Crop Simulation Modeling

The current agricultural production system is challenged by weather, climate extremes, variability, and economic risks.

There is pressure to grow more healthy food using sustainable practices.

At the same time, technology is rapidly improving with new sensor technologies, the Internet of Things, edge computing, and remote sensing.

The amount of data collected for agricultural production systems is exponentially expanding, providing opportunities for data analytics for strategic and actionable decisions.

The modeling of the ecosystem can play a major role in helping to understand the interaction between Genotype, Environment, and Management (G * E * M) and to provide alternative management options that increase crop yield and quality, optimize resource use, and minimize environmental impact for long-term sustainable agricultural production.

Model Definition

A model is a simplified representation of a system or a process. A model is a computer program, which describes the mechanism of the process or a system.

Modeling is based on the assumption that any given process can be expressed in a form of a mathematical statement or set of statements or a sets of statements to depict the real world system.

Discrete Model

The state variables change only at a countable number of points in time. These points in time are the ones at which the event occurs/change in state.

Example: Statistical model

Continuous Model

The state variables change in a continuous way, and not abruptly from one state to another (infinite number of states).

Example: Crop Simulation Model

Simulation Modelling

Simulation modelling is the process of creating and analyzing a digital prototype of a physical model to predict its performance in the real world.

Crop Simulation Models

- The crop simulation models are in fact a simple and meaningful representation of a crop, construed as systems research tool, which aid in solving the problems associated with agricultural crop production and these crop simulation models are needed to distill the knowledge obtained through field-based experimentation and observations.

- It provides a platform for interdisciplinary collaboration. Also, the systems approach adopted by crop simulation models helps in solving problems arising from crop production.

- Operationally, the crop models require input data pertaining to and limited to crop type and varieties, soil types and characteristics; weather data and agronomic practices.

- Crop simulation models are used to gauge the effects of soil, climate, and crop management practices on growth and development of crops; and agricultural productivity and sustainability of the agricultural production system.

- The use of crop simulation models for agricultural research greatly reduces the cost and time involved in the field experiments. This is because the results obtained for one location or season can be extrapolated to other locations and seasons.

- The development of crop simulation models, along with the application of decision support system approaches, greatly aids in augmenting resource use and agricultural productivity; minimising the environmental impacts borne out of agricultural practices; and mapping the yield gaps.

There are several tool of systems related to computer and information technology can help in solving agricultural problems.

One such tool is crop growth simulation model.

These models are based on quantitative understanding of the underlying processes, and integrate the effect of soil, weather, crop, pest and management factor on growth and yield.

The process are

- crop physiological
- Meteorological
- soil physical
- chemical
- biological.

Depending upon the objective, knowledge base of various agricultural disciplines can be integrated in a crop model

APPLICATIONS OF CROPMODEL

Estimation of Potential Yields

Calibrated and validated model will predict the potential yield perfectly under no stress condition

Estimation of Yield Gaps

Model will be used to estimate the yield gaps between

- potential yield and attainable yield
- potential yield and actual yield
- potential yield and farmers yield.

Assessment the principal causes, contribution and remedial measures for yield gap and bridging the yield gap.

Yield Forecasting

Calibrated and validated models are useful for yield forecasting, which will be useful for marketing of produce in right time at right place and at right price

Limitations

- The crop models can only aid in improving our understanding about the agricultural production system, and they cannot replace field experiments altogether.
- Application of models developed for a region, require parameterization and calibration before being applied in other regions

Agriculture

The agricultural system is a **complex** system that includes many interactions between biotic and abiotic factors

Abiotic factors = Non-Living

Weather/climate

Soil properties

Crop management

Crop and variety selection

Planting date and spacing

Inputs, including irrigation and fertilizer

Biotic factors

Pests and diseases

Weeds

Soil fauna

Socio-economic factors

- Prices of grain and byproducts
- Input and labor costs
- Policies
- Cultural settings
- Human decision making

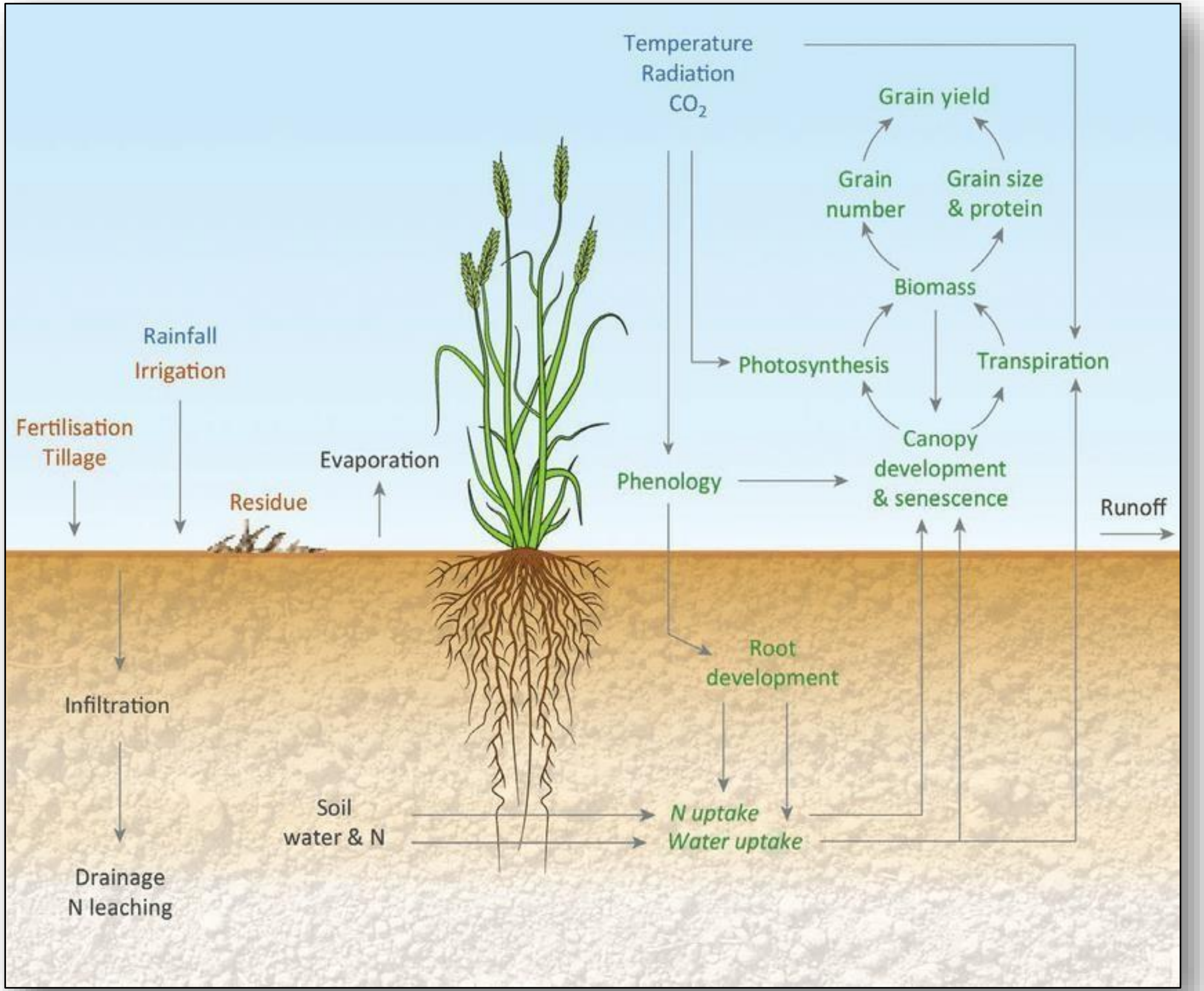
Environmental constraints

- Pollution
- Natural resources

Management

Some of these factors can be modified by farmer interactions and intervention, while others are controlled by nature.

Senescence is the process of aging or growing old. It can refer to the gradual decline in an organism's functional characteristics that occurs after its development phase. It can also refer to the permanent arrest of cell division in a cell, which occurs when a cell ages but does not die



Key processes involved in crop growth and development and their interactions with the crop system

A model is a mathematical representation of a real world system.

What is a crop simulation model?

- Crop simulation model is a combination of mathematical equations and logic used to conceptually represent a simplified crop production system.
- Simulation means that model acts like a real crop, gradually germinating, growing leaves, stem and roots during the season.
- In other words, simulation is the process of using a model dynamically by following a system over a time period.

Crop simulation models integrate the current state-of-the art scientific knowledge from many different disciplines, including

crop physiology

plant breeding

agronomy

agrometeorology

soil physics, soil chemistry, soil fertility plant

pathology, entomology economics and many others.

Simple Model

Air temperature

==>Vegetative and reproductive development

Solar radiation

==>Photosynthesis and biomass growth

Development * Biomass = Yield

Yield = *f* (Development, Biomass)

Development = *f* (Environment, Genetics)

Biomass = *f* (Environment, Genetics)

Environment = *f* (Weather, Soil)

Other factors:

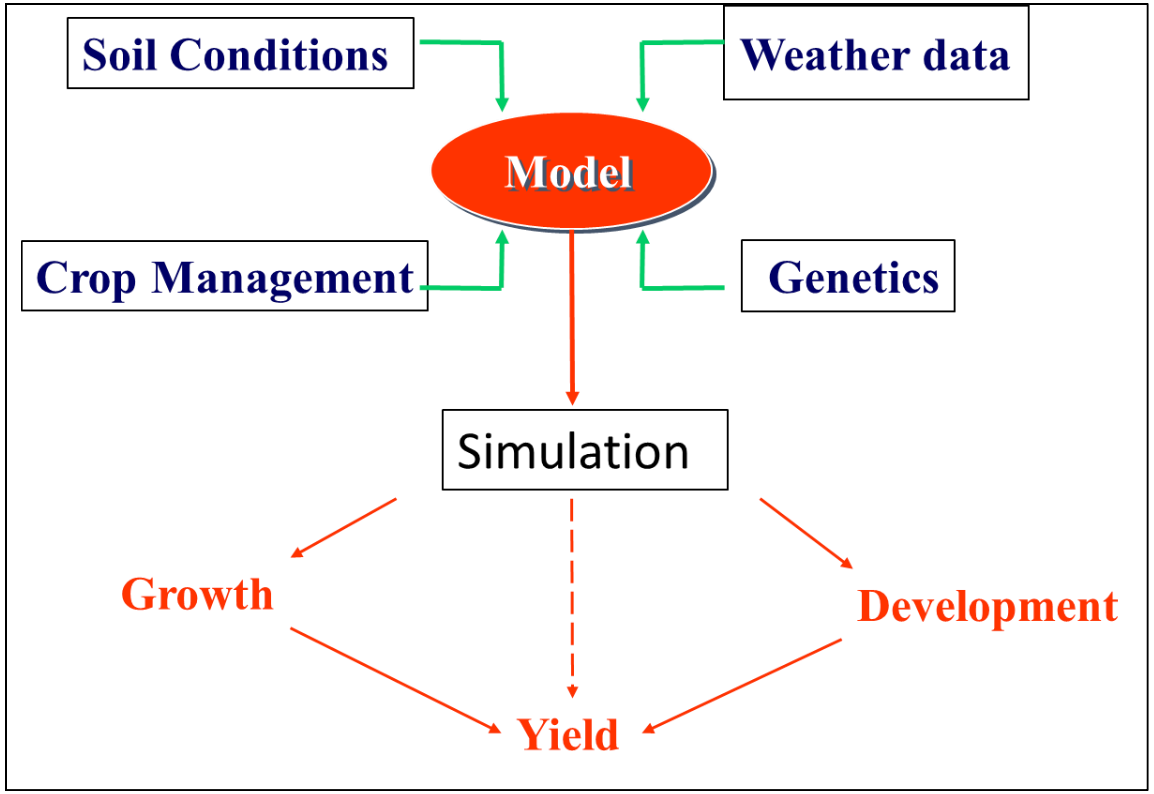
management

stress (biotic and abiotic)

Model Frame work

Crop simulation models in general calculate or predict ***crop growth and yield*** as a function of:

- Genetics
- Weather conditions
- Soil conditions
- Crop management



Agricultural Production

Potential production

Water-limited production

Nitrogen-limited production

Nutrient-limited production

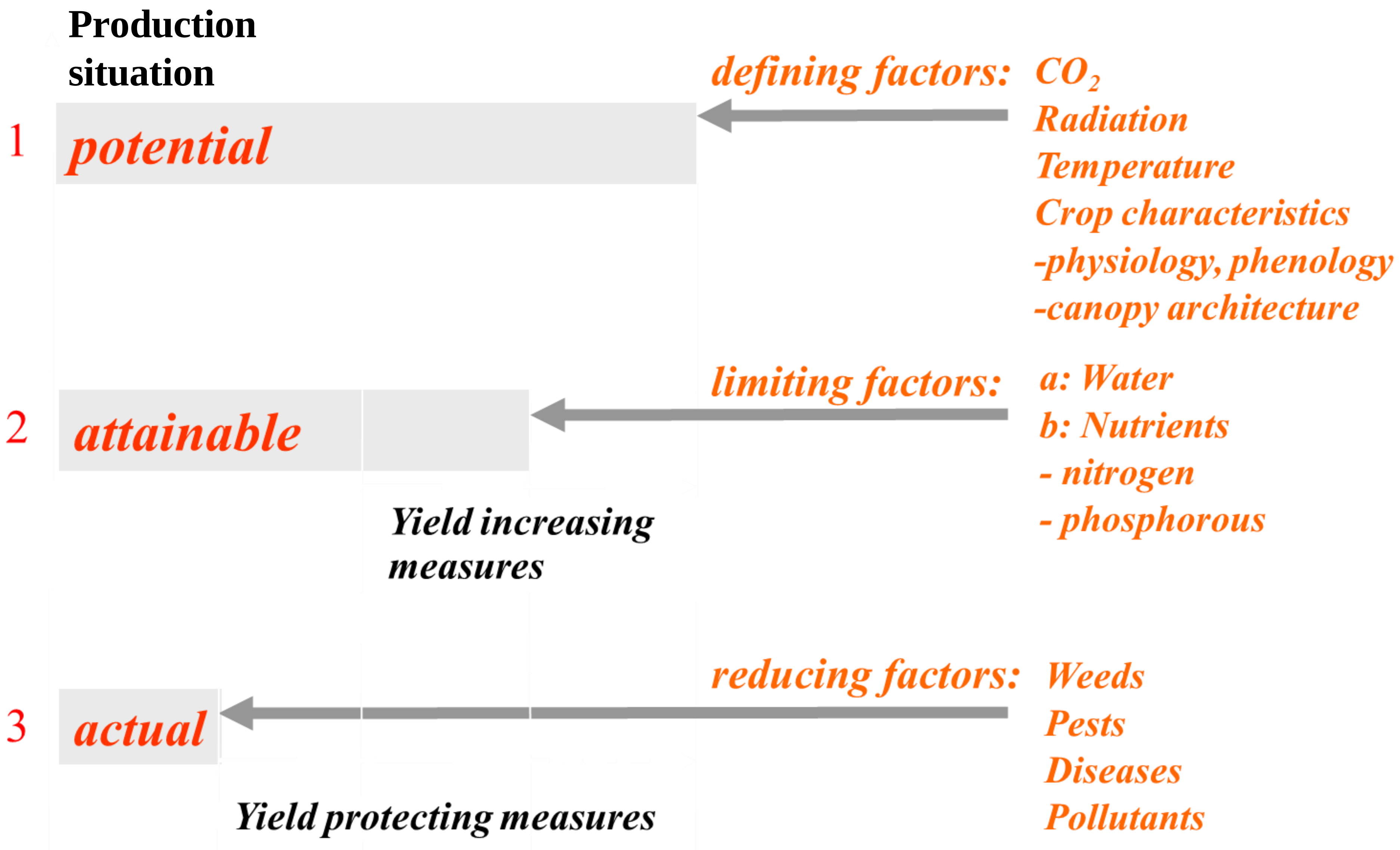
Pest-limited production

Other factors

- Extreme weather events
- Salinity

Complexity

Real World



Source: World Food Production: Biophysical Factors of Agricultural Production, 1992.

Crop Simulation Models

Require information (Inputs)

- Field and soil characteristics
- Weather (daily)
- Cultivar characteristics
- Management

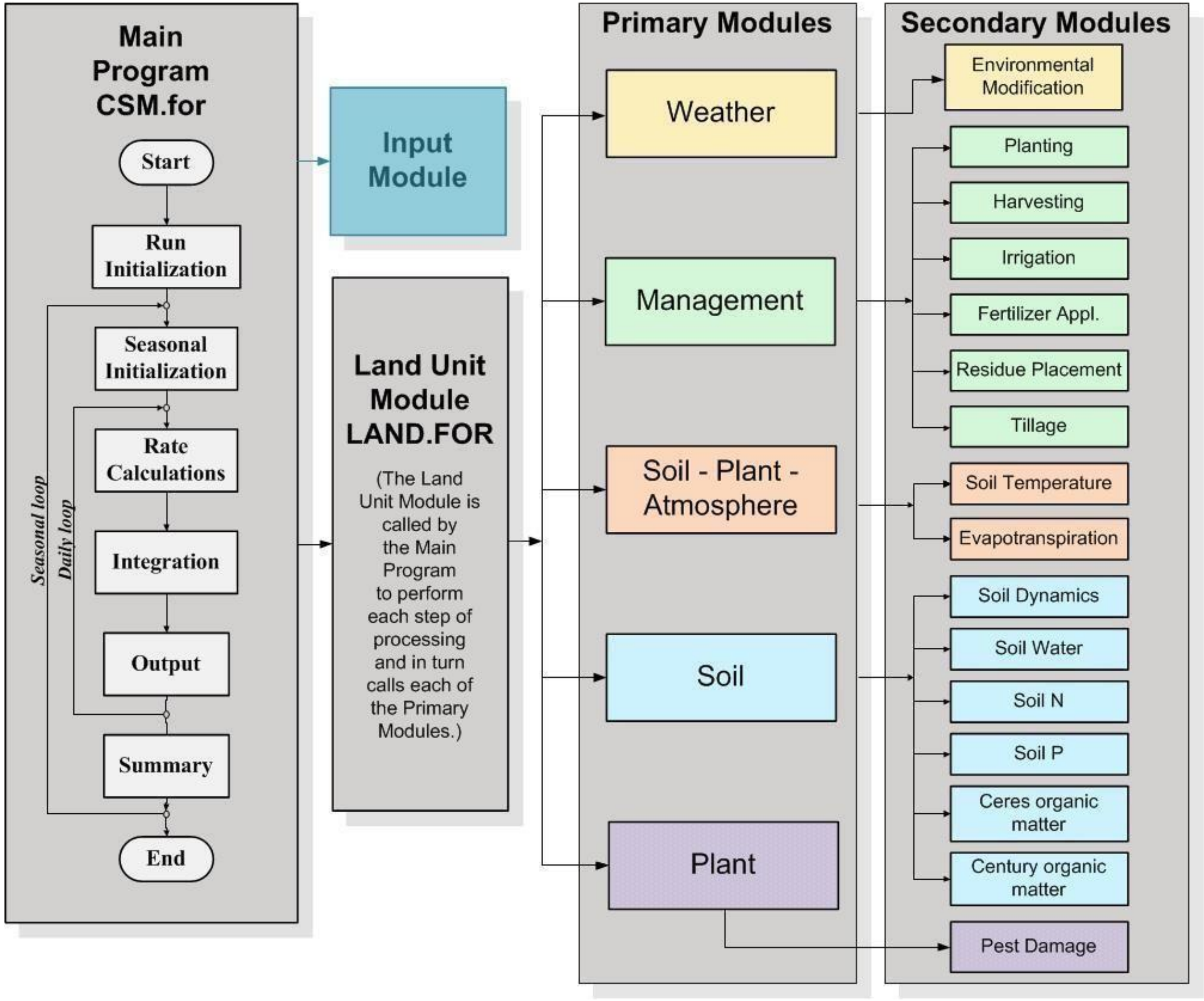
Model calibration for local variety

Model evaluation with independent data set

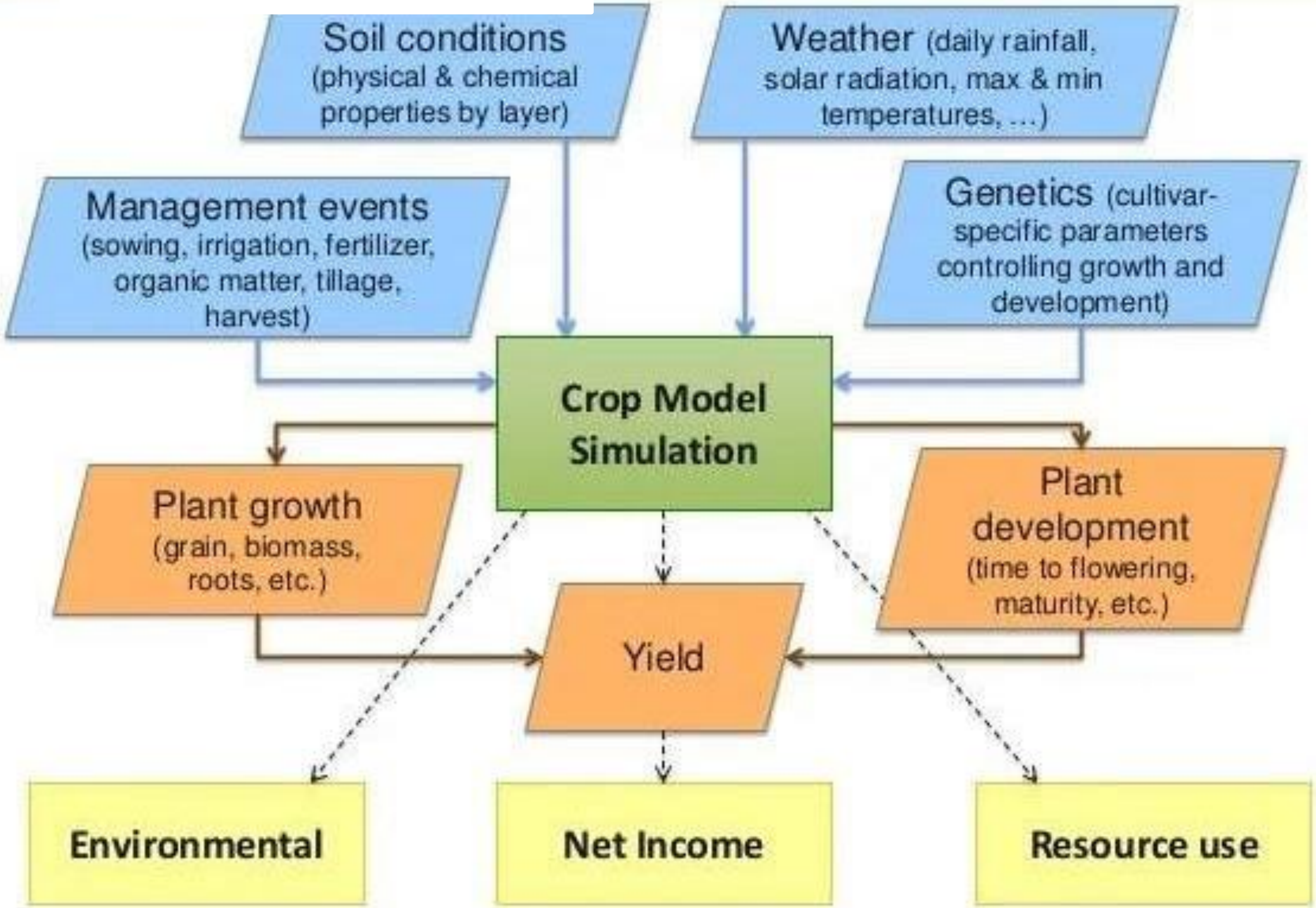
Can be used to perform "what-if" experiments

DSSAT Model

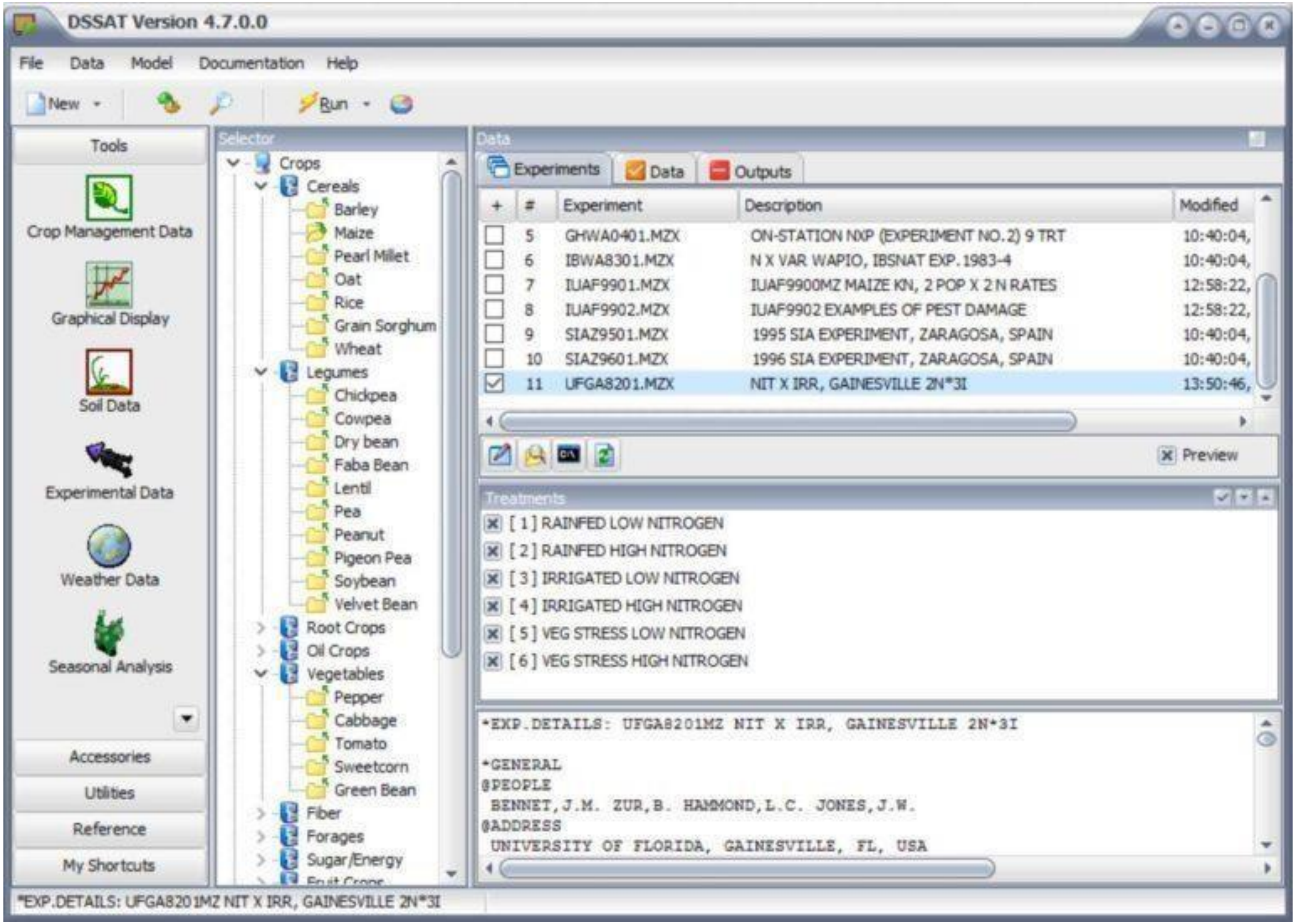
Decision Support System for Agrotechnology Transfer



DSSAT Crop Simulation Model

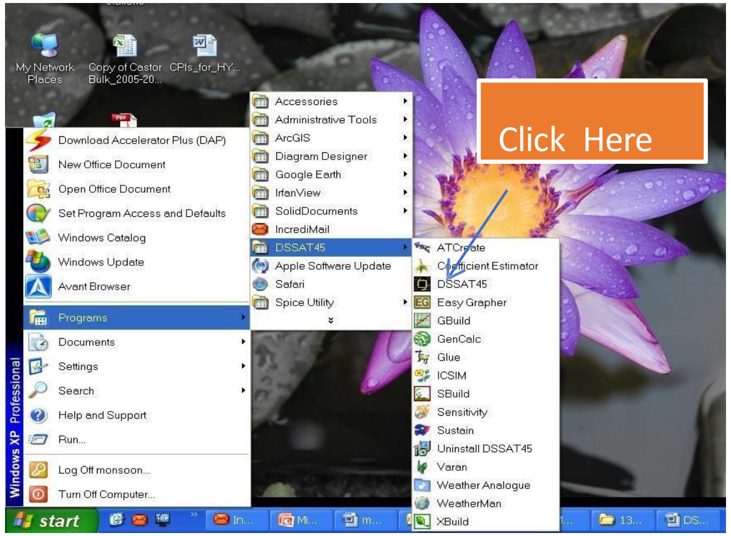


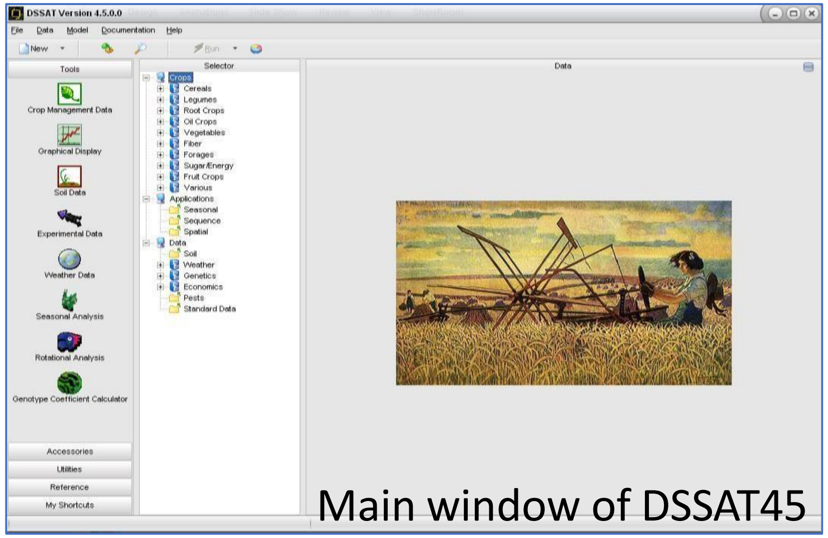
Starting the DSSAT model from Desktop
Different input files and their paths


DSSAT Version 4.7.0.0
File
Data
Model
Documentation
Help
New
Run
Tools
Crop Management Data
Graphical Display
Soil Data
Experimental Data
Weather Data
Seasonal Analysis
Accessories
Utilities
Reference
My Shortcuts
Selector
Crops
Cereals
Barley
Maize
Pearl Millet
Oat
Rice
Grain Sorghum
Wheat
Legumes
Chickpea
Cowpea
Dry bean
Faba Bean
Lentil
Pea
Peanut
Pigeon Pea
Soybean
Velvet Bean
Root Crops
Oil Crops
Vegetables
Pepper
Cabbage
Tomato
Sweetcorn
Green Bean
Fiber
Forages
Sugar/Energy
Data
Experiments
Data
Outputs
#
Experiment
Description
Modified
5 GHWA0401.MZX ON-STATION NXP (EXPERIMENT NO.2) 9 TRT 10:40:04,
6 IBWA8301.MZX N X VAR WAPIO, IBSNAT EXP.1983-4 10:40:04,
7 IUAF9901.MZX IUAF9900MZ MAIZE KN, 2 POP X 2 N RATES 12:58:22,
8 IUAF9902.MZX IUAF9902 EXAMPLES OF PEST DAMAGE 12:58:22,
9 SIAZ9501.MZX 1995 SIA EXPERIMENT, ZARAGOSA, SPAIN 10:40:04,
10 SIAZ9601.MZX 1996 SIA EXPERIMENT, ZARAGOSA, SPAIN 10:40:04,
11 UFGA8201.MZX NIT X IRR, GAINESVILLE 2N*3I 13:50:46,
Preview
Treatments
[1] RAINFED LOW NITROGEN
[2] RAINFED HIGH NITROGEN
[3] IRRIGATED LOW NITROGEN
[4] IRRIGATED HIGH NITROGEN
[5] VEG STRESS LOW NITROGEN
[6] VEG STRESS HIGH NITROGEN
*EXP.DETAILS: UFGA8201MZ NIT X IRR, GAINESVILLE 2N*3I
*GENERAL
@PEOPLE
BENNET,J.M. ZUR,B. HAMMOND,L.C. JONES,J.W.
@ADDRESS
UNIVERSITY OF FLORIDA, GAINESVILLE, FL, USA
*EXP.DETAILS: UFGA8201MZ NIT X IRR, GAINESVILLE 2N*3I

Starting the DSSAT v4.5 model from your Desktop

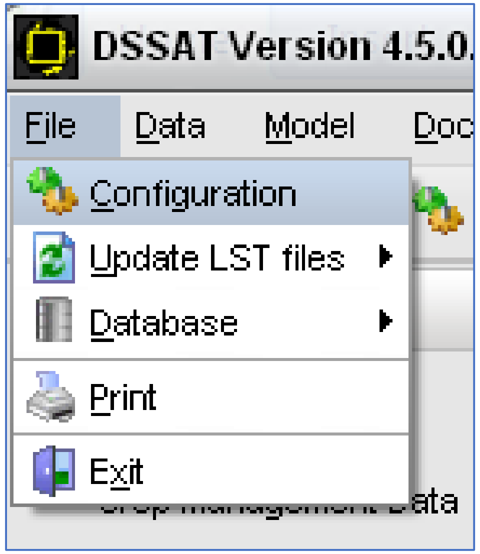
Start ⟶ programs ⟶ DSSAT45 ⟶ DSSAT45

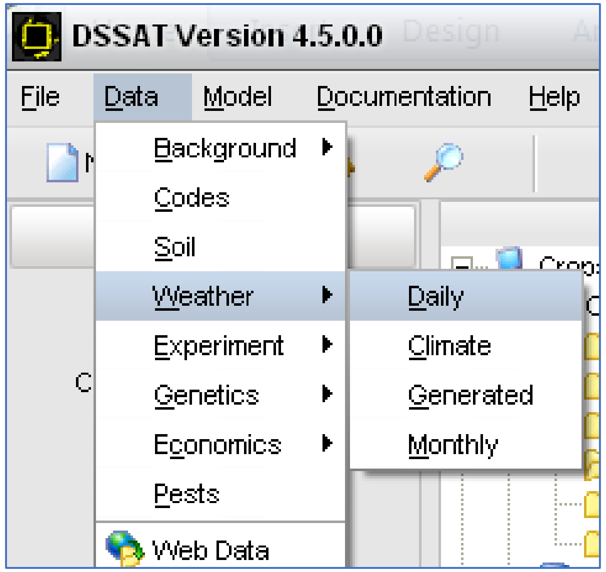


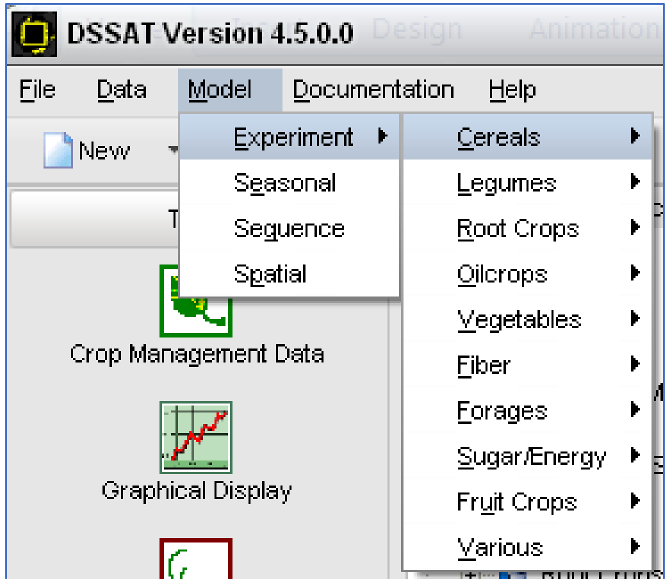


Main window of DSSAT45

Menu Items under DSSAT 45







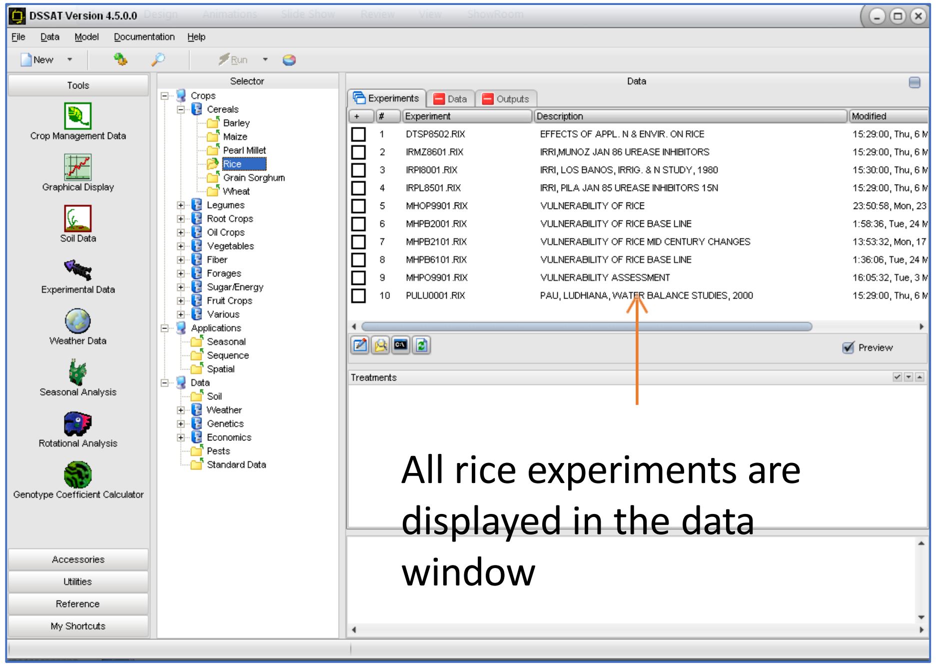
To begin rice model first click on cereals

From DSSAT 45 main window

Select -crops

Select -cereals

Select –rice



All rice experiments are displayed in the data window

There are six input files required for simulating rice model

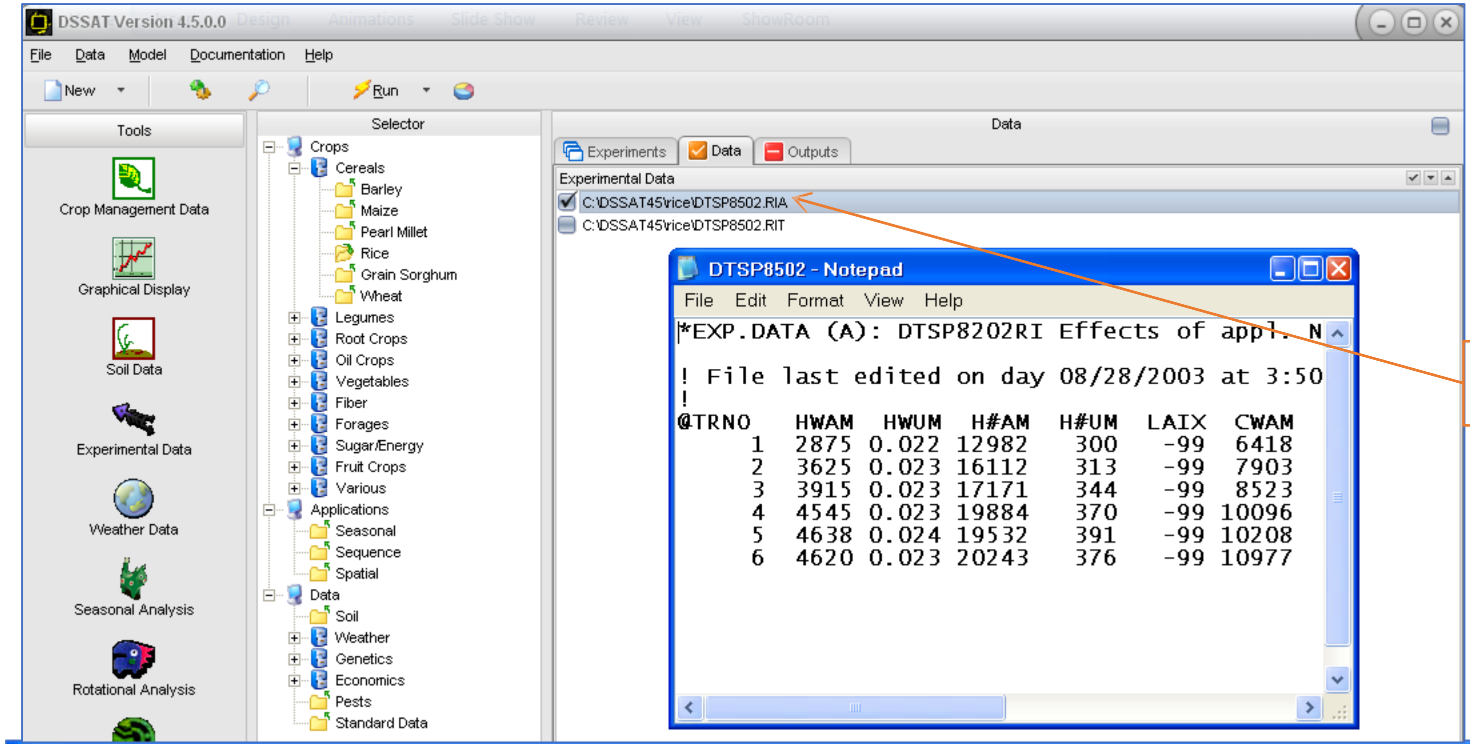
1. Weather file
2. Experimental file
3. Average (A) file (Growth)
4. Time (T) file (Growth)
5. Cultivar file
6. Soil file

Weather files are stored in C:\DSSAT45\Weather folder

Path of Rice Experimental files C:\DSSAT45\Rice
This includes FILEX, FILE A and FILET

Path of Rice genotype files C:\DSSAT45\Genotype

Opening the A file from data window



Open this file

MHOP9901 - Notepad

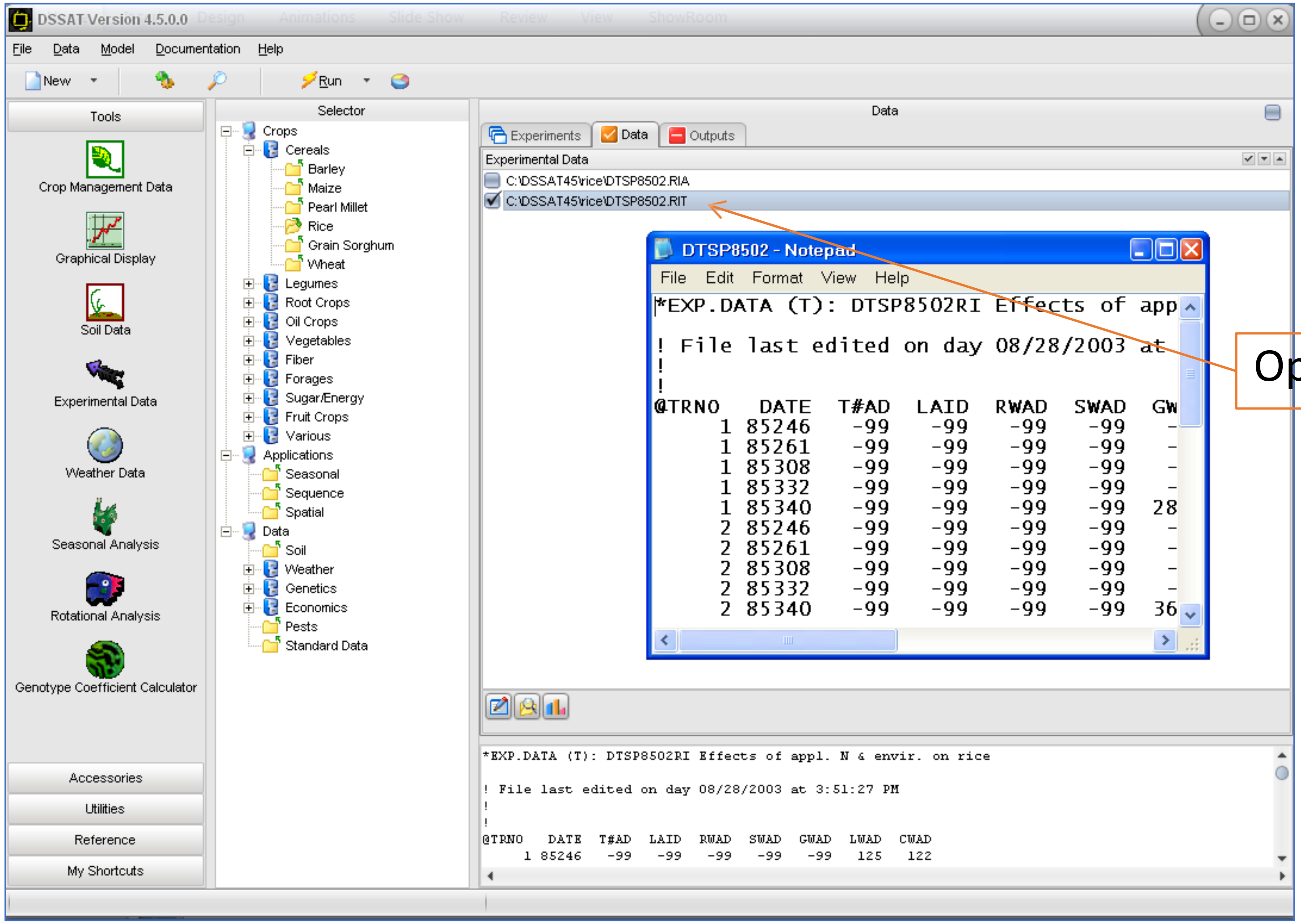
File Edit Format View Help

*EXP.DATA (A): MHOP9901RI RICE,MOHAN ENVI.IMP 1999

! File last edited on day 05/05/2011 at 4:27:58 PM
!

@TRNO	HWAM	HWUM	H#AM	H#UM	LAIX	CWAM	BWAH	ADAT	MDAT	IDAT	CNAM	SNAM	GNAM
1	2100	-99	-99	-99	3.11	8900	7253	99210	99231	-99	-99	-99	-99
2	2150	-99	-99	-99	3.20	10200	9768	99217	99231	-99	-99	-99	-99
3	2000	-99	-99	-99	2.90	7900	8343	99232	99251	-99	-99	-99	-99
4	1990	-99	-99	-99	2.93	9400	7767	99246	99273	-99	-99	-99	-99
5	2500	-99	-99	-99	2.90	11500	9725	99226	99246	-99	-99	-99	-99
6	2500	-99	-99	-99	3.00	13800	10457	99233	99258	-99	-99	-99	-99
7	2200	-99	-99	-99	2.60	11300	8817	99251	99273	-99	-99	-99	-99
8	2100	-99	-99	-99	2.80	7300	9942	99260	99279	-99	-99	-99	-99

Opening the T file from data window

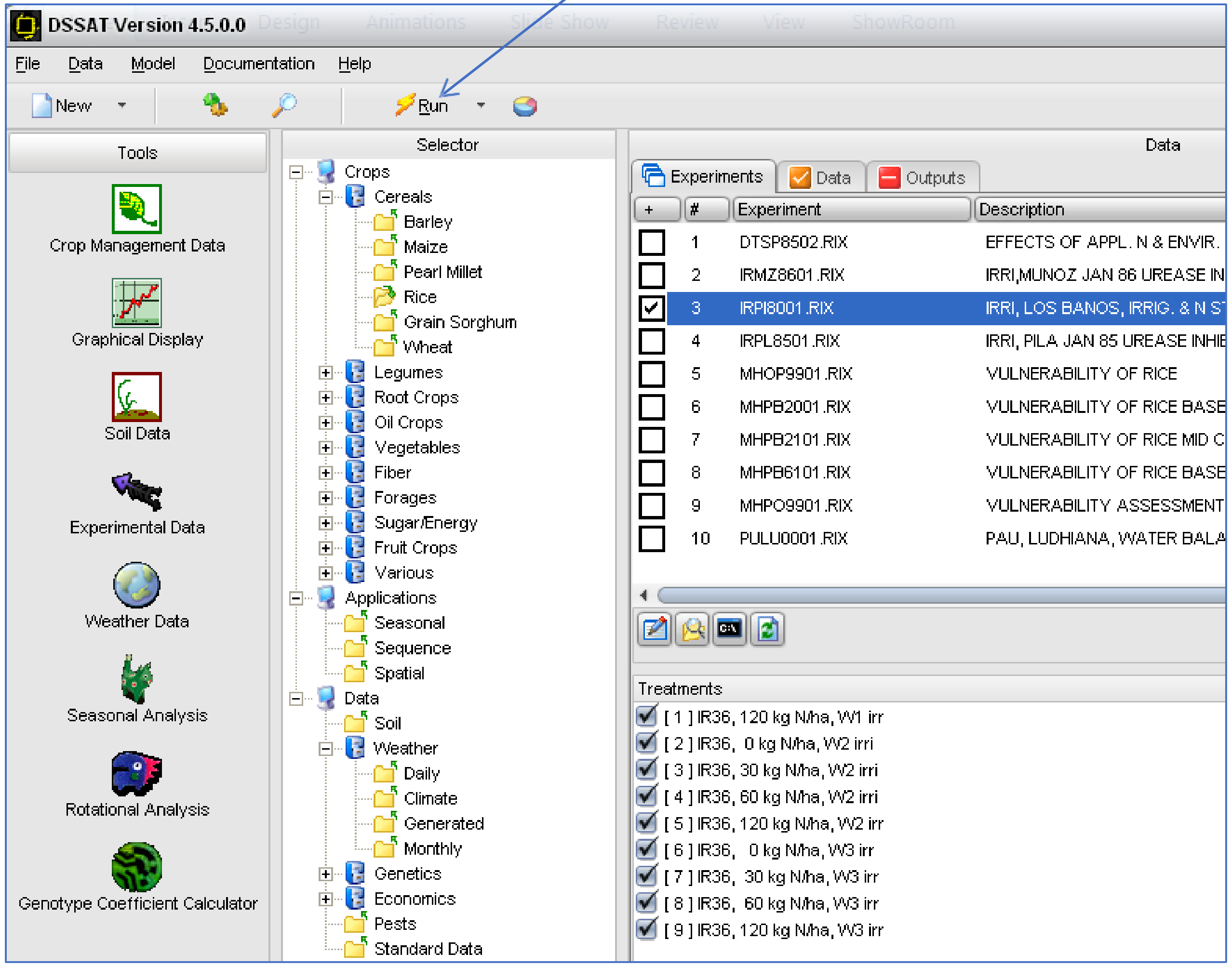


Open this (T) file

To Simulate the rice experiment

Click the run button

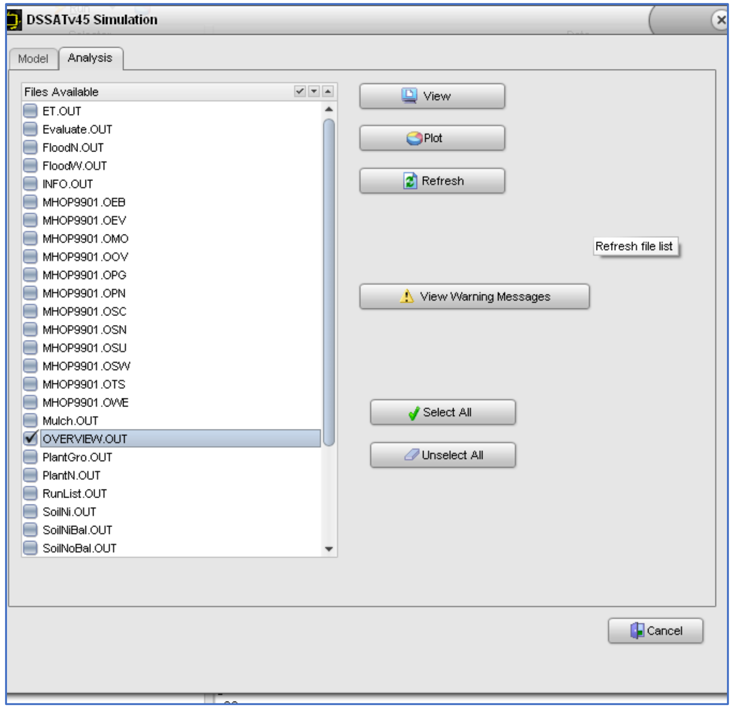
Select experimental file
↓
Click Run icon
↓
In the next screen
↓
Click run model

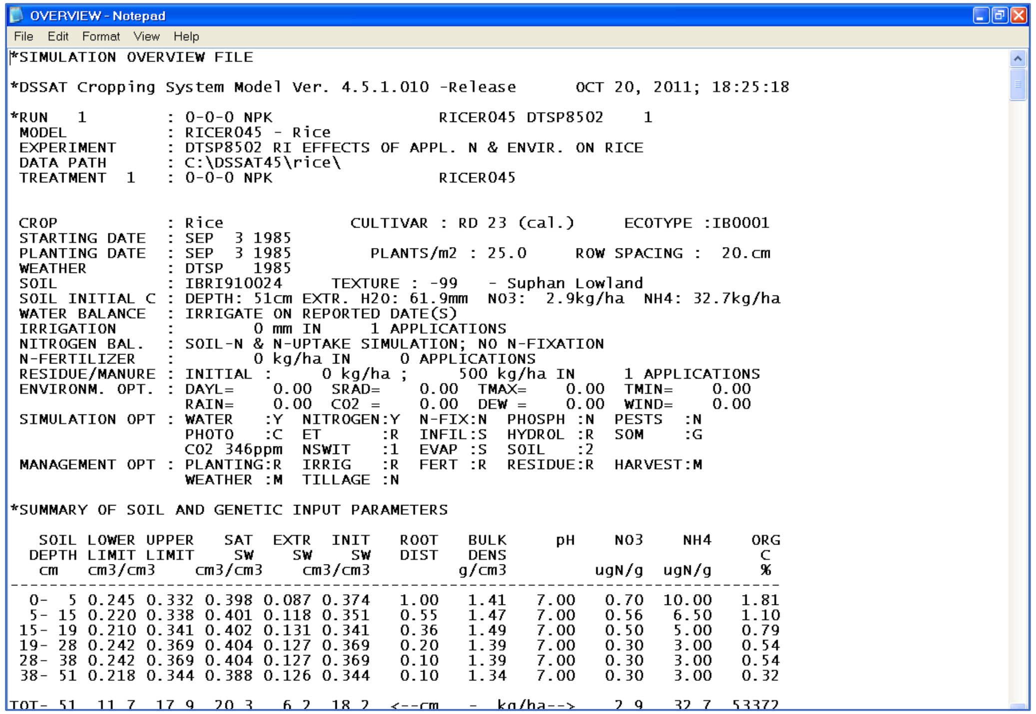


- After selecting the run model and click, the model simulates the rice crop . Under analysis window the model output files are arranged

- From this you select overview. Out and click view. This enable us to see an overview of the model simulation and stage wise weather and crop stress under different conditions

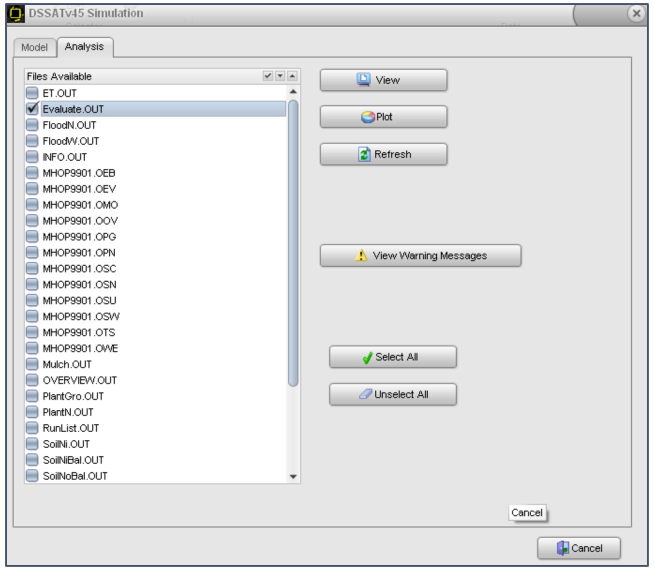
- Just click and view all the .out files one by one

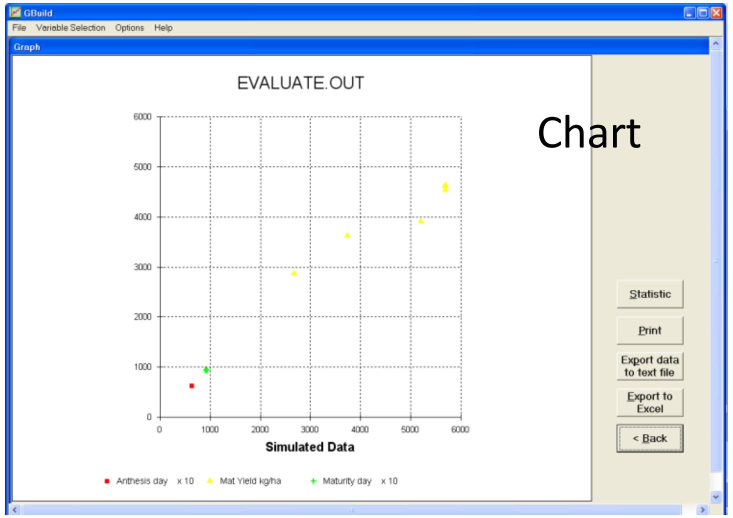


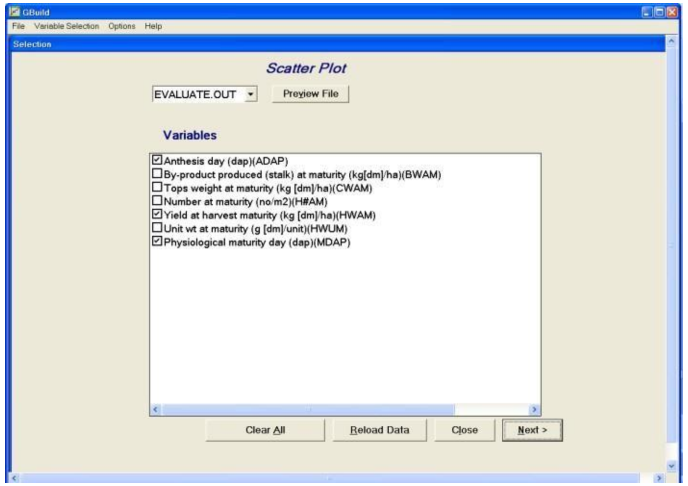


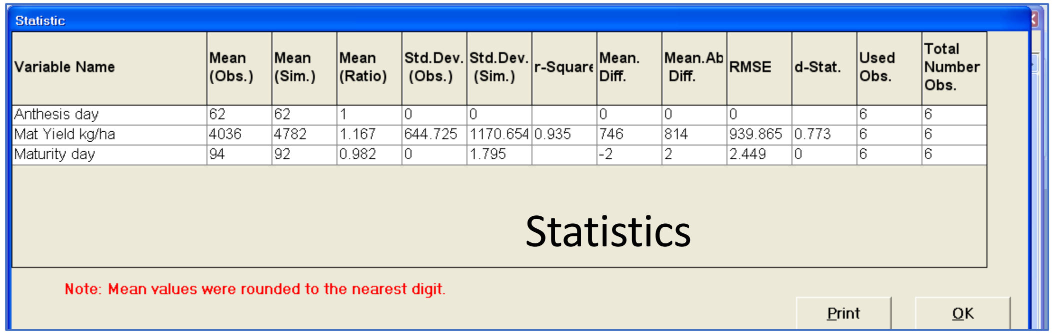
- For evaluating the Model select Evaluate. Out from the output and select plot
- The graphic display activates and shows the phenological events and yield
- Select anthesis (the period during which a flower is fully open and functional) and maturity dates and yield to look into the difference between the observed and simulated values
- Select statistic in the chart screen below

For model evaluation








Statistic

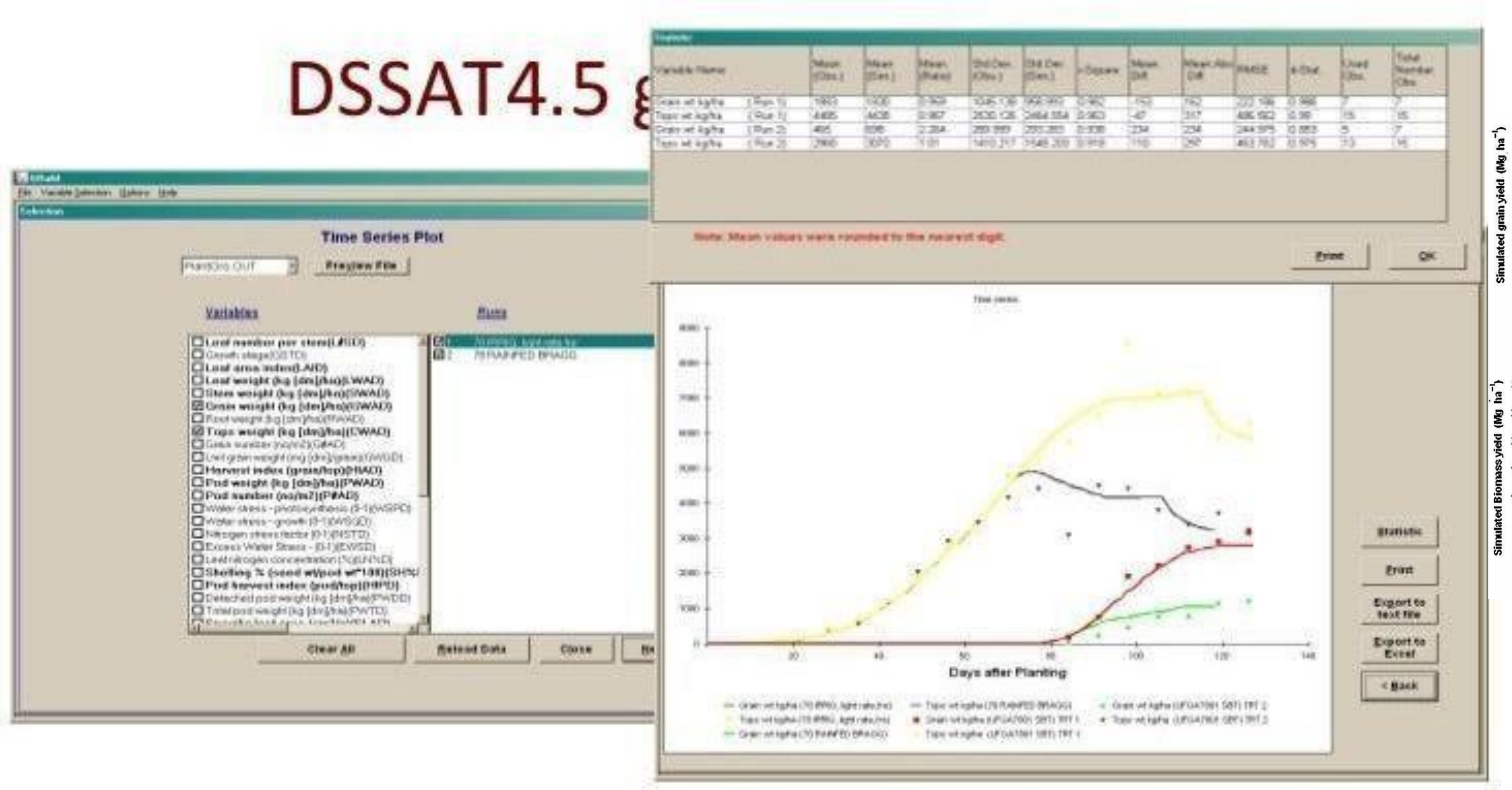
Variable Name	Mean (Obs.)	Mean (Sim.)	Mean (Ratio)	Std.Dev. (Obs.)	Std.Dev. (Sim.)	r-Square	Mean. Diff.	Mean.Ab Diff.	RMSE	d-Stat.	Used Obs.	Total Number Obs.
Anthesis day	62	62	1	0	0		0	0	0		6	6
Mat Yield kg/ha	4036	4782	1.167	644.725	1170.654	0.935	746	814	939.865	0.773	6	6
Maturity day	94	92	0.982	0	1.795		-2	2	2.449	0	6	6

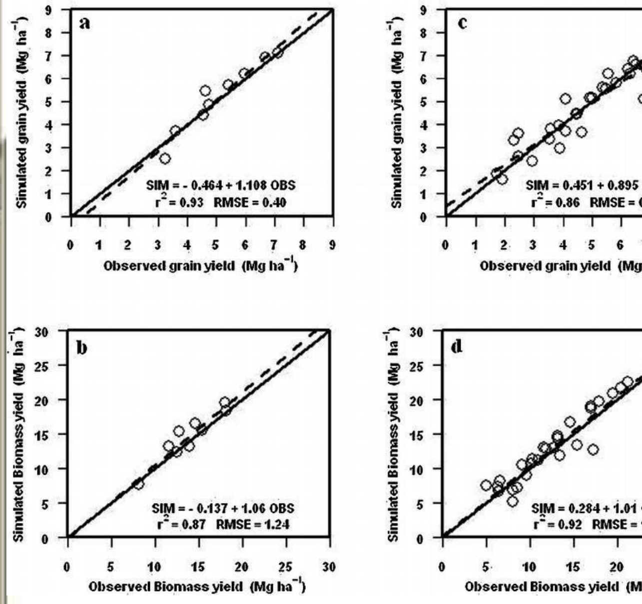
Statistics

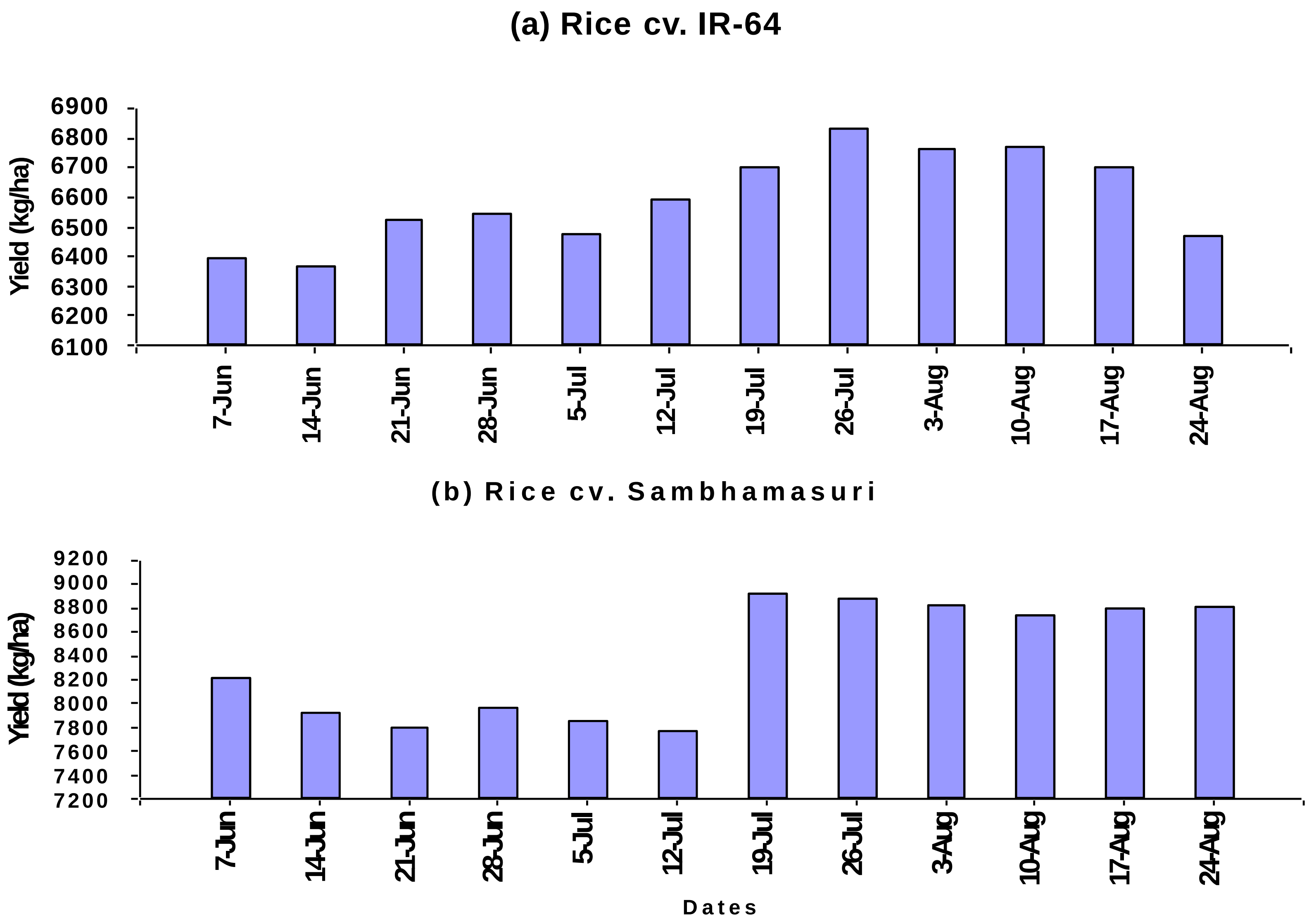
Note: Mean values were rounded to the nearest digit.

Print OK

Model Calibration







Grain yield simulated for different dates of transplanting for (a) IR-64 and (b) *cv.* Sambhamasuri

Evaluation of crop simulation model for rice genotypes under diverse environments in India

Cultivars under study

Stations	Name	Planting time	Duration (after transplanting)
Palampur	RP2421	20Jun-25 Jul	100-110
Faizabad	Sarjoo-52 NDR-359 PD-4	5Jul-25 Jul 5Jul-25 Jul 5Jul-25 Jul	100-120 90-110 90-110
Diphu	Ranjit	20Jun-25 Jul	120-130
Kalyani	Swarna	20Jun-25 Jul	120-130

Genetic coefficients

Name	RP2421	Sarjoo-52	NDR-359	PD-4	Ranjit	Swarna
(P1)	100.00	670.0	600.0	620.0	855.00	840.00
(P2O)	0.80	200.0	150.0	160.0	170.00	160.00
(P2R)	350.00	400.0	410.0	300.0	520.00	520.00
(P5)	11.00	12.7	12.0	12.0	11.30	11.40
(G1)	32.00	45.0	42.0	45.0	35.00	41.00
(G2)	0.024	.0200	.0200	.0200	0.021	0.230
(G3)	0.55	1.00	1.00	1.00	0.60	0.75
(G4)	1.00	0.80	0.80	0.80	0.80	0.80

Name	Genetic coefficients Description
(P1)	Time period (expressed as growing degree days [GDD] in ^{o}C over a base temperature of 9 ^{o}C) from seeding emergence during which the rice plant is not responsive to change in photoperiod.
(P2O)	Critical photoperiod or the longest day length (in hours) at which the development occurs at a maximum rate.
(P2R)	Extent to which phasic development leading to panicle initiation is delayed for each hour increase in photoperiod above P20.
(P5)	Time period in GDD ^{o}C) from beginning of grain filling (3 to 4 days after flowering) to physiological maturity with a base temperature of 9 ^{o}C.
(G1)	Potential spikelet number coefficient as estimated from the number of spikelets per g of main culm dry weight at anthesis.
(G2)	Single grain weight (g) under ideal growing conditions, i.e. non limiting light, water, nutrients, and absence of pests and diseases.
(G3)	Tillering coefficient (scalar value) relative to IR64 cultivar under ideal conditions.
(G4)	Temperature tolerance coefficient. Usually 1.0 for varieties grown in normal environments.

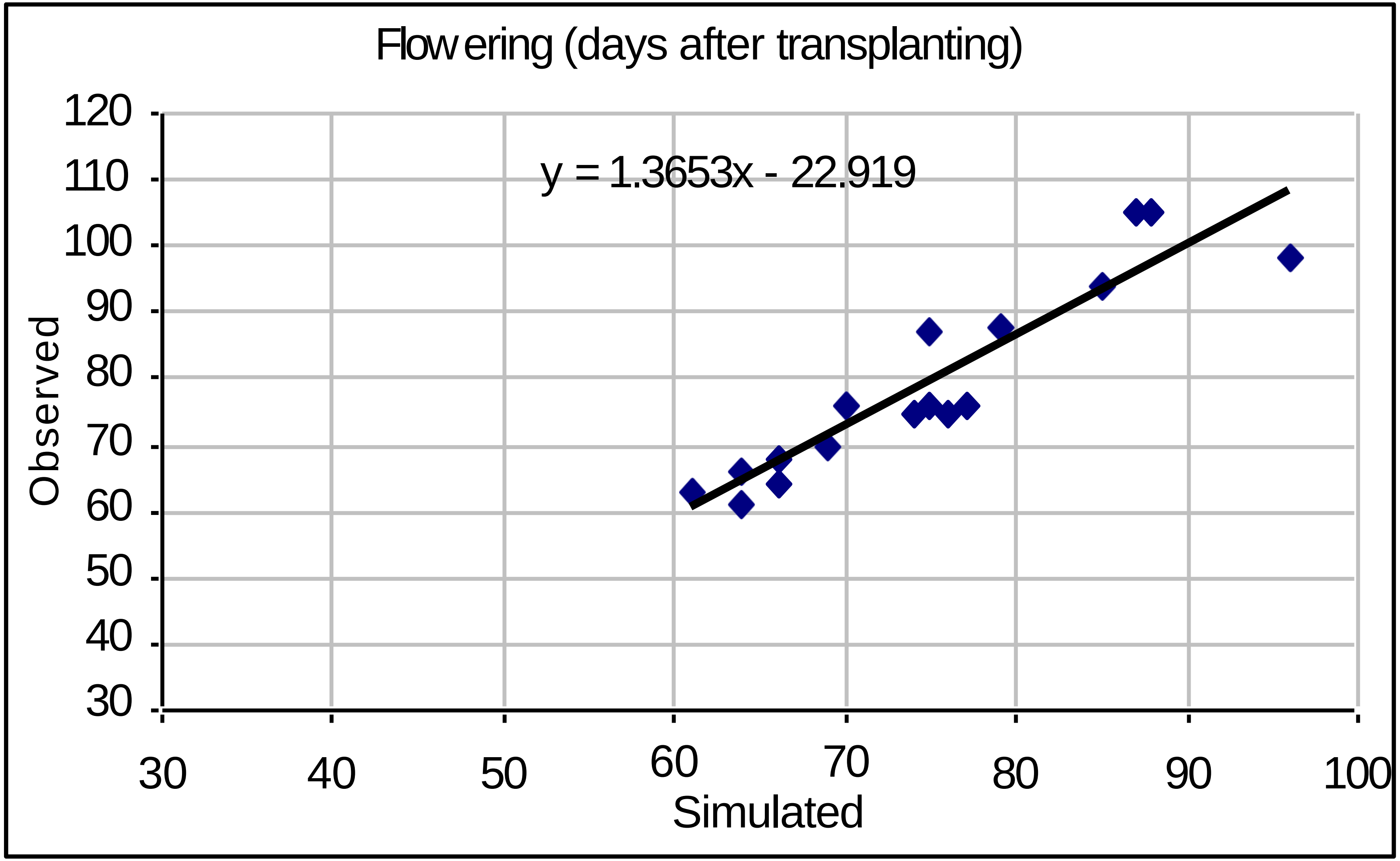
Comparisons bet. simulated and observed phenology and grain yield for **Diphu**

Planting date	Anthesis date (DAT)		Physiological maturity (DAT)		Grain yield	
	Simulated	Observed	Simulated	Observed	Simulated	Observed
11 Jul, 1999	85	94	134	125	5754	5104
09 Jul, 2000	96	98	142	124	3569	4722
10 Jul, 2001	87	105	128	125	4874	4650
20 Jul, 2002	79	88	121	122	1426	4825
07 Jul, 2003	88	105	128	127	5663	4400

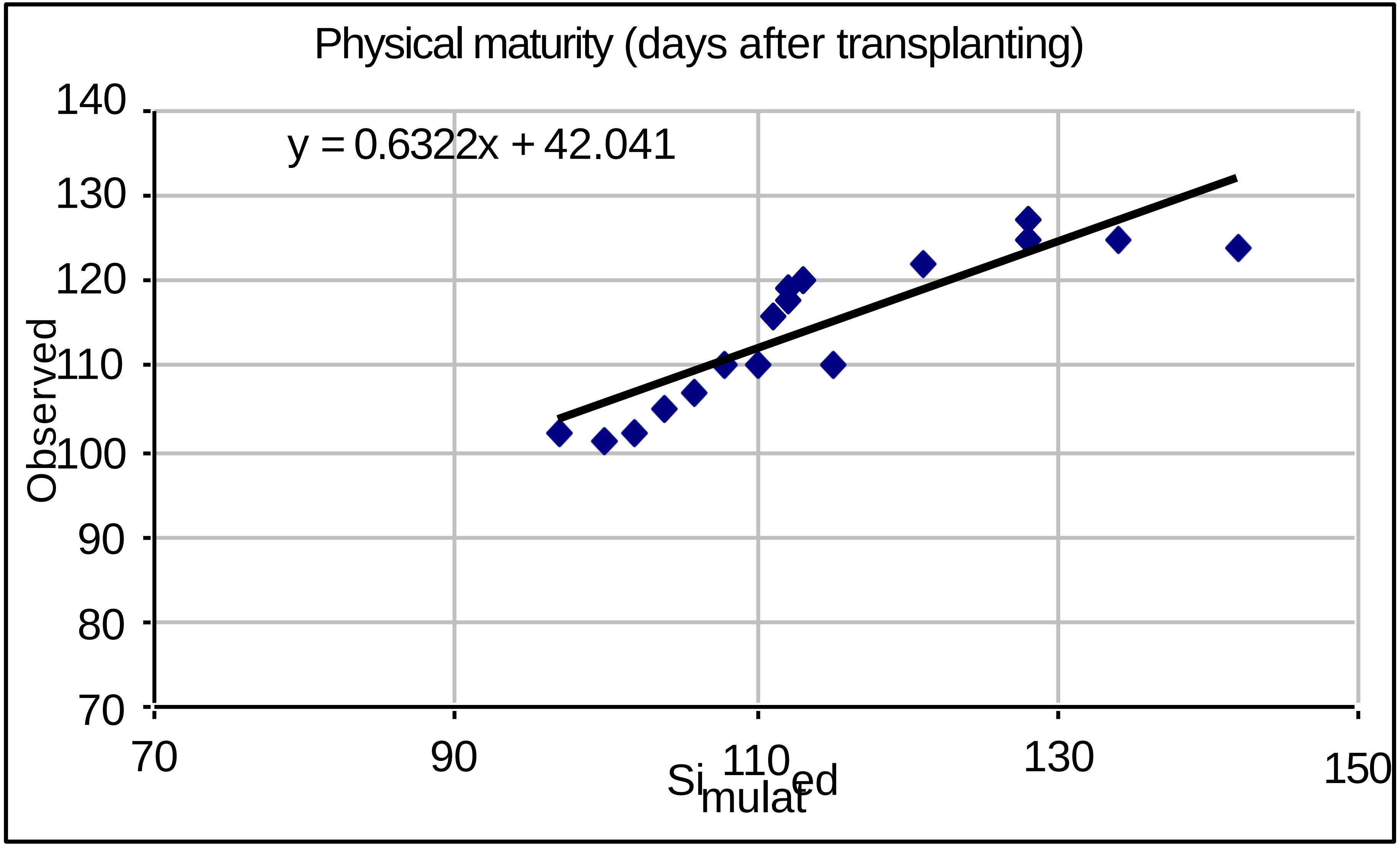
Comparisons bet. simulated and observed phenology and grain yield for **Kalyani**

Planting date	Anthesis date (DAT)		Physiological maturity (DAT)		Grain yield	
	Simulated	Observed	Simulated	Observed	Simulated	Observed
21 Jul, 2002	77	76	113	120	5800	4987
30 Jul, 2002	75	87	112	118	5624	5942
23 Jul, 2003	75	76	111	116	5924	4278
01 Aug, 2003	76	75	115	110	5965	6523
21 Jul, 2004	74	75	112	119	5262	6052
31 Jul, 2004	70	76	110	110	5570	5435

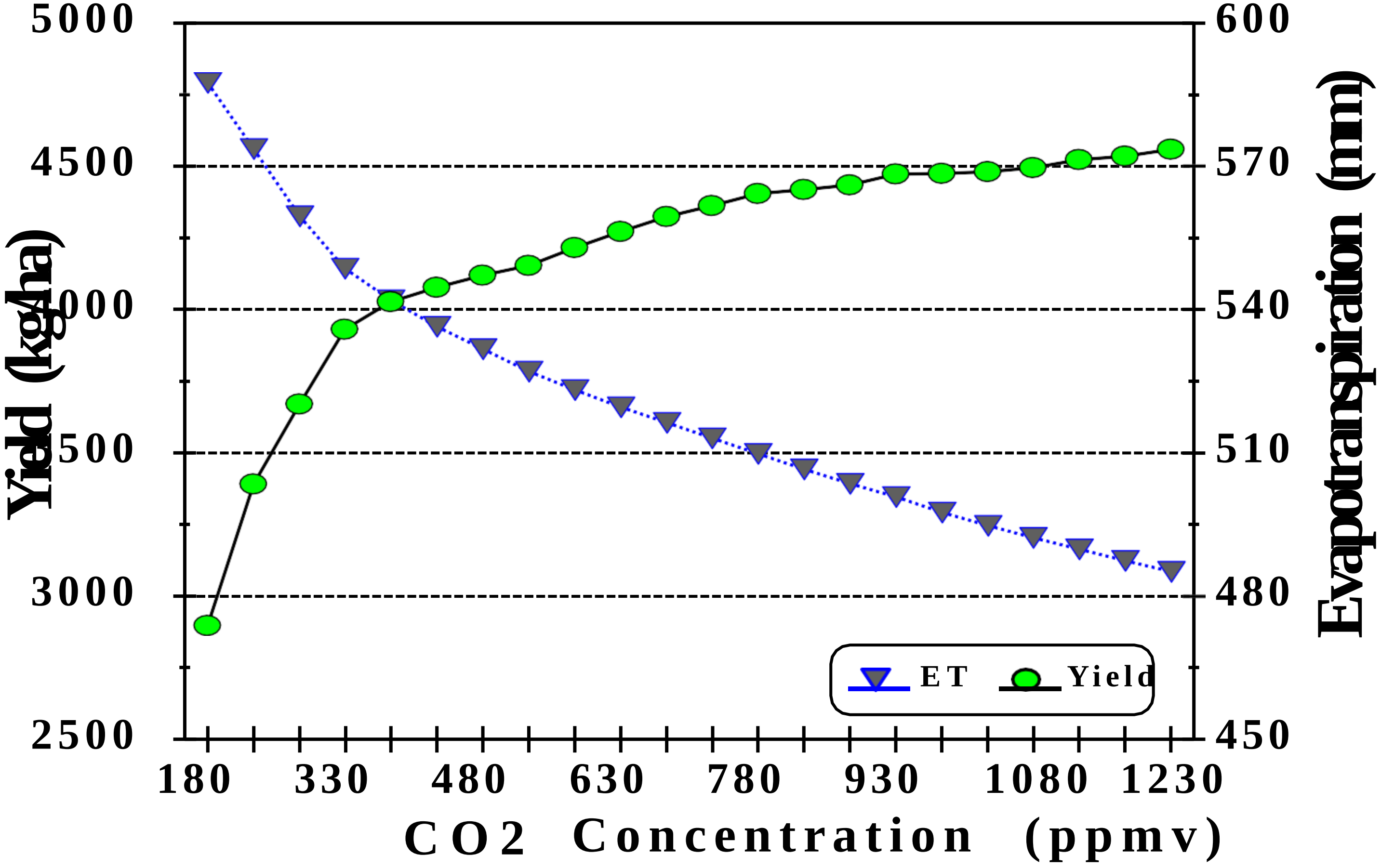
Comparisons between simulated and observed flowering (DAT)



Comparisons between simulated and observed physical maturity (DAT)



Effect of CO2 on Wheat Yield and ET



Thank You