. Then, it was scaled for recording the dry biomass (Leaf weight, stem weight, pod weight and seed weight). Leaf area index (LAI) was measured by using the automatic leaf area meter.

Yield and yield components were measured at final harvest by taking number of plants per square meter, then measured number of pod per m^2, number of seed per pod, weight of 1000-grain seeds, number of stems and branches per main stem, final height of plant. Grain yield was measured from plant sample taken from area of two square meter of each replication. The crop sample was employed to calculate the grain yield and scaled at seed moisture content of 13%.

4.3 Data analysis

Field survey data were analyzed by using general descriptive statistics: percentage, mean, standard errors. Field experiment data were analyzed by fitting curves and analysis of variance.

Model testing methods: To compare the simulated and observed data applied by suggestion of Kobayashi and Salam (2000) as follows:

Graphical method: Simulated data were plot against observed data, and one-to-one line would be base to consider the accuracy and best estimation of the model.

Statistical method: The following parameters would be measured the difference between simulated and observed data, bias, root mean square error (*RMSE)*, standardized bias (*R*), and standardized mean error (*V*).

Data simulated from the model were analyzed by comparing simulation and measurements. Consequently, two statistic indicators were commonly used to evaluate model as follows:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i}^{n}(X_i - Y_i)^2} \quad (1)$$

$$Bias = \frac{1}{n}\sum_{i}^{n}(X_i - Y_i) \quad (2)$$

Goodness of fit was evaluated by computing a standardized bias (R) and a standardized mean square error (V).

$$R = \frac{\sum_{i=1}^{n}(Y_i - X_i)}{\sum_{i=1}^{n} X_i} \quad (3)$$

$$V = \frac{\sum_{i=1}^{n}(Y_i - X_i)^2}{\sum_{i=1}^{n} X_i^2} \quad (4)$$

n represents the number of field observations, X_i and Y_i are observed and predicted values, respectively, at the *ith* observation, and R and V are estimates for the overall error of the model with regard to field data. R quantifies the model's

ability to reproduce the observed growth pattern. Negative deviations ($Y_i - X_i < 0$) compensate for positive deviations ($Y_i - X_i > 0$) and vice versa (eq. 3). On the other hand, V is a measure that reveals the model's tendency to generally over – or under-estimate field observations. It is based on the positive sum of proportional deviations (the signs are eliminated by squaring) (eq. 4). Obviously at the same relative deviation both procedures give heaviest weighting to large values i.e., toward maturity.

4.4 Estimation of genetic coefficients

According to Hunt's approach (1993) since the genetic coefficients for given varieties are not known they can be estimated using field data. This is accomplished iteratively by running model with approximate coefficients, comparing model output with actual data, adjusting coefficients and repeating process until acceptable fits are obtained. Genetic coefficient was modified by GENCAL; one component of CROPGRO soybean model embedded in DSSAT v3.5 was employed for determining the genetic coefficients from field experiment data.

The set of genetic coefficient for soybean includes 15 coefficients (Table 4.3) encompassing the supervision of phenology events and growth process of soybean, i.e., CSDL (1), PPSEN (2), EM-FL (3), FL-SH (4), FL-SD (5), SD-PM (6), FL-LF (7), SLAVR (9), SIZLF (10), XFRT (11), WTPSD (12), SFDUR (13), SDPDV (14) PODUR (15) (Tsuji, 1994).

The set of genetic coefficients of BRAGG (7), medium duration maturity, was used to be initial values to run the model. The genetic coefficient calibration would be done for four soybean varieties, namely TN12, AK 06, DT84 and CM60 from experiments based on the best-fit principle. Genetic coefficients EM-FL (3), FL-SH (4), FL-SD (5) and SD-PM (6), were adjusted until the difference between observed and simulated anthesis date, first pod, first seed and maturity dates as small as possible in two planting dates, in other words, the coefficients were adjusted until the simulated and observed phonological events were agreed. Similarly, remain coefficients CSDVAR, PPSEN, LFMAX, SIZLF, SLAVAR, WTPSD, SFDUR,

SDPDVR, PODUR were adjusted until growth results i.e., biomass, leaf max area, seed per pod, of simulated and observed data agreed, then the genetic coefficient would be accepted to use for model simulation.

Table 4.3 Genetic coefficients coded in CROPGRO-Soybean model.

Coefficients	Descriptions	Range
CSDL (1)	Critical day length below reproductive development (hour)	11.84-14.42
PPSEN (2)	Slope of relative rate of development for daylengths above CSDVAR(1/h)	0.129-0.340
EM-FL (3)	The time from end of juvenile phase to first flower in (photothermal days).	15.5-28.9
FL-SH (4)	The time from first flower to first pod greater than 0.5 cm in length (photothermal days).	5-10
FL-SD (5)	The time from first flower to first seed in (photothermal days)	12-16
SD-PM (6)	The time from first seed to physiological maturity in photothermal days	28-38
FL-LF (7)	The time from first flower to end of leaf growth in (photothermal days)	15-26
LFMAX (8)	Maximum leaf photosynthesis at saturated light level, optimal temperature (micromole (CO_2/m^2s))	1.02-1.40
SLAVR (9)	Specific leaf area (SLA) for new leaves during peak vegetative growth for cultivars , modified by environmental factors (cm^2/g)	345-400
SIZLF (10)	Maximum size of fully expanded leaf on the plant under standard growing conditions (3 leaflet), cm^2	140-200
XFRT (11)	Maximum fraction daily available gross photosynthesis (PG), which is allowed to go to seeds plus shells for cultivars.	1.0

(Cont'd)

Coefficients	Descriptions	Range
WTPSD (12)	Maximum weight per seed under non-limiting substrates (g)	0.160-0.192
SFDUR (13	Seed filling duration for a cohort of seed (photothermal days)	16-25
SDPDV (14)	Average seed per pod under standard growing conditions (seeds per pod)	2-3
PODUR (15)	Photothermal days for cultivars to add full pod load under optimal conditions (photothermal days).	8-14

Source: Tsuji *et al.*, 1994.

Based on *best-fit* principle, the genetic coefficients were adjusted from initial genetic coefficients of known varieties, then testing the agreement between measured and predicted data, which agree and not agreed, if agreed then level of agreement. The genetic coefficients were obtained when simulated and observed data were agreed nearly, which was illustrated that smallest RMSE.