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Genetic Coefficient and Validation of DSSAT Model for Cotton under Different Growing Environments

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A B S T R A C T

The field experiment was conducted at the research area of the Department of Agricultural Meteorology, CCS Haryana Agricultural University, Hisar, during the *kharif* season of 2015-16. The main plots treatments consisted of three date of sowing 2nd week of May (D1), 3rd week of May (D2) and 1st week of June (D3) and sub-plots consisted of three varieties (Pancham 541, SP 7121 and RCH 791. Genetic coefficient for DSSAT- CROPGRO model such as EM-FL, FL-SH, SD-PM, FL-LF, SLAVR, SIZLF, XFRT, SDPRO, SDLIP, SFDUR, THRSH, SDPDV, CSDL, PP-SEN, LFMAX, WTPSD and PO-DUR were evaluated. SLAVR, XFRT and THRSH were main coefficients which influenced LAI and seed cotton yield. The model performance in respect of phenology was good with error of ±5% for all the three cotton cultivars and growing environments. Also the model performance was within acceptable range of ±10.0% for LAI, seed cotton yield and biomass for all the cultivars and growing environments. But the model performance was not within acceptable range for the crop sown in 1st week of June.

Introduction

The Decision Support System for Agrotechnology Transfer (DSSAT) is the major product of the IBSNAT (International Benchmark Site Network for Agrotechnology Transfer) project, initiated in 1982 (Uehara and Tsuji, 1998). Although this project ended in 1993, its developers have expanded since then and continue to update and maintain this software under the auspices of ICASA. The central components of the DSSAT software are crop simulation models and programs to facilitate their application in different regions of the world. It is the quantitative tool based on scientific knowledge that can evaluate the effect of climatic, edaphic, hydrological and agronomic factors on crop growth and yield. The decision support system for agro-technology transfer (DSSAT) has been in use for the last 15 years by researchers worldwide (Hoogenboom *et al.*, 2012; Jones *et al.*, 2003). This package incorporates models of 28 different crops with software that facilitates the evaluation and application of the crop models for different purposes.

DSSAT was developed to assess yield, resource use and risk associated with different crop production practices (Tsuji *et al.*, 1994). The system DSSAT (Tsuji *et al.*, 1994) is an example of a management tool that enables farmers to match the biological requirement of a crop to the physical characteristics of the land and ambient air to attain specified objectives. DSSAT software could help the decision makers to implement future agriculture strategies under different scenarios related to agriculture practices with the use of measured site - specific pedological, physiological, agronomical and meteorological data (Hoogenboom *et al.*, 1994).

The study of impact of climate change on crops needs simulation model, as it provide a means to quantify the effects of climate, soil and management on crop growth, productivity and sustainability of agricultural production. These tools can reduce the expensive and time consuming field experimentation as they can be used to extrapolate the results of research conducted in one season or location to other season, location, or management (Boomiraj *et al.*, 2007).

Materials and Methods

The field experiment was conducted at the research area of the Department of Agricultural Meteorology, CCS Haryana Agricultural University, Hisar, during the *kharif* season of 2015-16. The main plots treatments consisted of three date of sowing and the sub-plots consisted of three varieties. The twenty seven treatment combinations were tested in random block design with three replications.

Plant height was measured at important phenophases on three tagged plants in each plot. The height was measured from the root-shoot junction to the apical point with a wooden meter scale and mean values were calculated.

Three plants were uprooted from each plot and their leaves were used for measuring leaf area per plant (cm^2) with the help of leaf area meter (LI-3000 Leaf Area Meter, LICOR Ltd., Nebraska, USA) at 30, 60, 90, 120 and 150 days after sowing. These samples were oven dried and weighted for dry biomass calculation on hectare basis. Yield, yield attributes and yield quality were recorded at harvest.

Input data for CROPGRO-Cotton model

'CROPGRO-Cotton' is a physiological based dynamic crop growth simulation model which is responsive to daily weather inputs. The minimum data required for running CROPGRO-Cotton are given in table 1.

Inputs required for creating a new soil profile for DSSAT Crop Model

I. General Information

1. Country: INDIA	2. Site Name: CCSHAU, HISAR
3. Latitude: 29° 10′	4. Longitude: 75° 46′
5. Soil Data source: NBSS	6. Soil Series name: NINDANA
7. Soil Classification: Typic ustochrept	

II. Surface Information

1. Colour (a) Brown
2. Drainage Moderate well
3. % slope ONE
4. Runoff potential Moderately low
5. Fertility factor (0 to 1) ONE
6. Runoff Curve Number
7. Albedo
8. Drainage rate

III. Layer-wise soil information: No. of layers depends on the location. Here layers up to 120 cm depth (Table 2).

Calibration of the model

Calibration of model involves computing and adjusting certain model parameters or relationships to make the model work for any desired location. When using a crop model, one has to estimate the cultivar characteristics if they have not been previously determined. The model requires twenty cultivar specific genetic coefficients. These genetic coefficients were computed as per details given below:

Parameters	**Description of parameters**
EXPON	Number of experiment used to estimate cultivar parameters
ECO#	Code for the ecotype to which this cultivar belongs
CSDL	Critical Short Day Length below which reproductive development progresses with no day length effect (for short day plants) (hour)
PPSEN	Slope of the relative response of development to photoperiod with time (Positive for short day plants) (1/hour)
EM-FL	Time between plant emergence and flower appearance (R1) (photothermal days)
FL-SH	Time between first flower and first pod (R3) (photothermal days)
FL-SD	Time between first flower and first seed (R5) (photothermal days)
SD-PM	Time between first seed (R5) and physiological maturity (R7) (photothermal days)
FL-LF	Time between first flower (R1) and end of leaf expansion (photothermal days)
LFMAX	Maximum leaf photosynthesis rate at 30^0 C, 350 vpm CO_2 and high light (mg CO_2/m^2-s) ---from Reddy Adv. Agron. 1997?
SLAVR	Specific leaf area of cultivar under standard growth conditions (cm^2/g)
SIZLE	Maximum size of full leaf (three leaflets) (cm^2)
XFRT	Maximum fraction of daily growth that is partitioned to seed+shell
WTPSD	Maximum weight per seed (g)
SFDUR	Seed filling duration for pod cohort at standard growth conditions (photothermal days)
SDPDV	Average seed per pod under standard growing conditions (#/pod)
PODUR	Time required for cultivar to reach final pod load under optimal conditions (photothermal days)
THRSH	Threshing percentage. The maxi. ratio of seed [seed/(seed+shell)]
SDPRO	Fraction protein in seeds [g(protein)/g(seed)]
SDLIP	Fraction oil in seed [g(oil)/g(seed)]

The model was run and validated by comparing the predicted output with observed parameters. Deviation of predicted value from observed were calculated and error of the model to predict different crop parameters was quantified using the methods given below:

$$MAE = \sum_{i=1}^{n} \left[1P_i - O_i 1 \right] / n$$

$$MBE = \sum_{i-1}^{n} \left[P_i - O_i \right] / n$$

$$RMSE = \left[\sum_{i=1}^{n} (P_i - O_i)^2 / n \right]^{1/2}$$

PE = {(P – O) / O} * 100

Where, O = observed, P = simulated.

Results and Discussion

The genetic coefficients were evaluated and the model was validated for different sowing environment with different cultivars: Pancham 541, SP 7121 and RCH 791. DSSAT model was calibrated by different data sets on phenology, leaf area index, bolls weight/plant, biomass and seed cotton yield for the evaluation of genetic coefficients.

Genetic coefficients

The core coefficients such as maximum threshing percentage was calculated and observed in RCH 791(91%) followed by SP 7121(79%) and Pancham 541(74%) sown in table 3. The value of CSDL, PP-SEN, LFMAX and WTPSD used as default, the value of EM-FL, FL-SH, SD-PM, FL-LF, SLAVR, SIZLF, XFRT, SDPRO and SDLIP was computed and they are maximum in cotton cultivar RCH 791 followed by SP 7121 and Pancham 541. SFDUR, SDPDV and PO-DUR were computed and found equal in SP 7121 and Pancham 541 and maximum in RCH 791. SLAVR, XFRT and THRSH have maximum influence on LAI and seed cotton yield. Ortiz *et al.*, (2009) also reported the values for most of the vegetative and reproductive cultivar coefficients were higher than those from the other commercial cotton cultivars that are part of the DSSAT data-base, suggesting that the cultivar grown in this experiment required more days to the beginning of the reproductive phase.

Validation

Days to flowering

The observed mean values of days to flowering for three cotton cv. Pancham 541, SP 7121 and RCH 791 were 70, 72 and 74, whereas the model simulated 70, 72 and 72 days, resp. (Table 4). The percent error was observed lower for cv. SP 7121 (0.0) followed by Pancham 541 (0.0) and RCH 791 (-3.3). Similarly, the percent error was observed lower for 3rd week of May (D2) followed by 1st week of June (D3) and 2nd week of May (D1). This clearly showed that model performance was found to be good for all the three cotton cultivars and for all the growing environments for simulation of days to flowering as percent error was <± 5. Ortiz *et al.*, (2009) also showed the difference between observed and simulated values for the flowering and physiological maturity dates over the control treatment was two days.

Days to maturity

Pancham 541, SP 7121 and RCH 791 matured in 136, 138 and 141 days, while model simulated 137, 139 and 142 days, respectively as sown in table 5. SP 7121 performed better and the model percent error was observed lower for 3rd week of May (D2) overestimated the days to maturity. The percent error was over estimated by the model or error was negligible. The simulation performance of the model in respect of days taken to maturity was found to be the best as error was < 1.0%. Also, the results of phenological stages of maize simulated by InfoCrop model are supported by Singh *et al.*, (1994), Akula (2003) and Soler *et al.*, (2007).

Growth and yield parameters

Maximum LAI

LAI of Pancham 541, SP 7121 and RCH 791 were 2.9, 3.1 and 3.5, while model simulated LAI were 3.1, 3.4 and 3.6, respectively as sown in table 6. The percent error was ranged between -9.6 and 19.4%.The performance of model was not in acceptable range in 3rd date of sowing (D3).

Table.1 List of input required by CROPGRO-Cotton model

Input variables	**Acronym**	**Units**
Site data		
Latitude	LAT	Degree
Longitude	LONG	Degree
Elevation	ELEV	M
Average air temperature	TAV	°C
Height of temperature measurement	TMHT	M
Height of wind measurement	WMHT	M
CO_2 concentration		ppm
Daily weather data		
Maximum temperature	TEMPMAX	°C
Minimum temperature	TEMPMIN	°C
Rainfall	RAIN	Mm
Sun Shine hours	SSH	hours
Soil characteristics		
Soil texture	SLTX	
Soil local classification	SLDESC	
Soil family SCS system	TACON	
Soil depth	SLDP	M
Colour, moist	SCOM	
Albedo (fraction)	SALB	Fraction
Evaporation limit	U	Cm
Drainage rate (fraction day^{-1})	SWCON	Fraction day^{-1}
Runoff curve number	CN2	
Mineralization (0 to 1 scale)	SLNF	
Photosynthesis factor (0 to 1 scale)	SLPE	
pH in buffer determination method	SMPX	
Potassium determination method	SMKE	
Horizon-wise		
Lower limit drained	LL(L)	cm^3cm^3
Upper limit drained	DUL(L)	cm^3cm^3
Upper limit drained	SAT(L)	cm^3cm^3
Saturated hydraulic conductivity	SWCN(L)	$cmhr^{-1}$
Bulk density moist	BD(L)	gcm^{-3}
Organic carbon	OC(L)	%
Clay (<0.002 mm)`	CLAY(L)	%
Silt(0.05 to 0.002 mm)	SILT(L)	%

Input variables	**Acronym**	**Units**
Coarse fraction (>2 mm)	STONES(L)	%
Total nitrogen	TOTN(L)	%
pH in buffer	PHKCL(L)	
Cation exchange capacity	CEC(L)	Cmolkg^{-1}
Root growth factor 0 to 1	SHF(L)	
Management data		
Sowing date	YRPLT	
Emergence date	IEMERG	
Plant population at seedling	PLNATS	Plantm^{-2}
Planting method (TP/direct seeded)	PLME	
Planting distribution (row/broadcast/hill)	PLDS	
Row spacing	ROWSPS	Cm
Row direction (degree from north)	AZIR	
Plants per hill	PLPH	
Seed rate	SDWTRL	kgha^{-1}
Sowing depth	SDEPTH	Cm
Irrigation dates	IDLAPL(J)	
Irrigation amount	AMT(J)	Mm
Method of irrigation	IRRCOD(J)	
Fertilizer application dates	FDAY(J)	
Fertilizer amount N	ANFER(J)	kgha^{-1}
Fertilizer type	IFTYPE(J)	
Fertilizer application method	FERCOD(J)	
Fertilizer incorporation depth	DFERT(J)	Cm
Tillage date	TDATE(J)	
Tillage implement	TIMPL(J)	
Tillage depth	TDEP(J)	Cm
Residue management	LNRES	
Chemical applications	LNCHE	
Environment modification	LNENV	
Harvest details		
Harvest	HDATE(J)	
Harvest stage	HSTG(J)	
Harvest component	HCOM(J)	
Harvest percentage	kg ha^{-1}	%

Table.2 Layer- wise soil information for input of DSSAT model

Depth (bottom) Cm	Master Horizon	Clay %	Silt %	Stones %	Organic Carbon %	pH in water	Cation Exchange Capacity C mol/kg
5	AP	10.7	22.3	-99	0.41	8.1	11.4
29	A1	13.4	25.0	-99	0.26	8.4	12.4
57	B2	14.3	26.2	-99	0.26	8.3	13.4
80	B2	16.0	27.9	-99	0.23	8.3	17.4
103	B2	16.5	28.3	-99	0.22	8.2	17.7
127	B3	16.9	28.7	-99	0.20	8.3	19.5

Depth (bottom) Cm	Lower limit	Drainage Upper Limit	Saturation	Bulk Density g/cm3	Saturated Hydraulic Conductivity Cm/hr	Root growth Factor 0.0-1.0
15	0.091	0.183	0.412	1.49	2.59	1.00
29	0.100	0.196	0.407	1.59	2.59	0.644
57	0.105	0.203	0.410	1.50	2.59	0.423
80	0.112	0.215	0.410	1.50	2.59	0.254
103	0.114	0.218	0.410	1.50	2.59	0.160
127	0.116	0.220	0.411	1.50	2.59	0.100

Table.3 Genetic coefficient of cotton cultivar evaluated under different growing environments

VARITIES	CSDL	PP-SEN	EM-FL	FL-SH	FL-SD	SD-PM	FL-LF	LF MAX	SLAVR	SIZLF
SP 7121	23	0.01	42	13	18	55	70	1.3	390	390
PANCHAM 541	23	0.01	40	11	16	54	68	1.3	380	380
RCH 791	23	0.01	46	14	19	56	75	1.3	420	410

VARITIES	XFRT	WTPSD	SFDUR	SDPDV	PO-DUR	THRSH	SD PRO	SDLIP
SP 7121	0.75	0.18	35	27	10	79	0.141	0.12
PANCHAM 541	0.65	0.18	35	27	10	74	0.153	0.10
RCH 791	0.91	0.18	40	30	12	91	0.145	0.13

Table.4 Test criteria of cotton phenology (Days to Flowering) using DSSAT model during 2015-16

Days to Flowering						
	O	**S**	**PE**	**RMSE**	**MBE**	**MAE**
D1(12MAY)	72	73	-1.4	1.7	1.0	1.0
D2(21MAY)	72	73	-0.9	1.2	0.7	0.7
D3(3JUNE)	69	70	-1.0	1.2	0.7	0.7
Pancham 541	70	70	0.0	0.0	0.0	0.0
SP 7121	72	72	0.0	0.0	0.0	0.0
RCH 791	72	74	-3.3	2.4	2.3	2.3

Where: **O**:- Observed, **S**:- Simulated, **E(%)**:- Error %, **RMSE**:- Root mean square error,**MBE**:- mean bias error, **MAE**:- mean absolute error

Table.5 Test criteria of cotton phenology (Days to physiological maturity) using DSSAT model in 2015-16

Days to Physiological maturity						
	O	**S**	**PE**	**RMSE**	**MBE**	**MAE**
D1(12MAY)	139	139	0.0	0.0	0.0	0.0
D2(21MAY)	140	139	0.2	0.6	-0.3	0.3
D3(3JUNE)	138	137	0.7	1.0	-1.0	1.0
Pancham 541	137	136	0.2	0.6	-0.3	0.3
SP 7121	139	138	0.2	0.6	-0.3	0.3
RCH 791	142	141	0.5	0.8	-0.7	0.7

Table.6 Test criteria of maximum LAI and bolls wt./plant using DSSAT model during 2015-16

Maximum LAI						
	O	**S**	**PE**	**RMSE**	**MBE**	**MAE**
D1(12MAY)	3.5	3.6	4.5	0.3	-0.2	0.3
D2(21MAY)	2.7	2.5	-9.6	0.3	0.3	0.3
D3(3JUNE)	3.3	4.0	19.4	0.7	-0.6	0.6
Pancham 541	2.9	3.1	6.8	0.5	-0.2	0.5
SP 7121	3.1	3.4	7.7	0.5	-0.2	0.4
RCH 791	3.5	3.6	2.7	0.3	-0.1	0.3
Bolls Weight / Plant						
	O	**S**	**PE**	**RMSE**	**MBE**	**MAE**
D1(12MAY)	27.7	25.9	-6.7	2.1	-1.9	1.9
D2(21MAY)	19.7	18.1	-7.7	1.6	-1.5	1.5
D3(3JUNE)	10.8	9.6	-11.8	1.4	-1.3	1.3
Pancham 541	17.7	16.2	-8.3	1.5	-1.5	1.5
SP 7121	19.3	18.0	-7.0	1.4	-1.3	1.3
RCH 791	21.2	19.4	-8.7	2.1	-1.9	1.9

Table.7 Test criteria of Biomass and Seed cotton yield using DSSAT model during 2015-16

Biomass (q/ha)						
	O	**S**	**PE**	**RMSE**	**MBE**	**MAE**
D1(12MAY)	36.3	37.8	4.1	3.3	1.5	3.1
D2(21MAY)	28.1	29.2	4.0	2.3	1.1	1.9
D3(3JUNE)	20.9	17.3	-17.4	3.7	-3.6	3.6
Pancham 541	24.9	26.8	7.4	3.8	1.8	3.7
SP 7121	28.6	28.4	-0.5	2.4	-0.1	2.1
RCH 791	31.8	29.1	-8.5	3.1	-2.7	2.7
Seed cotton yield (q/ha)						
	O	**S**	**PE**	**RMSE**	**MBE**	**MAE**
D1(12MAY)	17.7	19.3	9.0	1.7	-1.6	1.6
D2(21MAY)	14.8	14.2	-4.0	2.1	0.6	1.7
D3(3JUNE)	10.1	8.3	-17.6	2.1	1.8	1.8
Pancham 541	11.3	11.5	2.5	0.8	-0.3	0.7
SP 7121	13.2	13.6	3.2	1.4	-0.4	1.4
RCH 791	18.2	16.7	-8.2	3.0	1.5	3.0

The evaluation of the model on an overall basis revealed that the simulation performance of the model in respect of LAI was found good with an accepted level (±10.0%) for 1st and 2nd date of sowing and all the three cultivars. Ortiz *et al.*, (2009) reported that model under predicted maximum LAI for all fumigated treatments. The evaluation of the model on an overall performance of simulation was good.

Bolls weight/plant

Bolls weight/plant obtained for cv. Pancham 541, SP 7121 and RCH 791 were 17.7, 19.3 and 21.2 g, while model simulated 16.2, 18.0 and 19.4 g, respectively as shown in table 6. The average percent error was 8.7 (RCH 791). The model underestimated bolls weight/plant in all the three growing environments and in all the three cotton cultivars. The overall performance of simulation was found good within accepted level (±10%) for cotton. Ortiz *et al.*, (2009) also reported the changes in boll weight accumulation throughout the season and the final boll weight at harvest were fairly well predicted by the CSM-CROPGRO-Cotton model.

Biomass

The biomass yield of RCH 791and SP 7121 was underestimated and of Pancham 541 overestimated by the model (Table 7). The average percent error for biomass yield was found 8.5(RCH 791), 0.5 (SP 7121) and 7.4 % (Pancham 541). The average percent error was 4.1(D1), 4.0(D2) and 17.4(D3). The biomass yield simulation was found good (±10.0%) for cotton for all cultivars and 1st and 2nd date of sowing, except 3rd date of sowing. Ortiz *et al.*, (2009) also reported that calibrated coefficients improved the total biomass and boll weight predictions by 14.3% and 6.1%, respectively, when compared to the original default values.

Seed cotton yield

The seed cotton yield observed in field experiment for cv. Pancham 541, SP 7121 and RCH 791 were 18.2, 13.2 and 11.3 q/ha while model simulated yield was16.7, 13.6 and 11.5 q/ha, respectively (Table 7). The average percent error was within acceptable error limit in all the treatment except 1st week of June (D3) which was not within acceptable limit of the model. This shows that the evaluation of the model on an overall basis revealed that the simulated yield was good with an accepted level of percent error for cotton except 1st week of June (D3) sown crop. Also, these results are supported by finding of Soler *et al.*, (2007) for maize and Singh *et al*., (1994) for groundnut yield and yield attributes simulated by PNUTGROW model.

In conclusion, genetic coefficients were evaluated and DSSAT Model was validated for cotton cultivars: Pancham 541, SP 7121 and RCH 791. The model performance in respect of phenology was found to be good for all the three cotton cultivars and for all the growing environments. Also the model performance was good for all the cultivars, 2nd and 3rd week of May sown crop in case of seed cotton yield, biomass and maximum LAI. But the model performance was not good for the crop sown in 1st week of June.

References

Akula, B. 2003.Ph.D thesis, Anand Agricultural University, Gujarat.

Boomiraj, K., Chakrabarti, B., Aggarwal, P.K., Choudhary, R. and Chander, S. 2007. Impact of Climate Change on Indian mustard (*Brassica juncea*) in contrasting Agro-environments of the tropics.*ISPRS Archives XXXVIII-8/W3 Workshop Proceedings: Impact of Climate Change on Agriculture*.

DeGui, Z., K. FanLing, Z. QunYuan, L. WenXin, Y. FuXin, X. NaiYin, L. Qin and Z. Kui. 2003. Genetic improvement of cotton varieties in the Yangtse valley in China since 1950s. I. Improvement on yield and yield components. *Acta Agron. Sinica*, 29(2): 208-215.

Hoogenboom, G., Jones, J.W., Wilkens, P.W., Porter, C.H., Boote, K.J., Hunt, L.A., Singh, U., Lizaso, J.L., White, J.W., Uryasev, O., Royce, F.S., Ogoshi, R., Gijsman, A.J., Tsuji, G.Y. and Koo, J. 2012. Decision Support System for Agrotechnology Transfer (DSSAT) Version 4.5. University of Hawaii, Honolulu, Hawaii.

Jones, J.W., Hoogenboom, G., Porter, C.H., Boote, K.J., Batchelor, W.D., Hunt, L.A., Wilkens, P.W., Singh, U., Gijsman, A.J. and Ritchie, J.T. 2003. DSSAT Cropping System Model. *Euro. J. Agro*., 18: 235-265.

Jost, P.H. and J.T. Cothren. 2000. Growth and yield comparisons of cotton planted in conventional and ultra-narrow row spacing. *Crop Sci.,* 40(2): 430-435.

Ortiz, B.V., Hoogenboom, G., Vellidis, G., Boote, K.,Davis, R.F. and Perry, C. 2009. Adapting the CROPGRO- cotton model to simulate cotton biomass and yield under southern root knot nametodes parasitism. *Ameri. Soc. Agril. Bio. Engi.,* ISSN 2151-0032. 52(6): 2129-2140.

Singh, P., Boote, K.J., Rao, A.Y., Iruthayaraj, Sabani, M.B., Shakh, A.M., Hundal, S.S., Natraj, R.S. and Singh, P. 1994. Evaluation of the groundnut model PNUTGRO for crop response to water availability, sowing dates and seasons. *Field Crops Res*., 39: 147-162.

Singh, M., Kalra, N., Chakraborty, D., Kamble, K., Barman, D., Saha, S., Mittal, R.B. and Pandey, S. 2008. Biophysical and socioeconomic characterization of a water-stressed area and simulating Agri-production estimates and land use planning under normal and extreme climatic events.

Soler, C.M.T., Sentelhas, P.C. and Hoogenboom, G. 2007. Application of the CSM-CERES-Maize model for planting date evaluation and yield forecasting for maize grown off-season in a subtropical environment. *Eur. J. Agron*., doi:10.1016/ j.eja.2007.03.002.

Tsuji, G.Y., Uehara, G. and Balas, S.(eds.). 1994. DSSAT: a decision support system for agrotechnology transfer. Version 3.Vols. 1, 2 and 3. University of Hawaii, Honolulu, HI.

Uehara, G. and Tsuji, G.Y. 1998. Overview of IBSNAT. In: Tsuji, G.Y., Hoogenboom, G., Thornton, P.K. (Eds.), Understanding Options for Agricultural Production. Kluwer Academic Publishers, Dordrecht, The Netherlands, pp. 1–7.

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