



## 1 The APSIM Soybean Model

### 1.1 The APSIM Soybean Model

The APSIM Soybean model has been developed using the Plant Modelling Framework (PMF) of (Brown et al., 2014). This new framework provides a library of plant organ and process submodels that can be coupled, at runtime, to construct a model in much the same way that models can be coupled to construct a simulation. This means that dynamic composition of lower level process and organ classes (e.g. photosynthesis, leaf) into larger constructions (e.g. maize, wheat, sorghum) can be achieved by the model developer without additional coding.

The model consists of:

- \* a phenology model to simulate development between growth phases
- \* a structure model to simulate plant morphology
- \* a collection of organs to simulate the various plant parts
- \* an arbitrator to allocate resources (N, biomass) to the various plant organs

The model has been developed using the Plant Modelling Framework (PMF) of Brown et al., 2014. This new framework provides a library of plant organ and process submodels that can be coupled, at runtime, to construct a model in much the same way that models can be coupled to construct a simulation. This means that dynamic composition of lower level process and organ classes (e.g. photosynthesis, leaf) into larger constructions (e.g. maize, wheat, sorghum) can be achieved by the model developer without additional coding.

The model is constructed from the following list of software components. Details of the implementation and model parameterisation are provided in the following sections.

### 1.2 Plant Model Components

Component Name	Component Type
Arbitrator	Models.PMF.OrganArbitrator
Phenology	Models.PMF.Phen.Phenology
Leaf	Models.PMF.Organs.SimpleLeaf
Grain	Models.PMF.Organs.ReproductiveOrgan
Root	Models.PMF.Organs.Root
Nodule	Models.PMF.Organs.Nodule
Shell	Models.PMF.Organs.GenericOrgan
Stem	Models.PMF.Organs.GenericOrgan
MortalityRate	Models.Functions.Constant
SeedMortalityRate	Models.Functions.Constant

### 1.3 Composite Biomass

Component Name	Component Type
AboveGround	Models.PMF.CompositeBiomass
BelowGround	Models.PMF.CompositeBiomass
AboveGroundLive	Models.PMF.CompositeBiomass

Component Name	Component Type
Total	Models.PMF.CompositeBiomass
TotalLive	Models.PMF.CompositeBiomass
TotalDead	Models.PMF.CompositeBiomass
Pod	Models.PMF.CompositeBiomass

#### 1.4 Cultivars

Cultivar Name	Alternative Name(s)
Buchanan	Buchanan
Djakal	Djakal
Davis	Davis
Hooper_MG40	Hooper_MG40
Stephens_MG40	Stephens_MG40
FiskebyV	FiskebyV
F148_7	F148_7
Bowyer	Bowyer
Bunya	Bunya
Cowrie	Cowrie
Soya791	Soya791
Manark	Manark
Warrigal	Warrigal
Leichhardt	Leichhardt
Djakal1	Djakal1
Trial_MG00	Trial_MG00
Lambert_MG0	Lambert_MG0
IA1006_MG10	IA1006_MG10
IA2008_MG20	IA2008_MG20
PioneerP22T61_MG22	PioneerP22T61_MG22
PioneerP22T69R_MG22	PioneerP22T69R_MG22
Pioneer92MGI_MG26	Pioneer92MGI_MG26
PioneerP92Y75_MG27	PioneerP92Y75_MG27
Macon_MG30	Macon_MG30
PioneerP93M11_MG31	PioneerP93M11_MG31
Becks321NRR_MG32	Becks321NRR_MG32
PioneerP932T16R_MG32	PioneerP932T16R_MG32
Becks367NRR_MG37	Becks367NRR_MG37

Cultivar Name	Alternative Name(s)
AsgrowAG4403_MG40	AsgrowAG4403_MG40
HornbeckHBK4891_MG40	HornbeckHBK4891_MG40
Pioneer94B01_MG40	Pioneer94B01_MG40
PioneerP9504_MG50	PioneerP9504_MG50
AsgrowAG5701_MG50	AsgrowAG5701_MG50
Hutcheson_MG50	Hutcheson_MG50
NK622_MG60	NK622_MG60
Nandou12	Nandou12
Texuan13	Texuan13
Jiuyuehuang	Jiuyuehuang
Hedou19	Hedou19
Generic_MG000	Generic_MG000
Generic_MG00	Generic_MG00
Generic_MG0	Generic_MG0
Generic_MG1	Generic_MG1
Generic_MG2	Generic_MG2
Generic_MG3	Generic_MG3
Generic_MG4	Generic_MG4
Generic_MG5	Generic_MG5
Generic_MG6	Generic_MG6
Generic_MG7	Generic_MG7
Generic_MG8	Generic_MG8
Generic_MG9	Generic_MG9
Generic_MG10	Generic_MG10

## 1.5 Child Components

### 1.5.1 Arbitrator

The Arbitrator class determines the allocation of dry matter (DM) and Nitrogen between each of the organs in the crop model. Each organ can have up to three different pools of biomass:

- \* **Structural biomass** which is essential for growth and remains within the organ once it is allocated there.
- \* **Metabolic biomass** which generally remains within an organ but is able to be re allocated when the organ senesces and may be retranslocated when demand is high relative to supply.
- \* **Storage biomass** which is partitioned to organs when supply is high relative to demand and is available for retranslocation to other organs whenever supply from uptake, fixation, or re allocation is lower than demand.

The process followed for biomass arbitration is shown in the figure below. Arbitration calculations are triggered by a series of events (shown below) that are raised every day. For these calculations, at each step the Arbitrator exchange information with each organ, so the basic computations of demand and supply are done at the organ level, using their specific parameters.

1. **doPotentialPlantGrowth**. When this event occurs, each organ class executes code to determine their potential

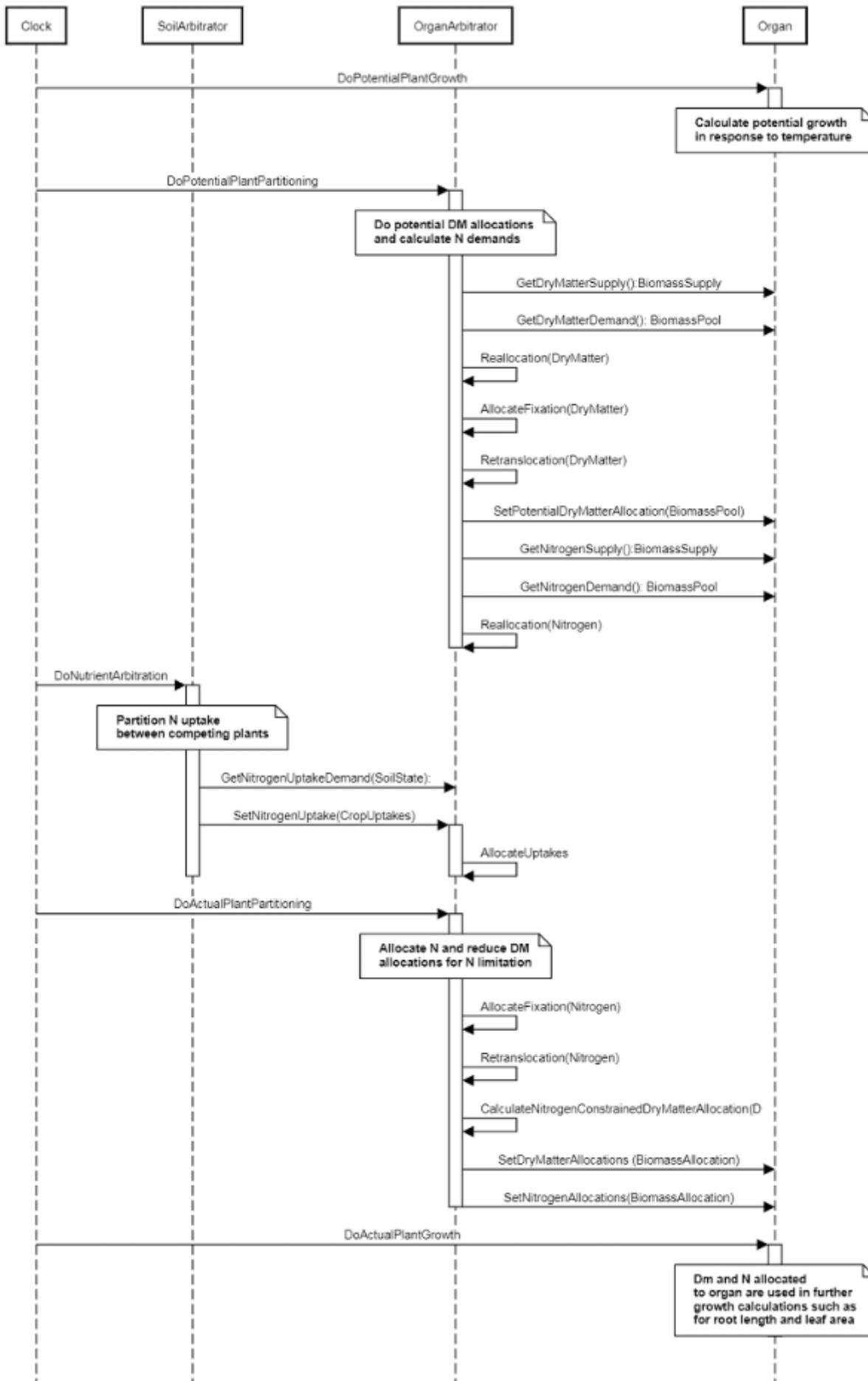
growth, biomass supplies and demands. In addition to demands for structural, non structural and metabolic biomass (DM and N) each organ may have the following biomass supplies:

- \* **Fixation supply.** From photosynthesis (DM) or symbiotic fixation (N)
- \* **Uptake supply.** Typically uptake of N from the soil by the roots but could also be uptake by other organs (eg foliage application of N).
- \* **Retranslocation supply.** Storage biomass that may be moved from organs to meet demands of other organs.
- \* **Reallocation supply.** Biomass that can be moved from senescing organs to meet the demands of other organs.

1. **doPotentialPlantPartitioning.** On this event the Arbitrator first executes the DoDMSetup() method to gather the DM supplies and demands from each organ, these values are computed at the organ level. It then executes the DoPotentialDMAAllocation() method which works out how much biomass each organ would be allocated assuming N supply is not limiting and sends these allocations to the organs. Each organ then uses their potential DM allocation to determine their N demand (how much N is needed to produce that much DM) and the arbitrator calls DoNSetup() to gather the N supplies and demands from each organ and begin N arbitration. Firstly DoNReallocation() is called to redistribute N that the plant has available from senescing organs. After this step any unmet N demand is considered as plant demand for N uptake from the soil (N Uptake Demand).

2. **doNutrientArbitration.** When this event occurs, the soil arbitrator gets the N uptake demands from each plant (where multiple plants are growing in competition) and their potential uptake from the soil and determines how much of their demand that the soil is able to provide. This value is then passed back to each plant instance as their Nuptake and doNUptakeAllocation() is called to distribute this N between organs.

3. **doActualPlantPartitioning.** On this event the arbitrator call DoNRetranslocation() and DoNFixation() to satisfy any unmet N demands from these sources. Finally, DoActualDMAAllocation is called where DM allocations to each organ are reduced if the N allocation is insufficient to achieve the organs minimum N concentration and final allocations are sent to organs.



**Figure 1:** Schematic showing the procedure for arbitration of biomass partitioning. Pink boxes represent events that occur every day and their numbering shows the order of calculations. Blue boxes represent the methods that are called when these events occur. Orange boxes contain properties that make up the organ/arbitrator interface. Green boxes are organ specific properties.

## 1.5.2 Phenology

The phenological development is simulated as the progression through a series of developmental phases, each bound by distinct growth stage.

In the new model we simplified phenology by taking out stages that are not measurable (e.g. end of juvenile stage) and by adding new stages that are measurable (e.g. start pod). The new phenology follows the V/R staging system.

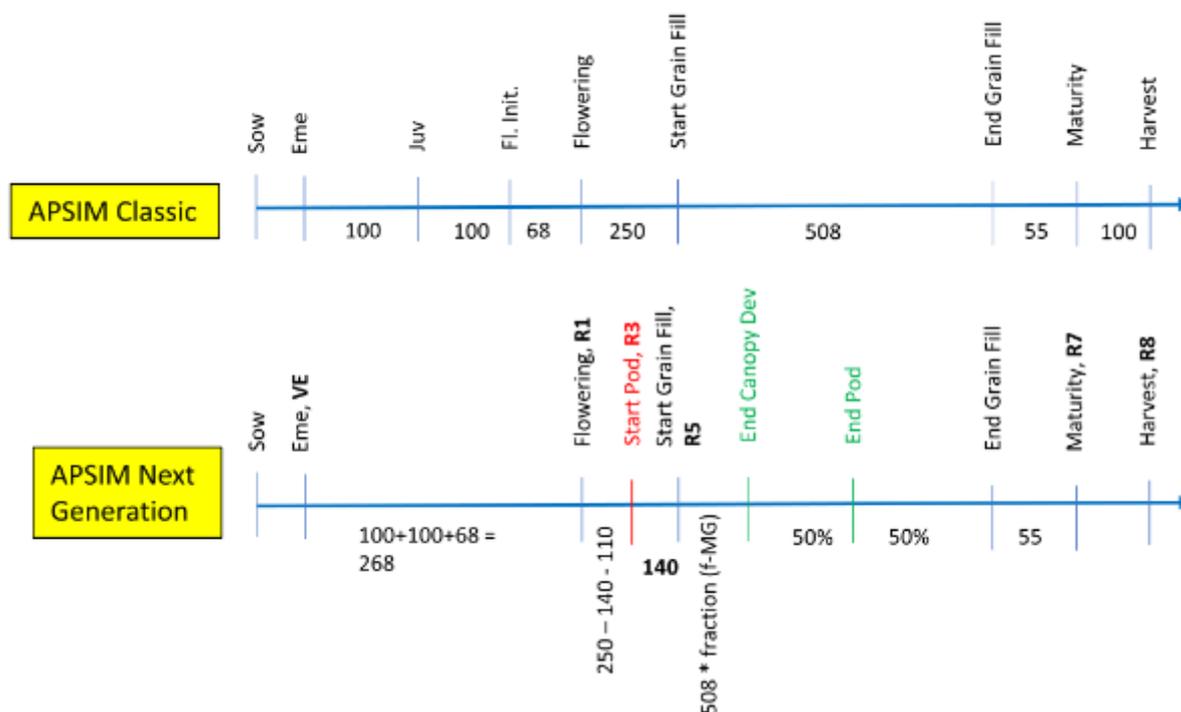


Figure 2: Alt Text

Figure [FigureNumber]: Comparison of soybean phenological stages for APSIM Classic and APSIM Next Generation.

The key differences for cultivars are mostly phenological parameters (e.g., Vegetative.Target, ReproductivePhotoperiodModifier). In some cases, some additional parameters have been changed, see parameter values in the cultivar section.

## 1.5.3 Leaf

This organ is simulated using a SimpleLeaf organ type. It provides the core functions of intercepting radiation, producing biomass through photosynthesis, and determining the plant's transpiration demand. The model also calculates the growth, senescence, and detachment of leaves. SimpleLeaf does not distinguish leaf cohorts by age or position in the canopy.

Radiation interception and transpiration demand are computed by the MicroClimate model. This model takes into account competition between different plants when more than one is present in the simulation. The values of canopy Cover, LAI, and plant Height (as defined below) are passed daily by SimpleLeaf to the MicroClimate model. MicroClimate uses an implementation of the Beer Lambert equation to compute light interception and the Penman Monteith equation to calculate potential evapotranspiration.

These values are then given back to SimpleLeaf which uses them to calculate photosynthesis and soil water demand.

SimpleLeaf has two options to define the canopy: the user can either supply a function describing LAI or a function describing canopy cover directly. From either of these functions SimpleLeaf can obtain the other property using the Beer Lambert equation with the specified value of extinction coefficient. The effect of growth rate on transpiration is captured by the Fractional Growth Rate (FRGR) function, which is passed to the MicroClimate model.

## 1.5.4 Grain

This organ uses a generic model for plant reproductive components. Yield is calculated from its components in terms of organ number and size (for example, grain number and grain size).

## 1.5.5 Root

The root model calculates root growth in terms of rooting depth, biomass accumulation and subsequent root length density in each soil layer.

### **1.5.6 Nodule**

This organ simulates the root structure associate with symbiotic N fixing bacteria. It provides the core functions of determining N fixation supply and related costs. It also calculates the growth, senescence and detachment of nodules.

### **1.5.7 Shell**

This organ is simulated using a GenericOrgan type. It is parameterised to calculate the growth, senescence, and detachment of any organ that does not have specific functions.

### **1.5.8 Stem**

This organ is simulated using a GenericOrgan type. It is parameterised to calculate the growth, senescence, and detachment of any organ that does not have specific functions.

### **1.5.9 MortalityRate**

A constant function (name=value)

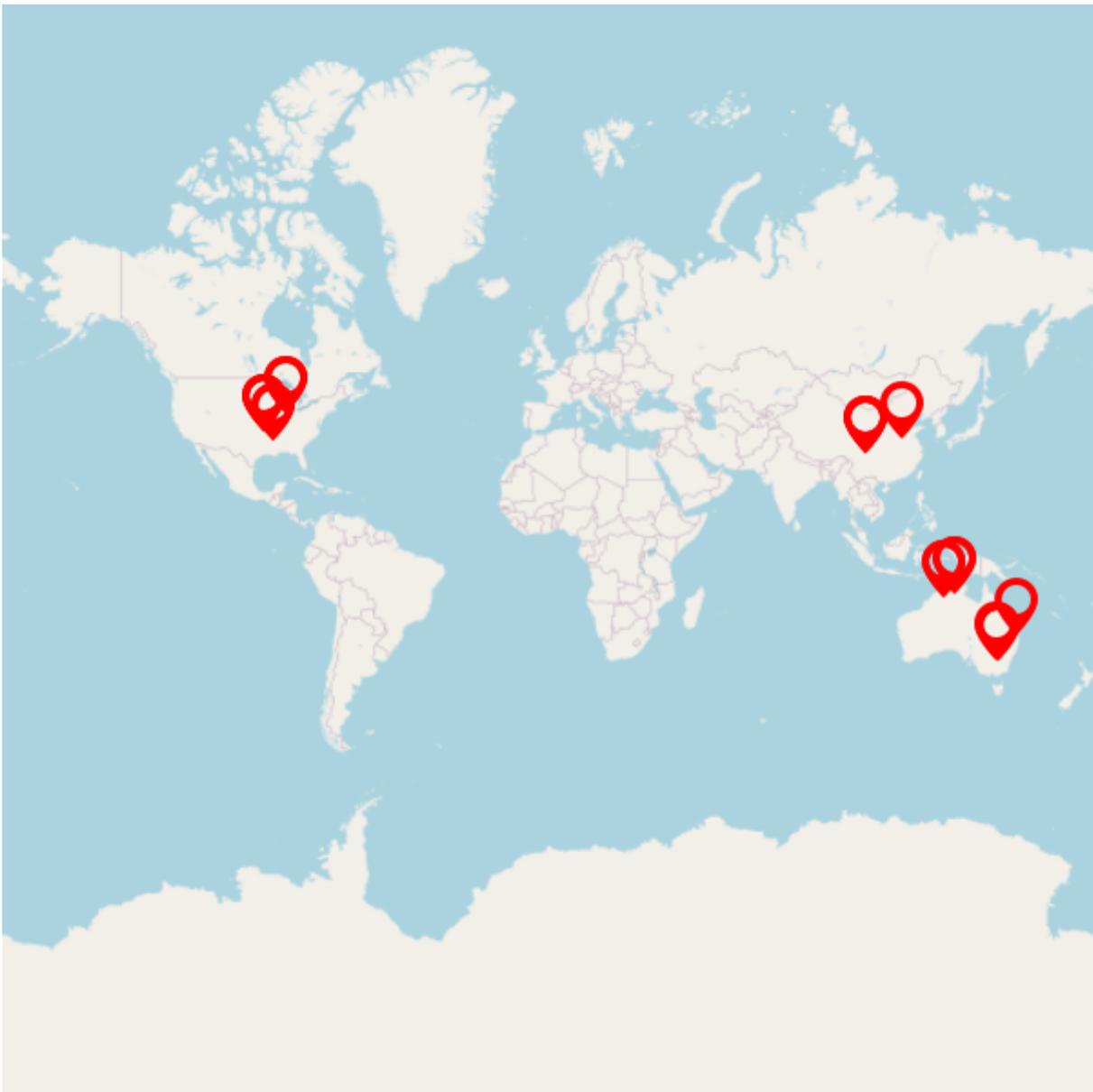
### **1.5.10 SeedMortalityRate**

A constant function (name=value)

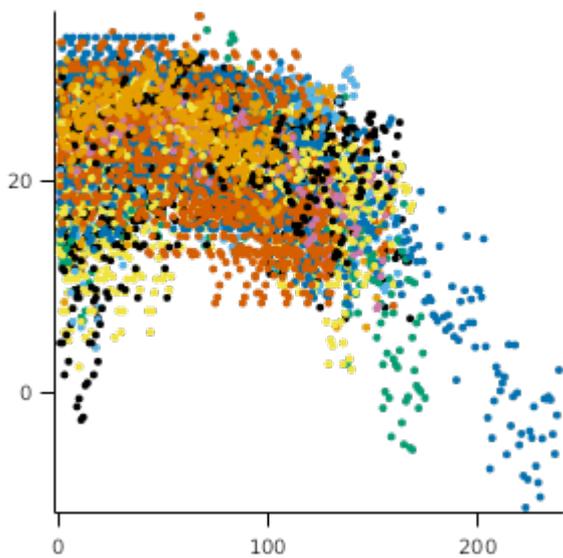
## **2 Validation**

The soybean model has been tested across a range of planting and agronomic conditions. These include datasets from Australia, USA and China covering a wide range of weather conditions (See graphs that follow) and agronomic factors (irrigation, fertiliser, sowing dates).

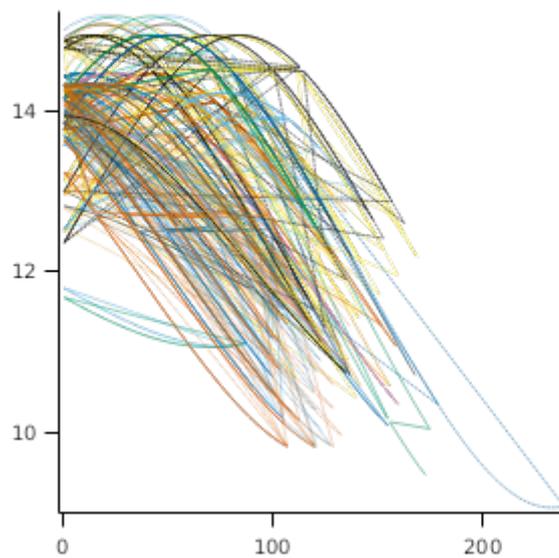
### **2.1 Map**



Growing Season Mean Air Temperature



Growing Season Photoperiod



## 2.2 USA

### 2.2.1 FACTS

This trial was conducted on deep fertile soils, in central Iowa (Ames) and in northwest Iowa (Sutherland), USA, in years 2015, 2016 and 2017. In each year two planting date were studied, early versus late. Row spacing was 76 cm, and plant

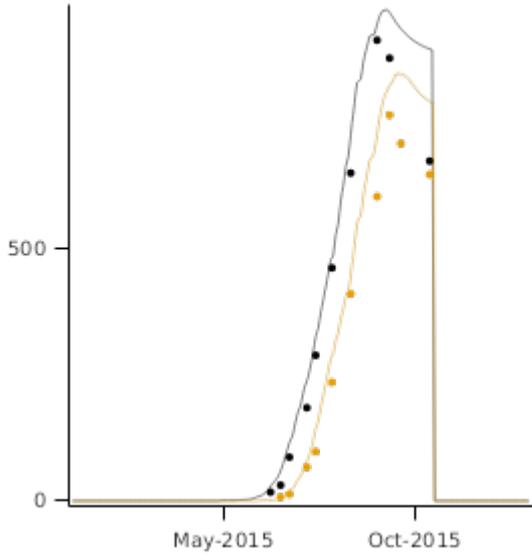
population was around 35 plants/m<sup>2</sup> (see details in APSIM managers). No nitrogen or irrigation applied. This region has shallow water tables (about 1.2 m below surface, range 0.3 to 3m) and the soil has no subsurface drainage. Data from years 2015 and 2017 have been incorporated while data from year 2016 will be added later. Local weather data (the station was positioned 10 m from the trial) and actual soil profile data (measured in Nov 2014 up to 1.2 meter, soil organic matter, texture, and pH by layer) were used. Additional soil data were taken from ssurgo. The following measurements were taken per plot (each treatment was replicated 3 times): Phenology (visual observations in the field using the V/R coding system); biomass samplings 6-9 times per season and per treatment (destructive sampling of 1 m<sup>2</sup> per plot); biomass partitioning and dry weight of each plant tissue including green and yellow leaves, stem plus petioles, and pod-walls plus seeds (note that seeds were separated at the final harvest only); carbon and nitrogen concentration of each plant tissue (LECO CN analyzer); green leaf area index (LI Area Meter); node number and pod number per plant; leaf area per node in year 2015 only; root front depth over time (manual soil core technique) and maximum root depth, mass and length (mechanical gidding probe technique, depth of 240 cm) at approximately middle grain fill stage; daily soil water and temperature at two depths, 15 and 45 cm (5TM sensors placed horizontally, METEO group), daily water table depth (CTD-10 sensors, METEO group), and soil nitrate and ammonium approximately 10 times over each season and treatment at two depths 0-30 and 30-60 cm (sample was extracted in 2 M potassium chloride), and N-fixation over time (Isotope dilution method); soybean leaf senescence (gages to measure drop leaves dry matter and CN concentration, 1m<sup>2</sup> size, 3-4 measurements per season per treatment); crop residue dry matter, soil cover and soil nitrogen and water measurements (manual samplings 10 times from crop harvest to planting of the next crop). This dataset is licensed by the Iowa State University Research Foundation.

### 2.2.1.1 List of experiments

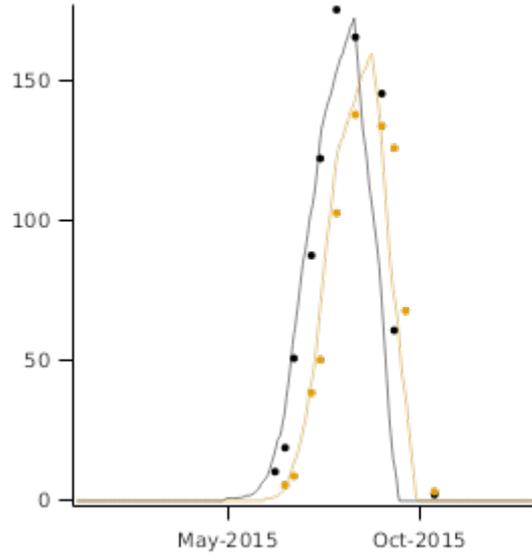
Experiment Name	Design (Number of Treatments)
Ames2015	Sow (2)
Ames2017	Sow (2)
Sutherland2015	Sow (2)
Sutherland2017	Sow (2)

### 2.2.1.2 Ames2015

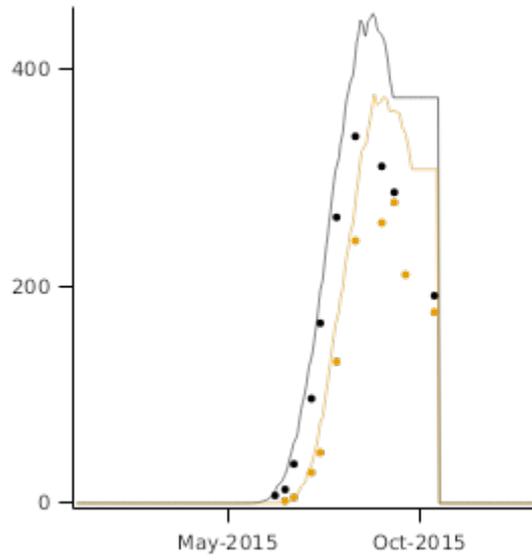
**Biomass**



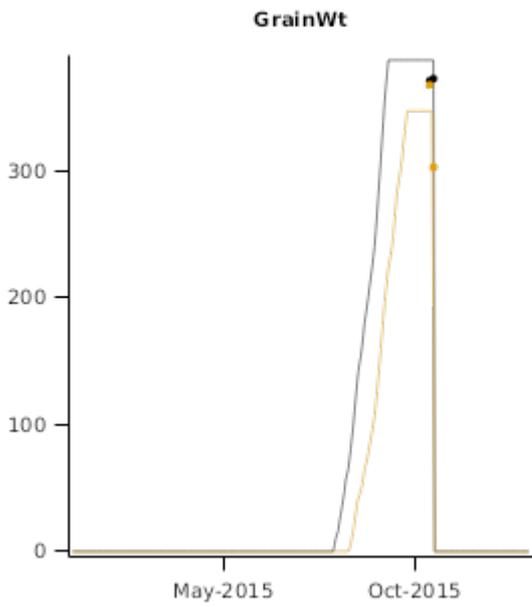
**LeafLiveWt**



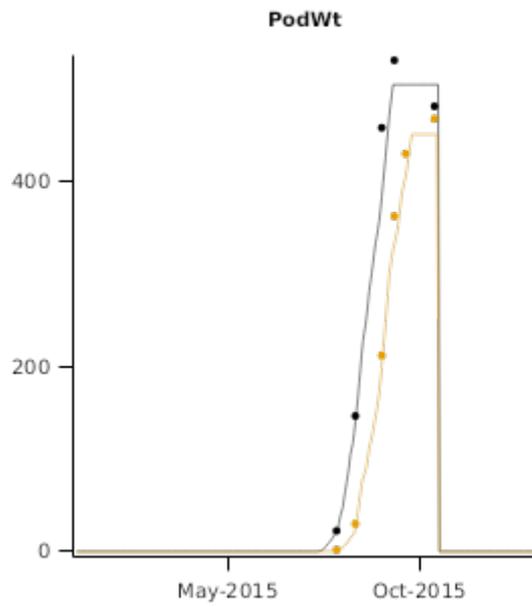
**LeafDeadWt**



**StemWt**

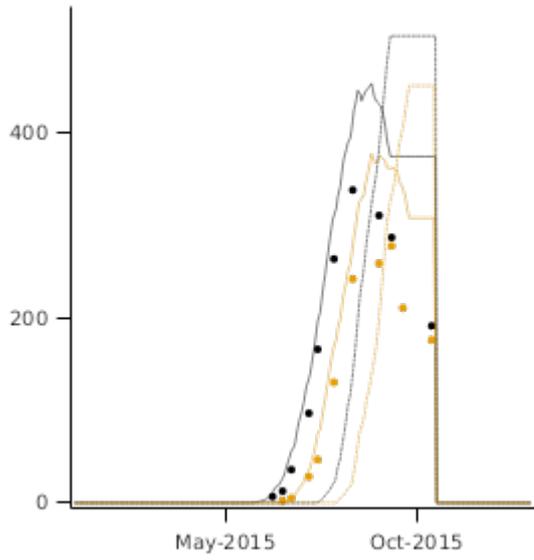


**GrainWt**

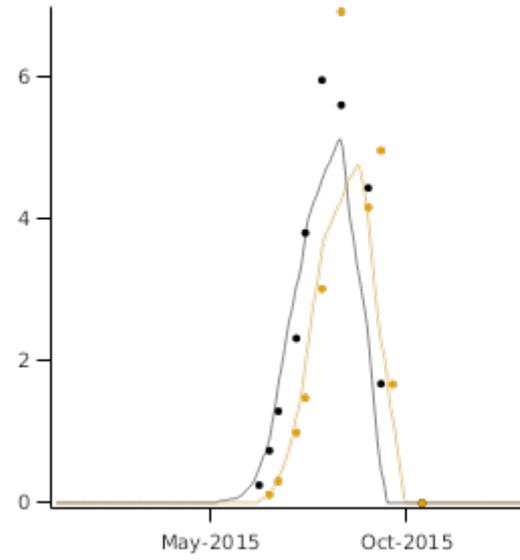


**PodWt**

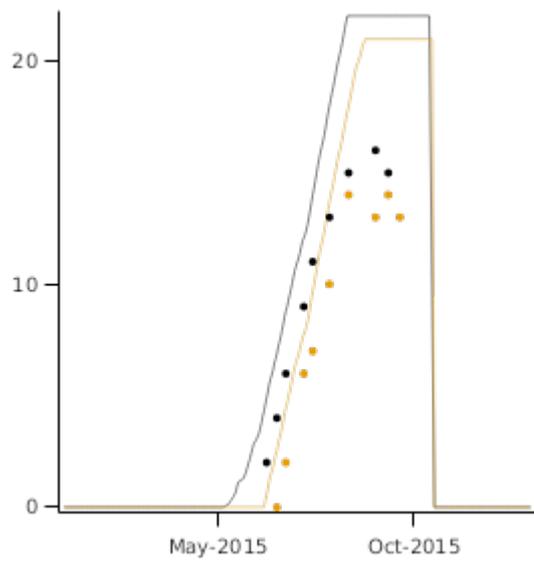
**StemWt and PodWt**



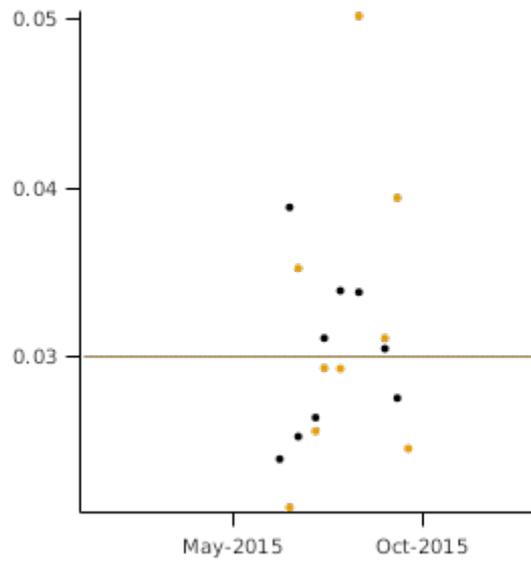
**LAI**



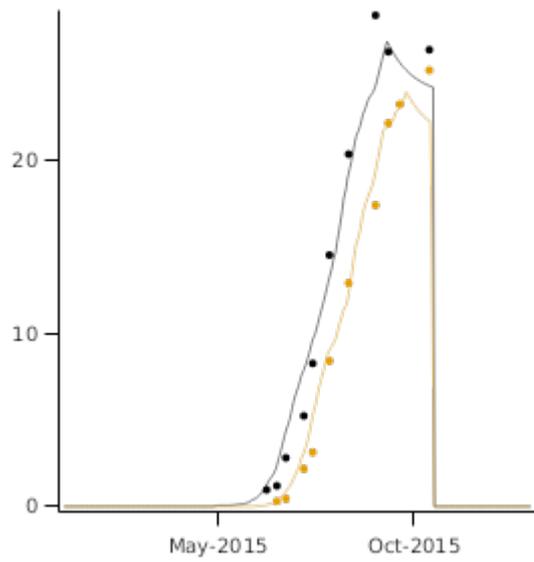
**MainStemLeafNo**



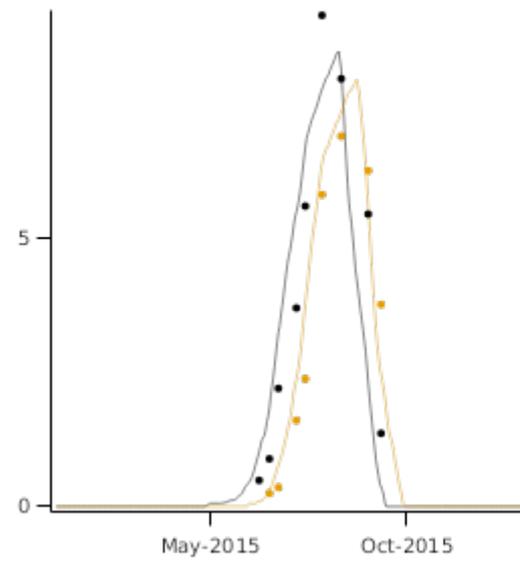
**SpecificLeafArea**



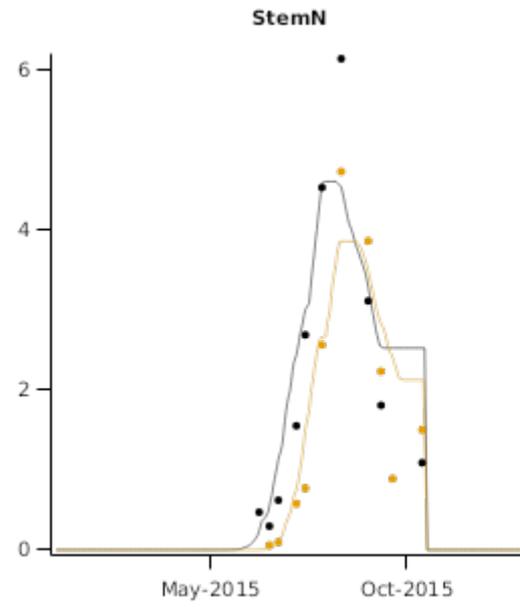
**BiomassN**



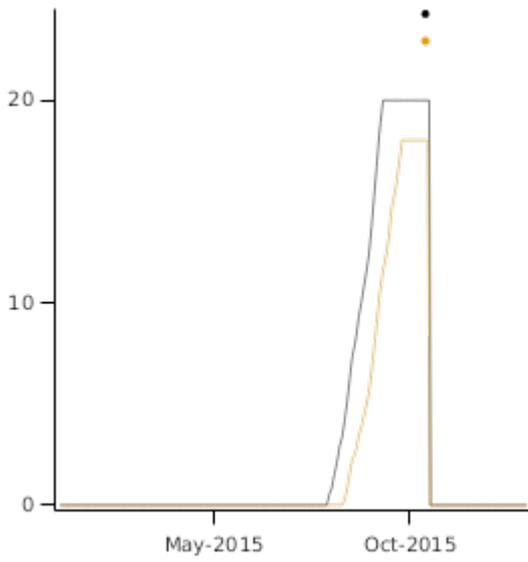
**LeafLiveN**



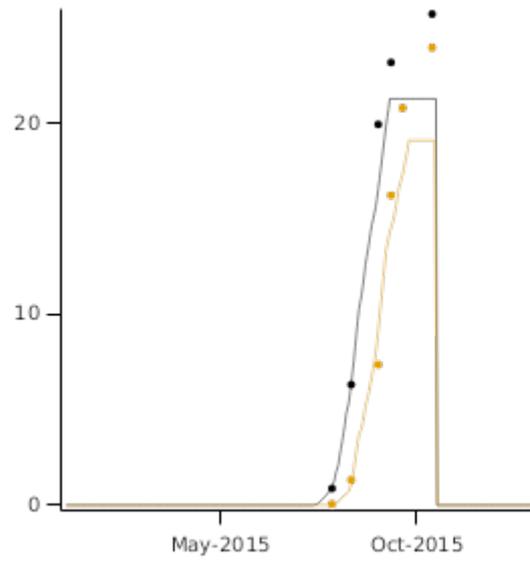
**LeafDeadN**



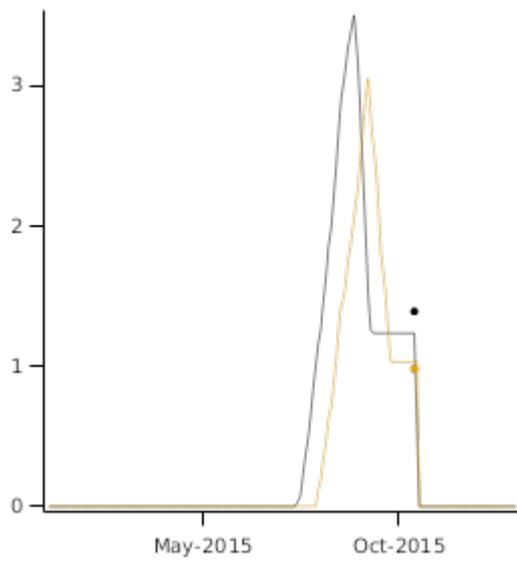
**GrainN**



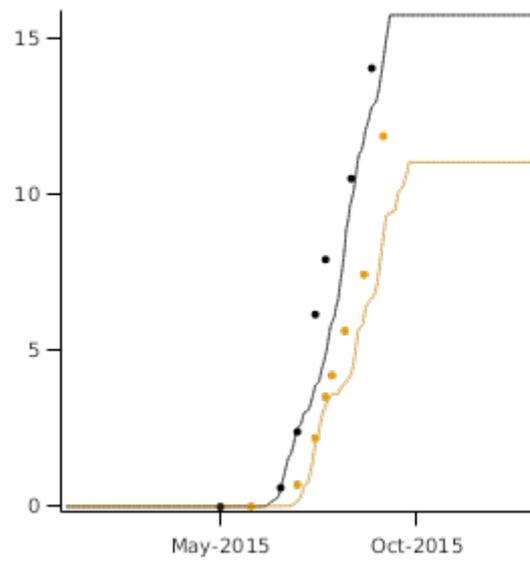
**PodN**



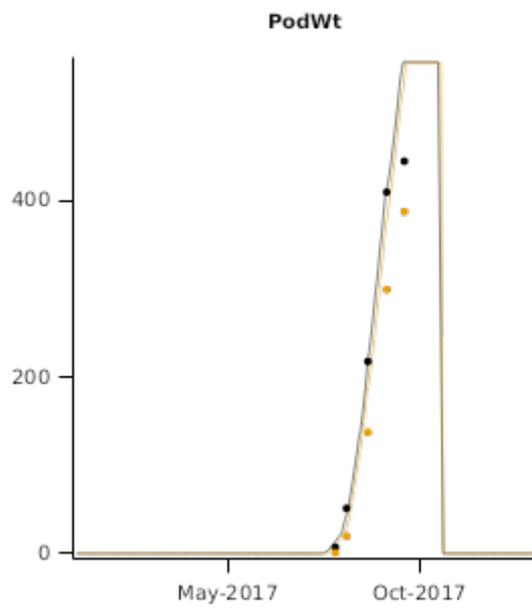
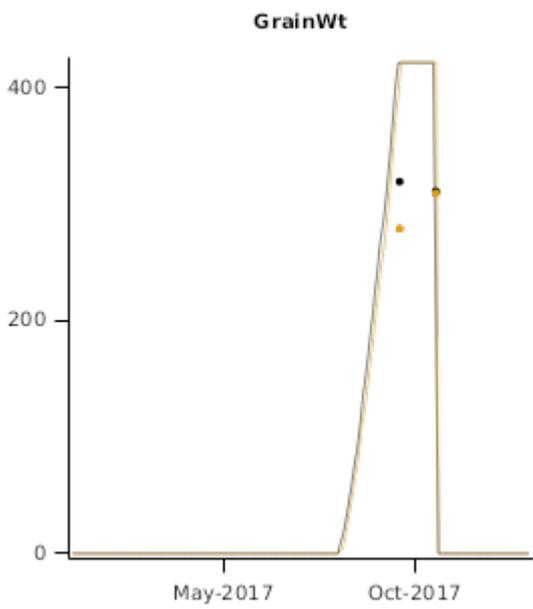
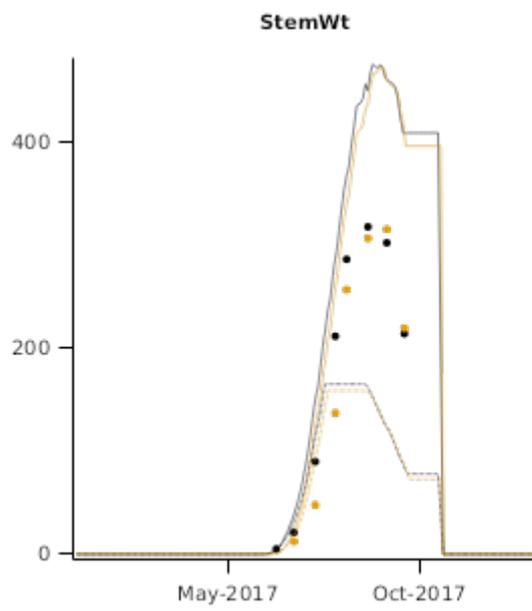
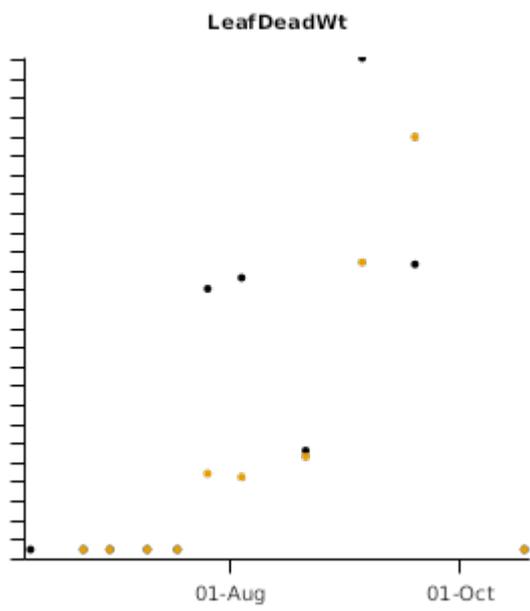
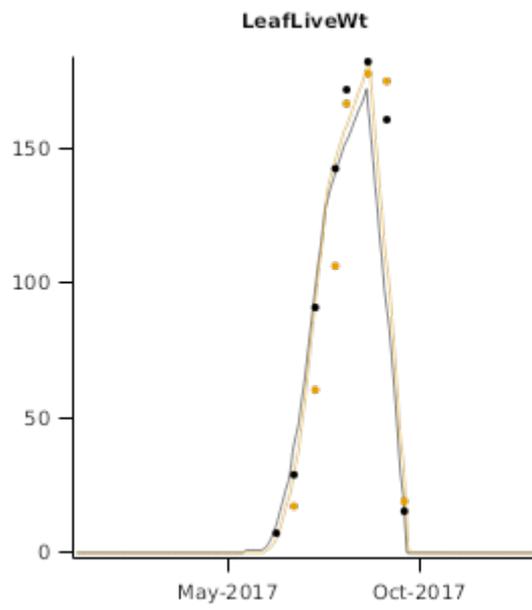
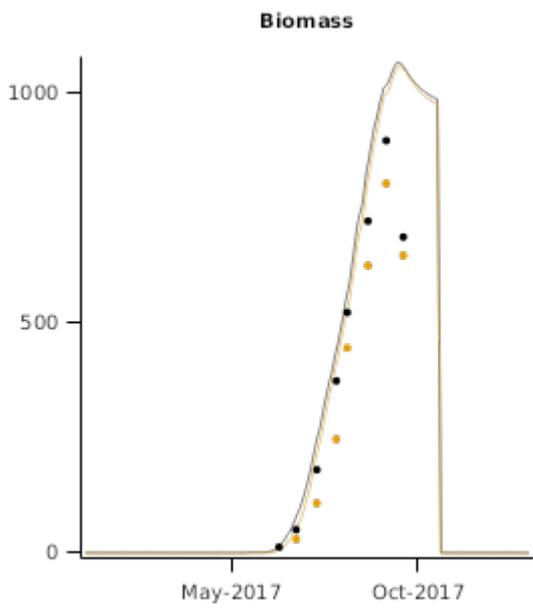
**ShellN**



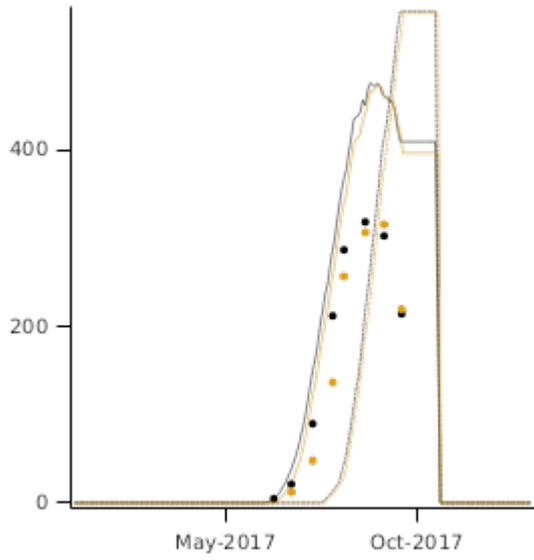
**FixationRate**



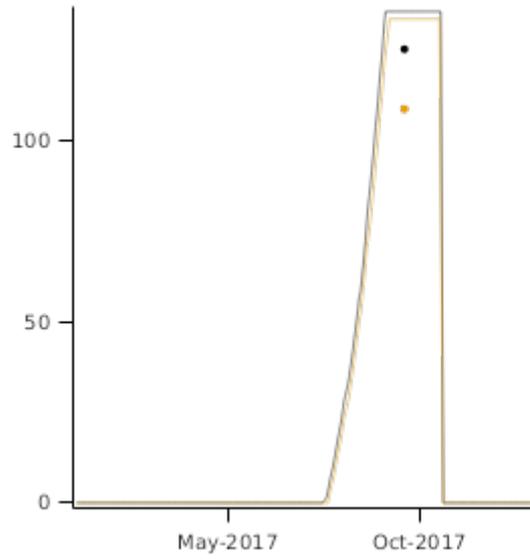
**2.2.1.3 Ames2017**



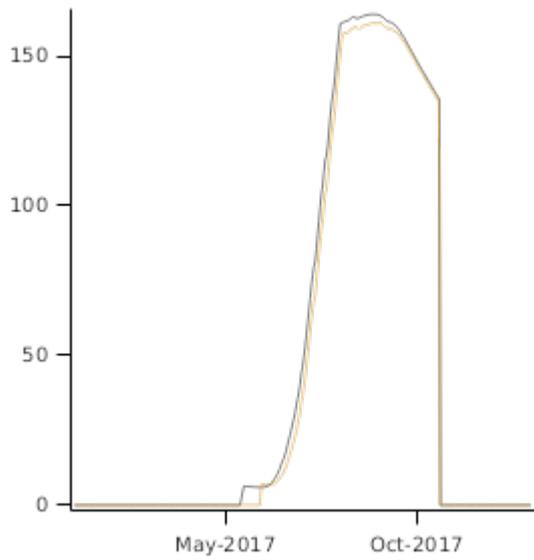
**StemWt and PodWt**



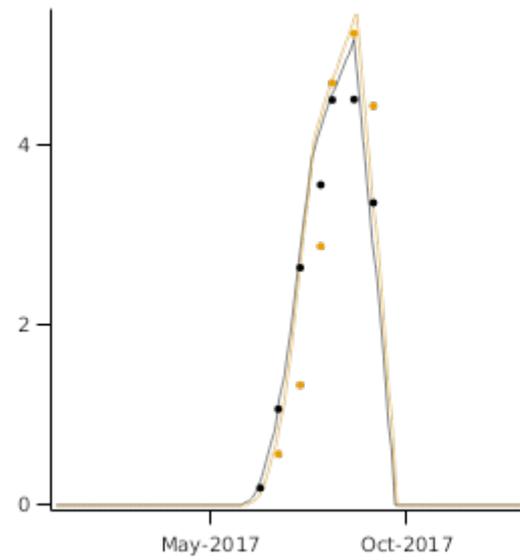
**ShellWt**



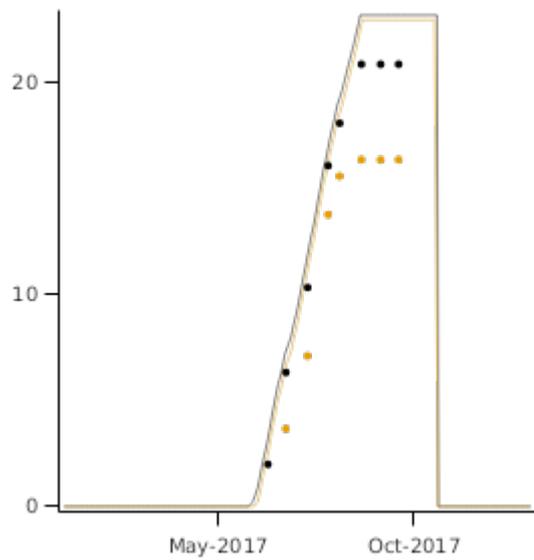
**RootWt**



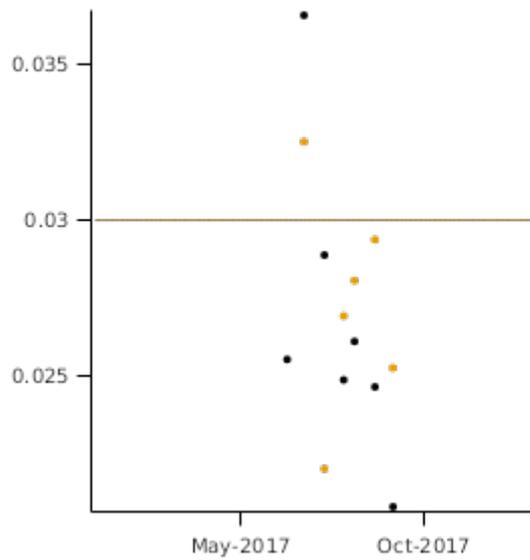
**LAI**



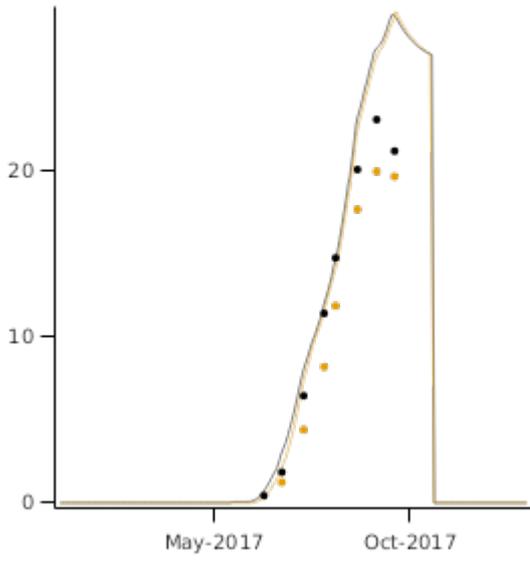
**MainStemLeafNo**



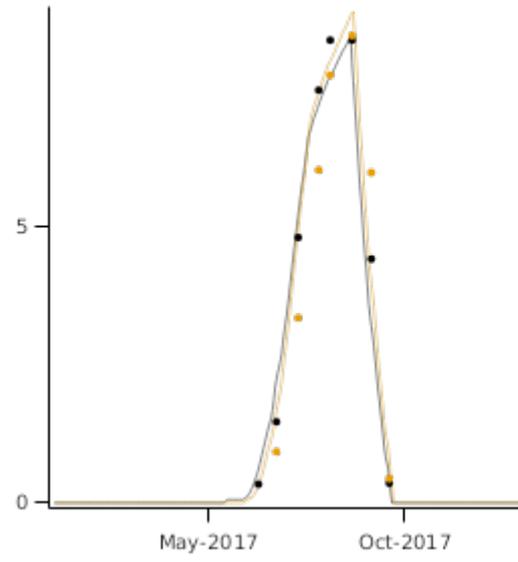
**SpecificLeafArea**



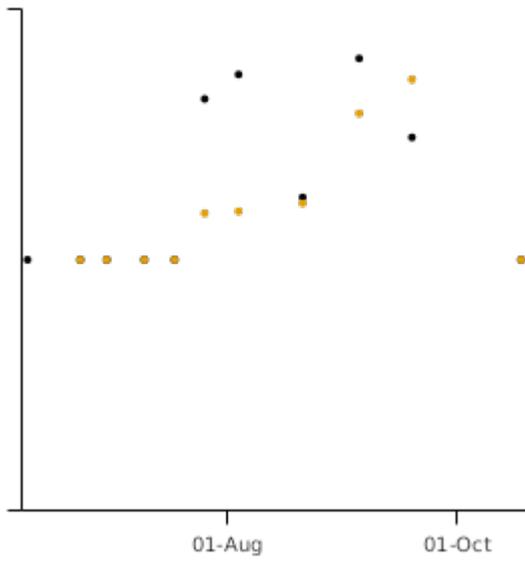
**BiomassN**



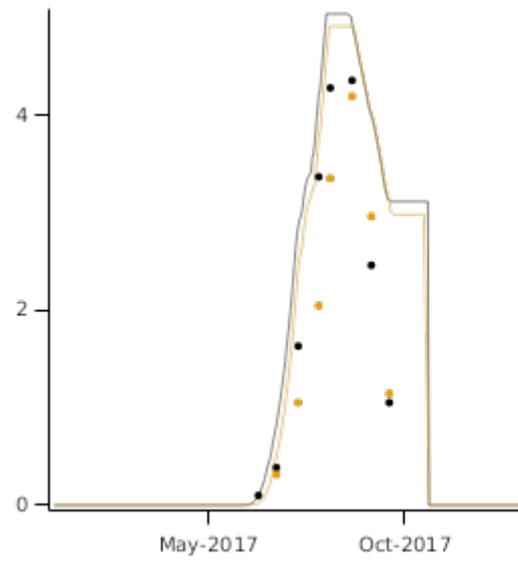
**LeafLiveN**

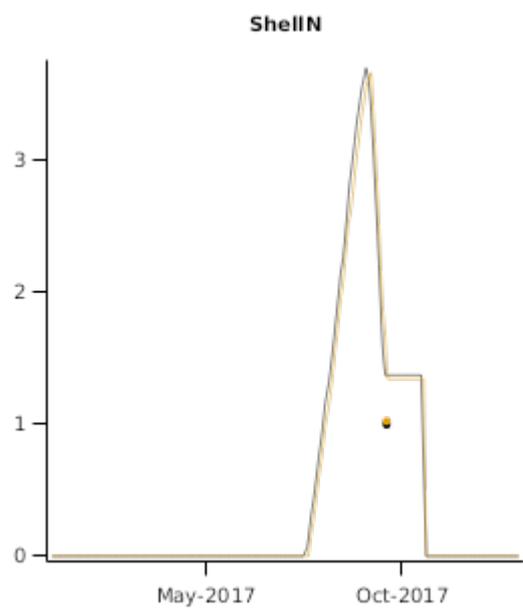
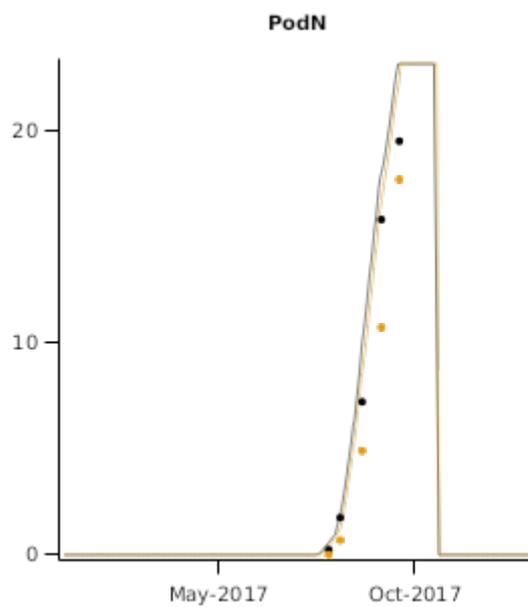
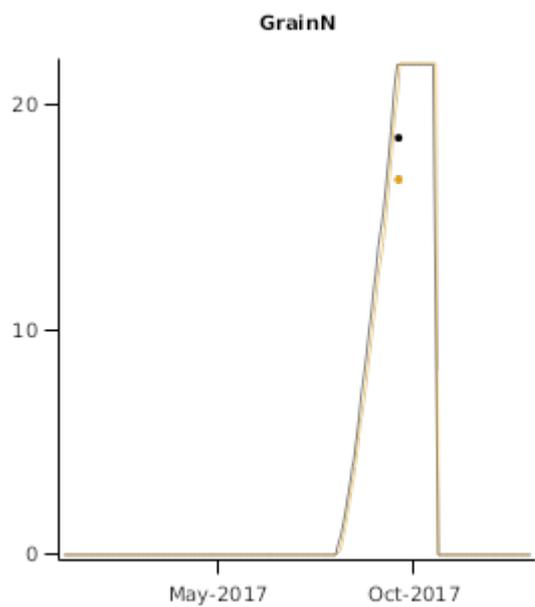


**LeafDeadN**



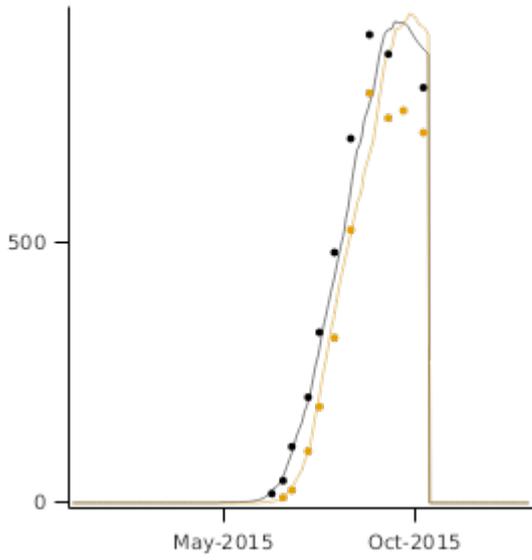
**StemN**



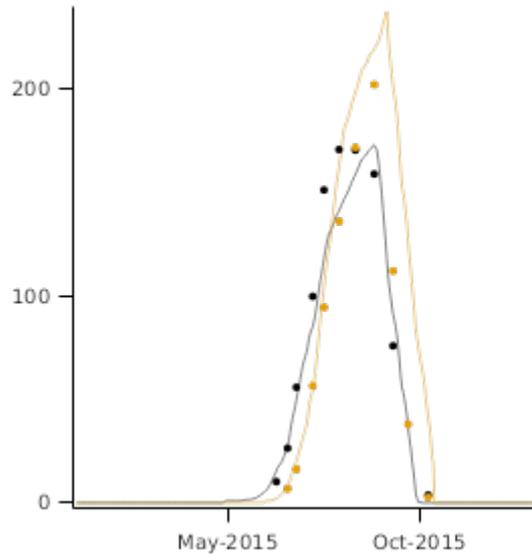


**2.2.1.4 Sutherland2015**

**Biomass**



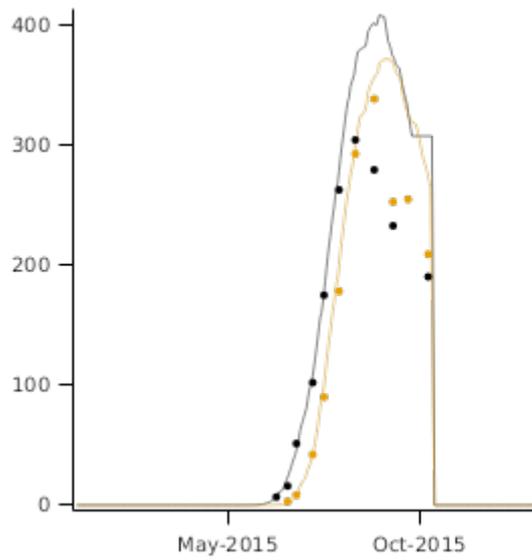
**LeafLiveWt**



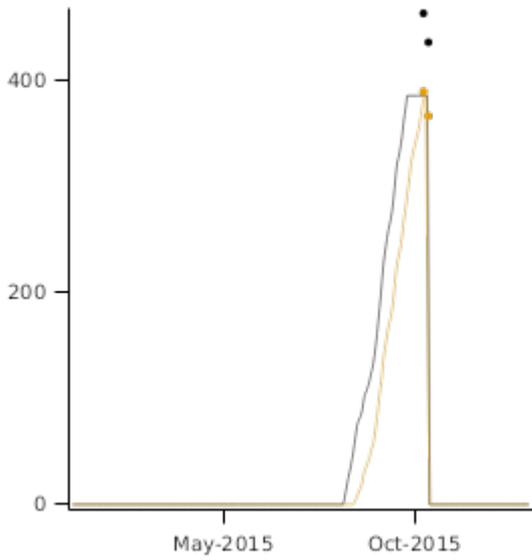
**LeafDeadWt**



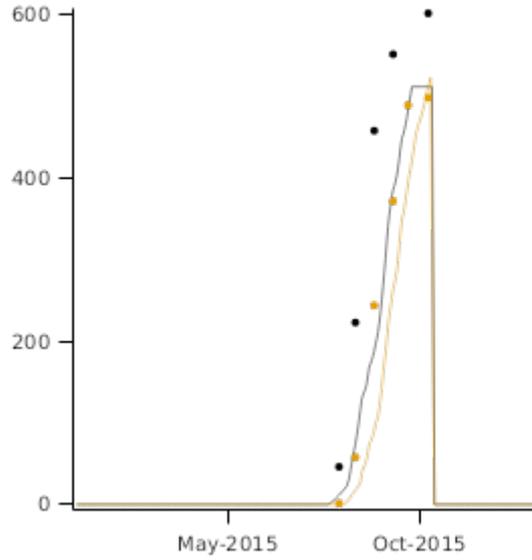
**StemWt**

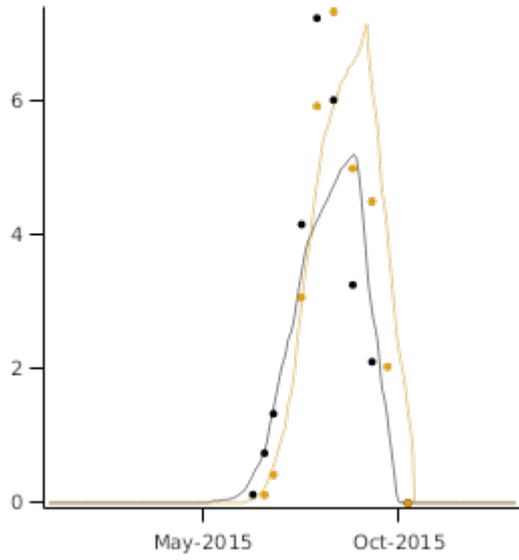
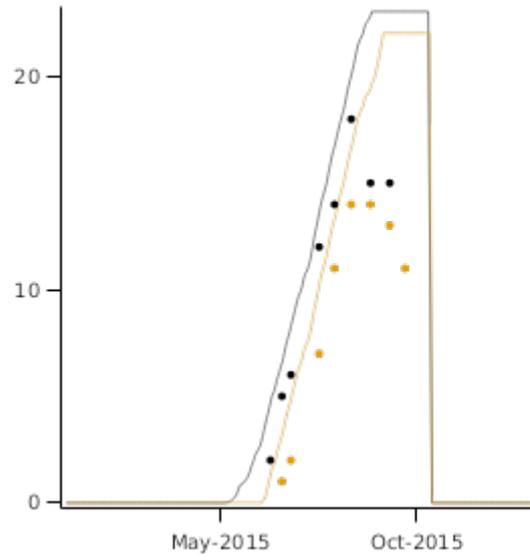
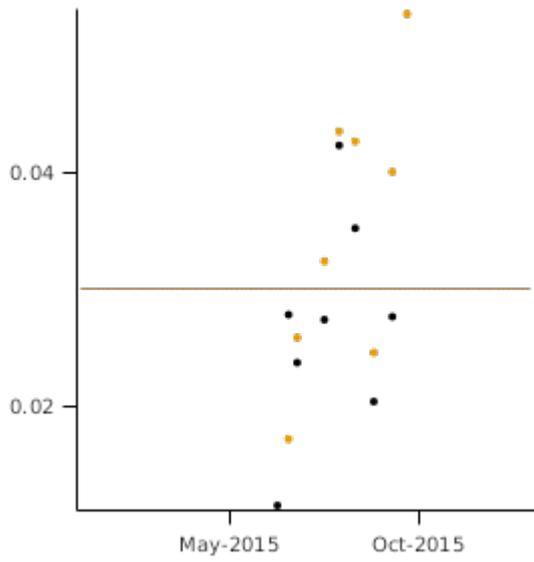
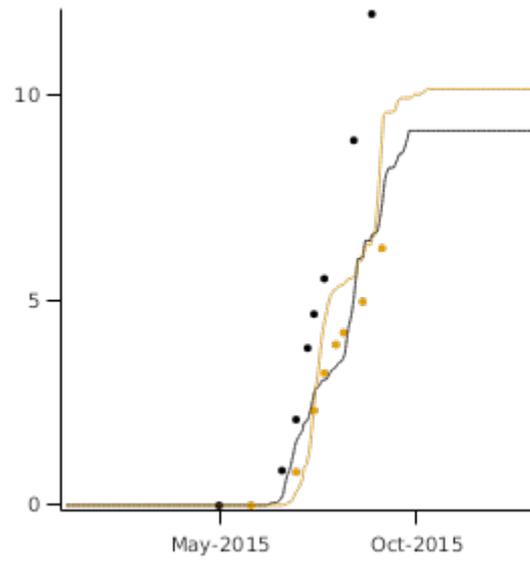
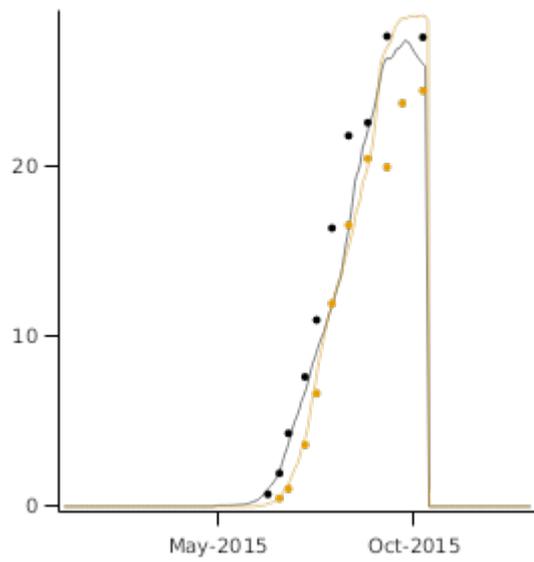
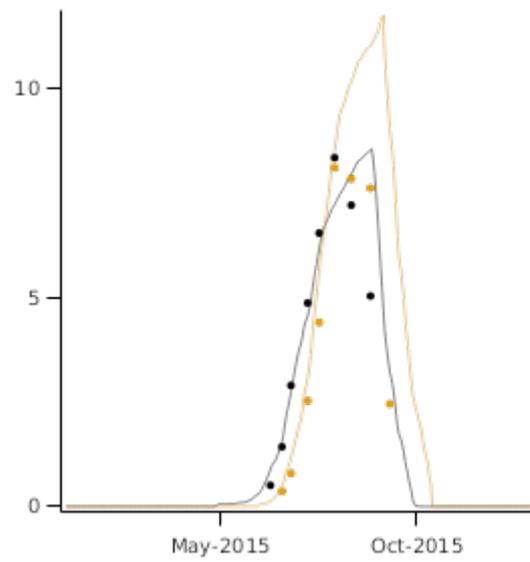


**GrainWt**



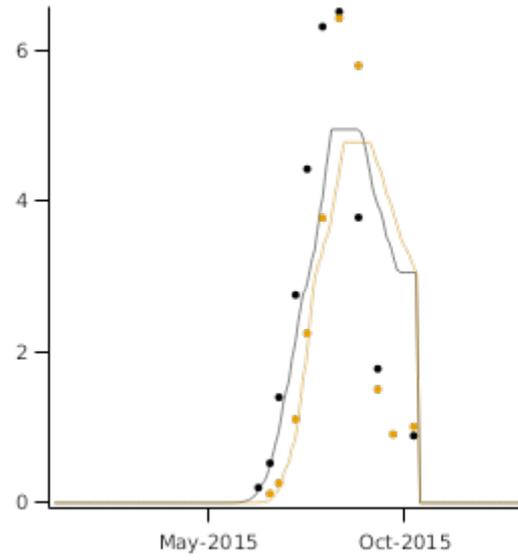
**PodWt**



**LAI****MainStemLeafNo****SpecificLeafArea****FixationRate****BiomassN****LeafLiveN**

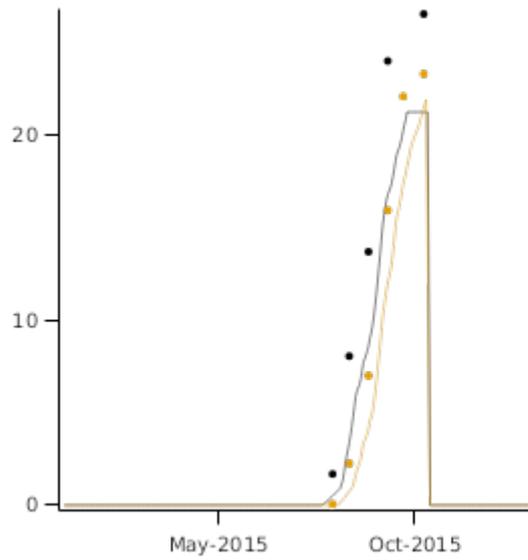
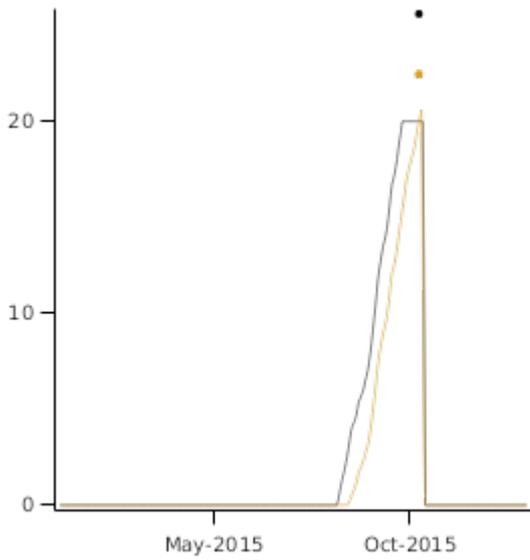
**LeafDeadN**

**StemN**

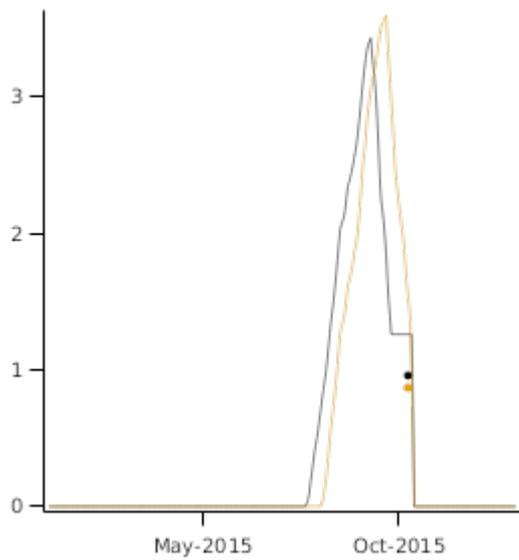


**GrainN**

**PodN**

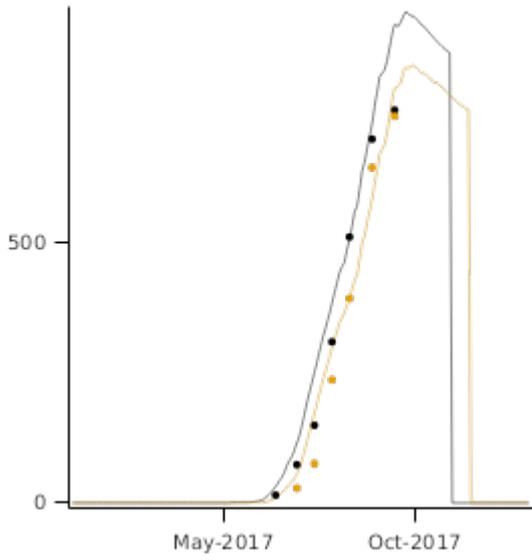


**ShellN**

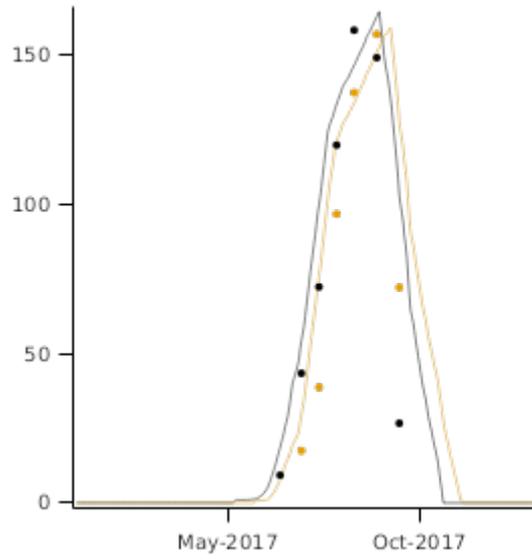


**2.2.1.5 Sutherland2017**

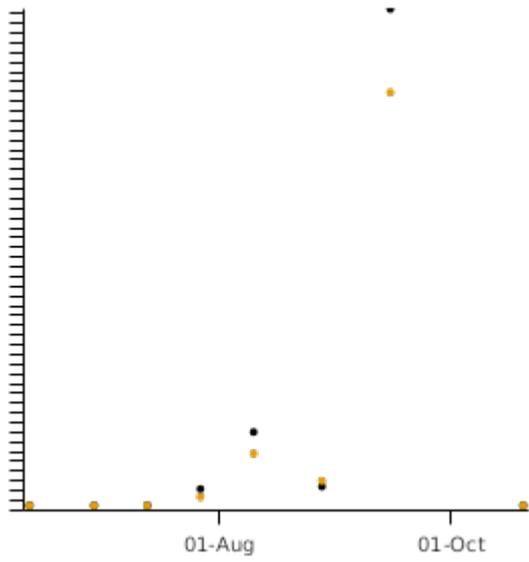
**Biomass**



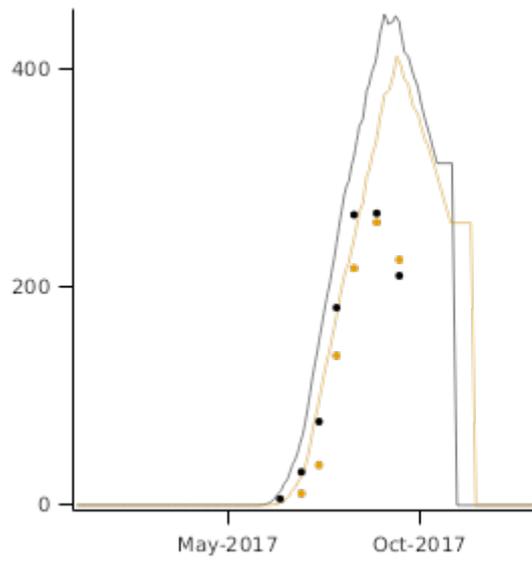
**LeafLiveWt**



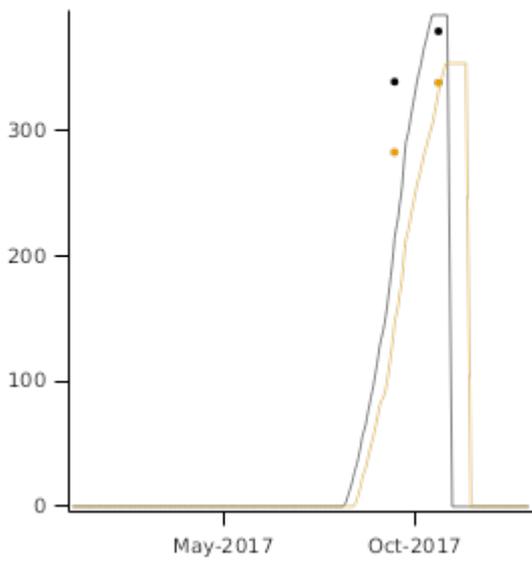
**LeafDeadWt**



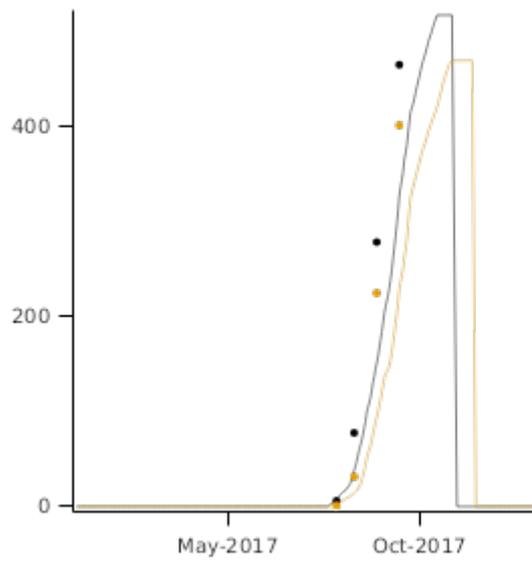
**StemWt**

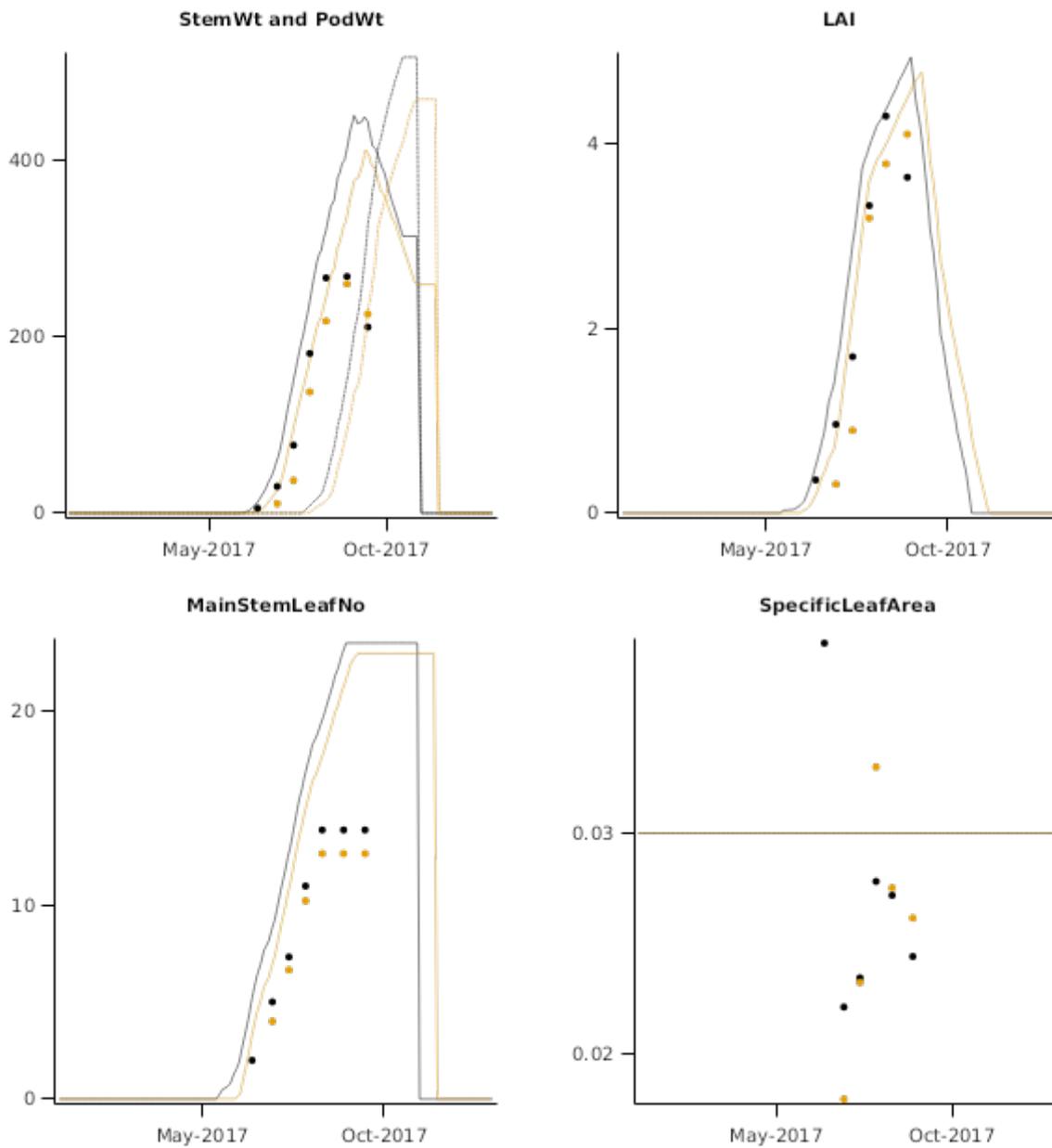


**GrainWt**



**PodWt**





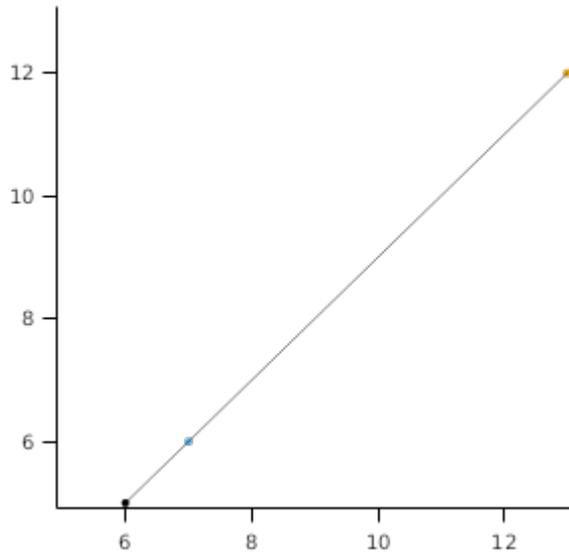
## 2.2.2 Arkansas

This trial ([Edwards, 2005](#)) was conducted on a silt loam soil in Fayetteville Arkansas, USA, in years 2001, 2002 and 2003. The factor studied were seven soybean maturity groups (from mg 00 to mg 6) and in some year multiple varieties within a maturity group. Crops were irrigated. No N fertilization was applied. This region has no shallow water tables. Phenology data were collected at different growth stages and were used in this work. Weather and soil data for the site were estimated from public sources. For additional information about this trial, see [Archontoulis et al., 2014](#).

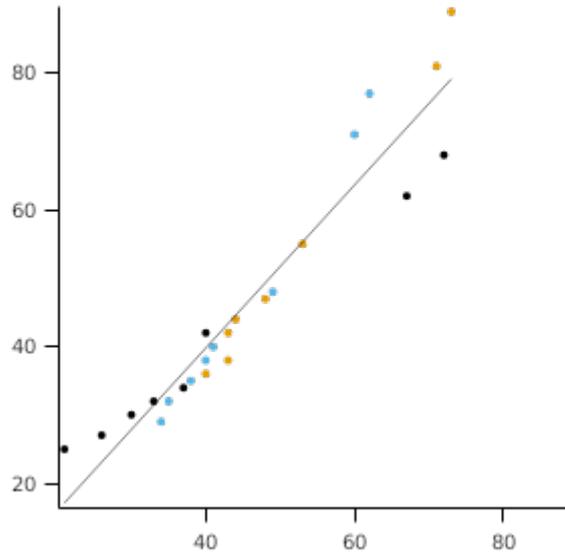
### 2.2.2.1 List of experiments

Experiment Name	Design (Number of Treatments)
Arkansas2001	Cv (8)
Arkansas2002	Cv (8)
Arkansas2003	Cv (8)

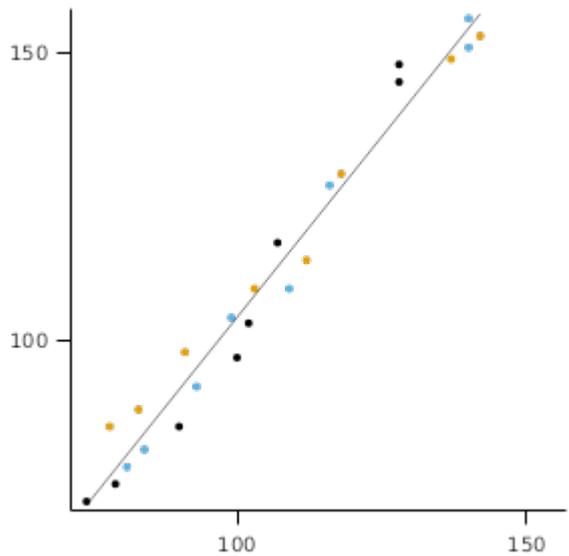
**Pred vs Obs EmergenceDAS**



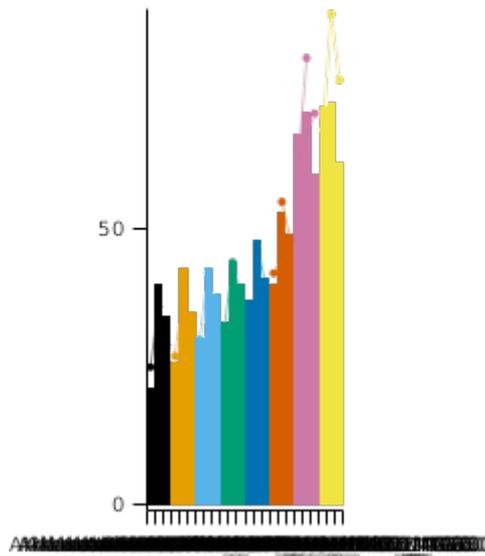
**Pred vs Obs FloweringDAS**



**Pred vs Obs MaturityDAS**



**FloweringDAS**

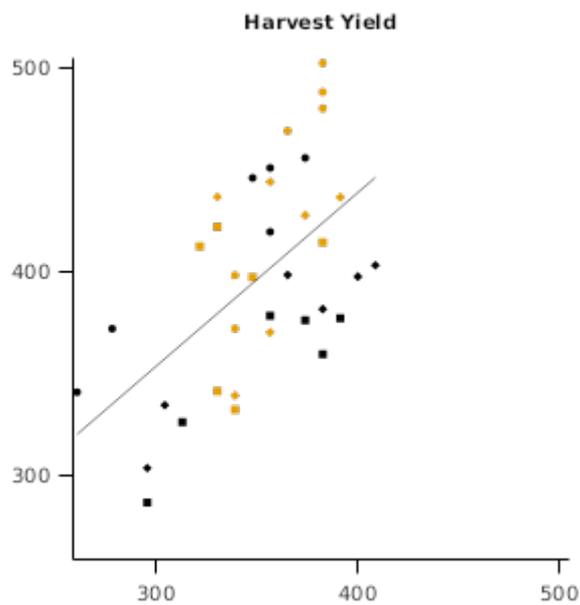
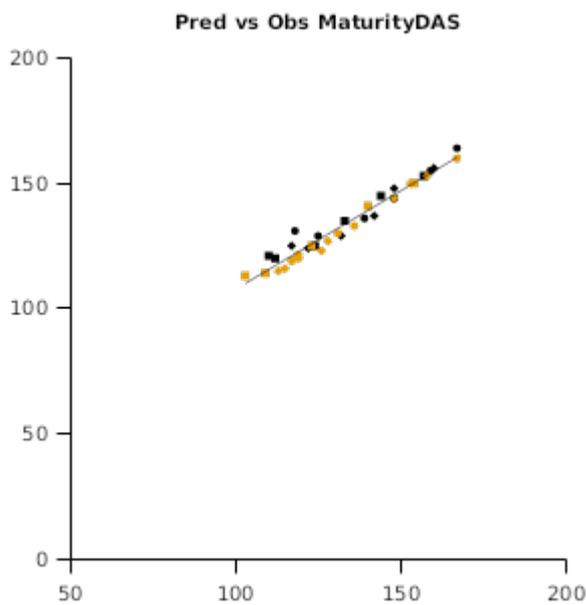
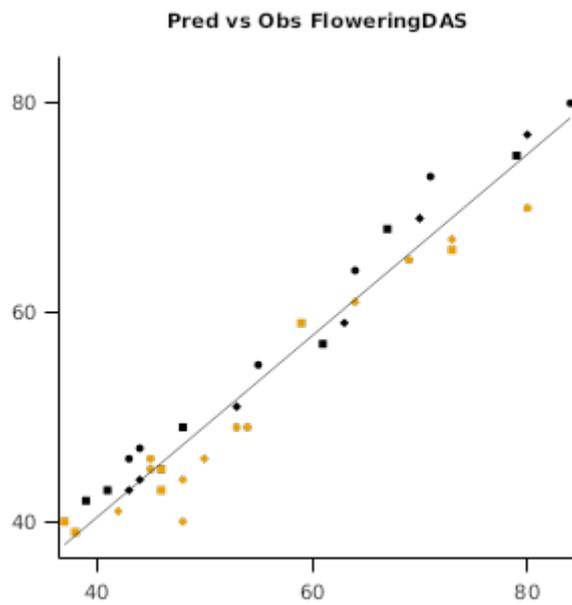
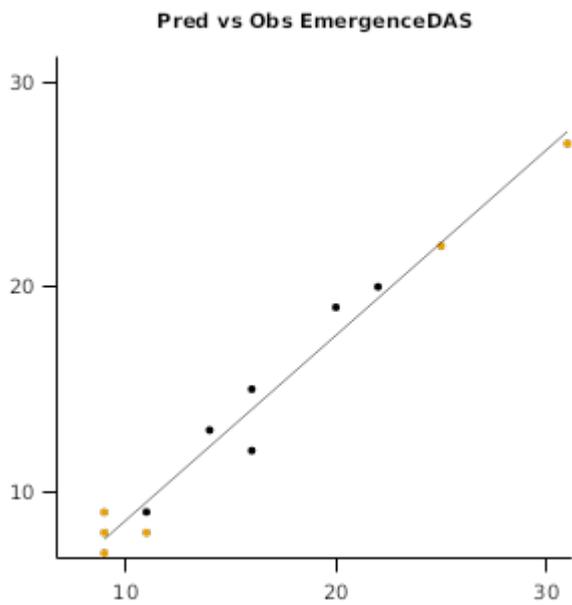


### 2.2.3 Indiana

This trial ([Robinson, 2009](#)) conducted in West Lafayette Indiana, USA, in years 2006 and 2007. The factors studied were six planting dates x three varieties (from mg 2.6 to mg 3.7). No irrigation or fertilization applied. Phenology, gravimetric soil moisture at three depth (manual soil cores), pod numbers, seed size, grain yield, protein and oil data were collected. Weather and soil data for the site were estimated from public sources. For additional information about this trial, see [Archontoulis et al., 2014](#).

#### 2.2.3.1 List of experiments

Experiment Name	Design (Number of Treatments)
Indiana2006	Sow x Cv (18)
Indiana2007	Sow x Cv (18)

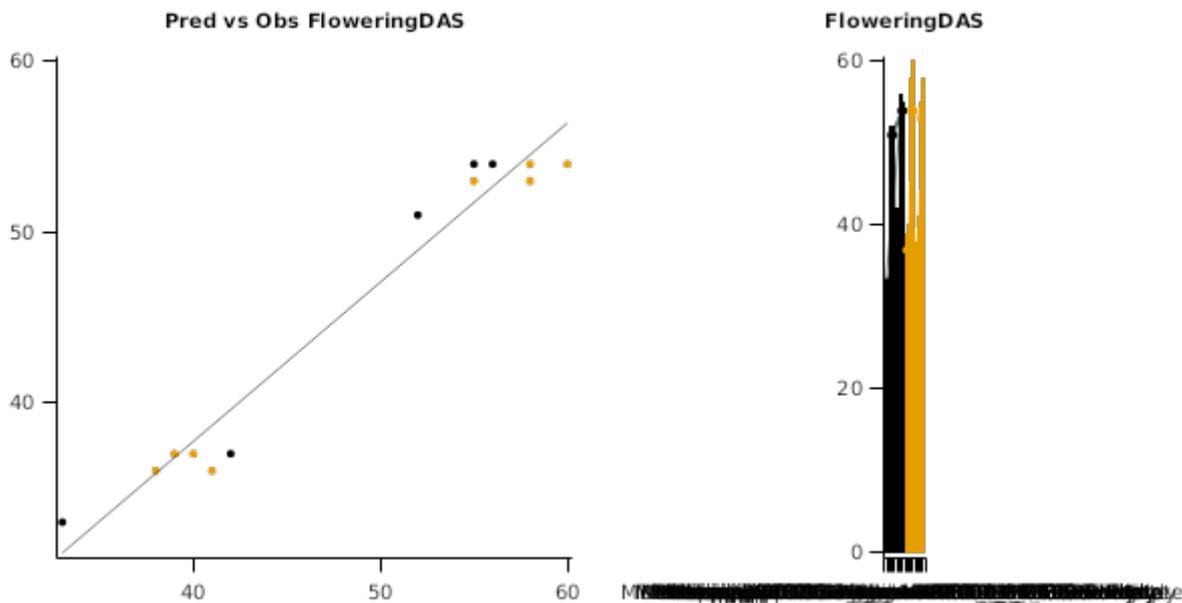


## 2.2.4 Mississippi

This trial ([Zhang, 2004](#)) was conducted in Stoneville Mississippi USA, in years 1998 to 2002. The factors studied were planting dates (ranged from early March to early July) and varieties (from mg 3.4 to mg 5.6). Crops were irrigated. Phenological measurements were obtained in the field following the V/R staging system. For additional information about this trial, see [Archontoulis et al., 2014](#).

### 2.2.4.1 List of experiments

Experiment Name	Design (Number of Treatments)
Mississippi2002	Cv x Sow (8)
Mississippi2003	Cv x Sow (8)



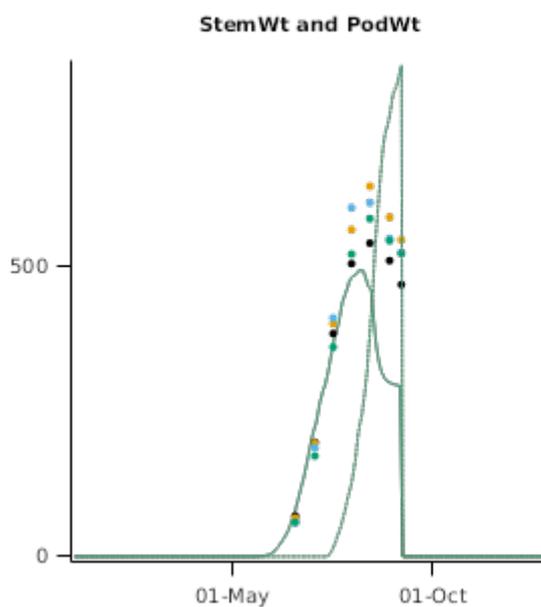
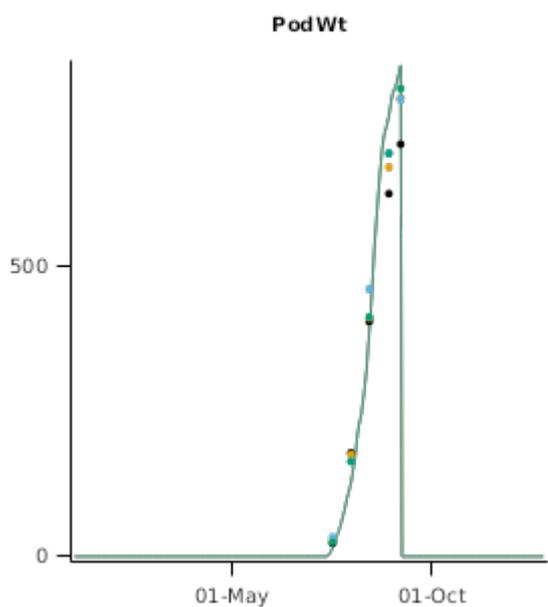
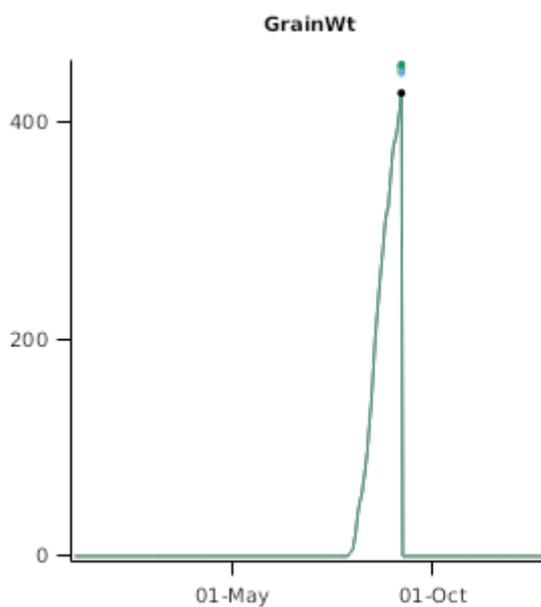
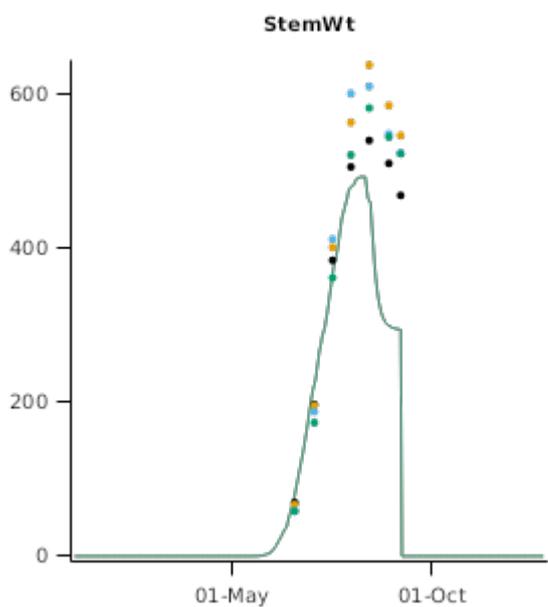
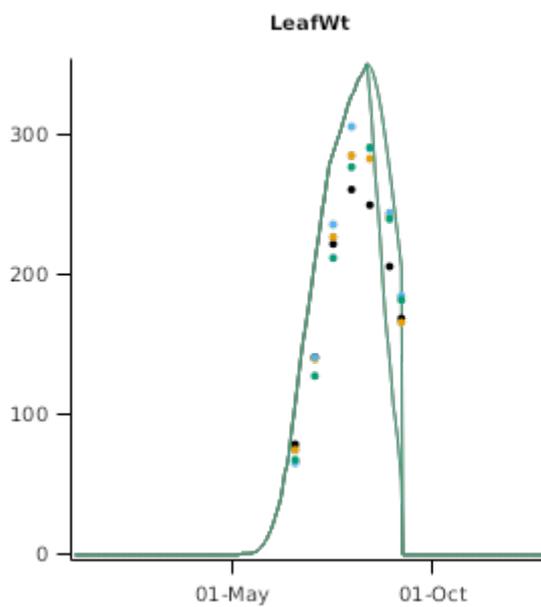
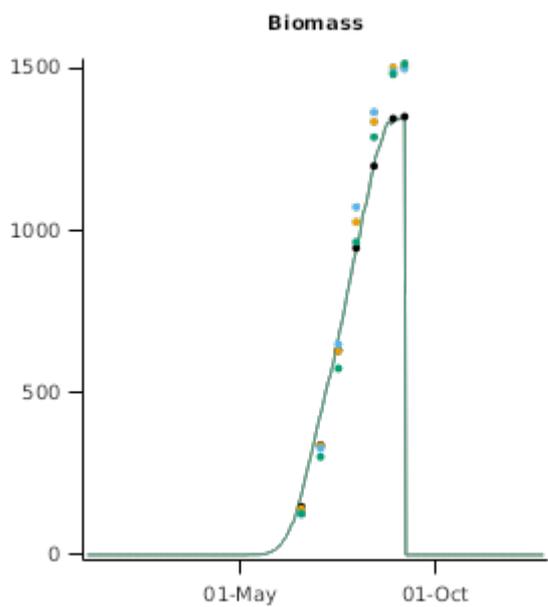
### 2.2.5 Nebraska

This trial (Salvagiotti, 2009) was conducted on a deep silt loam soil in Lincoln Nebraska USA, in years 2006 and 2007. The factors studied were different crop histories (normal N applied to corn-soy rotation and high N applied to the rotation) and 4 N fertilization treatments to the soybean crop (zero N, 180 kg N/ha at planting, 180 kg N/ha as split between preplanting and V6 leaf stage, and 180 kg N/ha at R5 stage). Crops were irrigated. Row spacing was 76 cm, plant density about 31 pl/m<sup>2</sup> and planting date around late april to early May. The following measurements were taken: initial soil nitrate, destructive biomass samples six times during the season (size 0.46 m<sup>2</sup> per plot) per year and per treatment, biomass partitioning, dry weight and N concentrations of each tissue (Dumas method in Rapid N Cube; Elementer, Germany), fallen leaves, phenology, and N-fixation during the growing season using the ureide method. Local weather data and public soil data were used to drive the simulations.

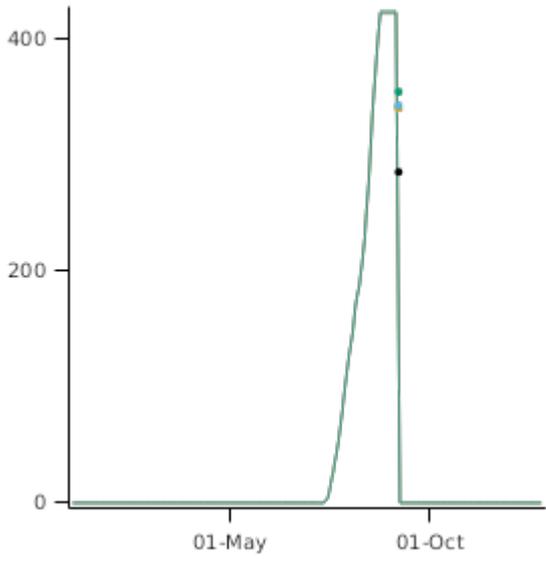
#### 2.2.5.1 List of experiments

Experiment Name	Design (Number of Treatments)
Nebraska2006	N (4)
Nebraska2007	N (4)

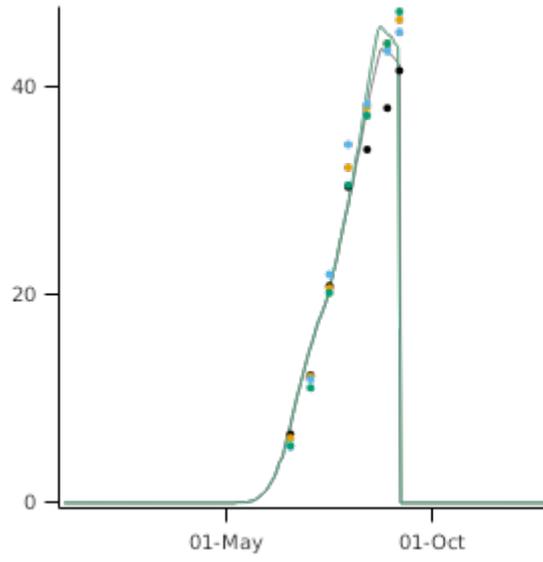
#### 2.2.5.2 Nebraska2006



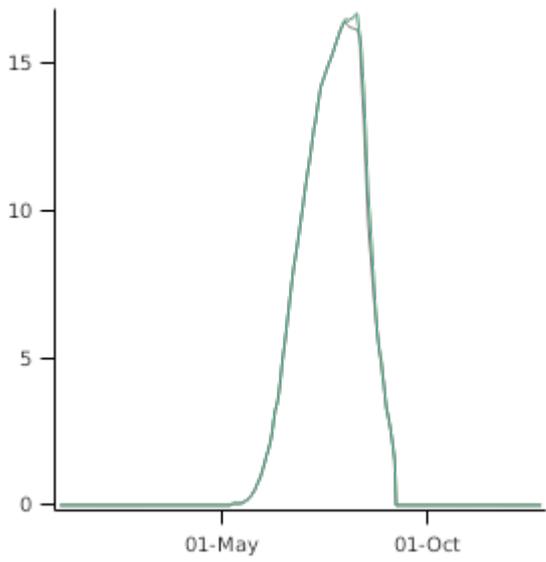
**ShellWt**



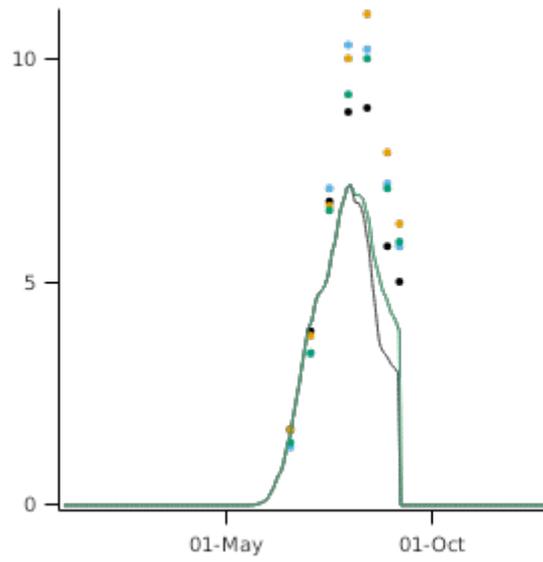
**BiomassN**

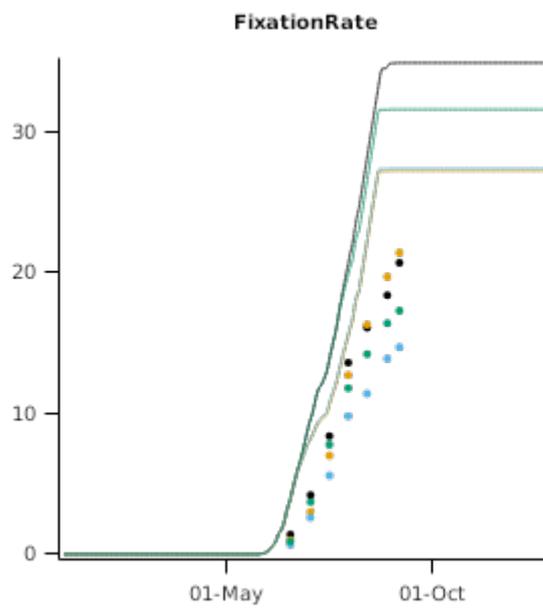
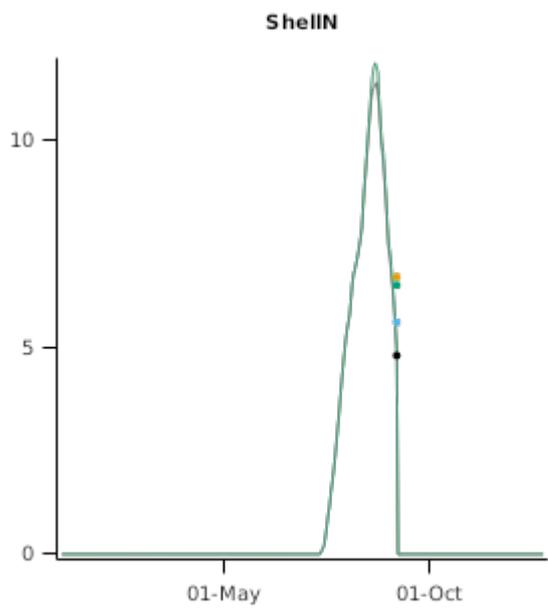
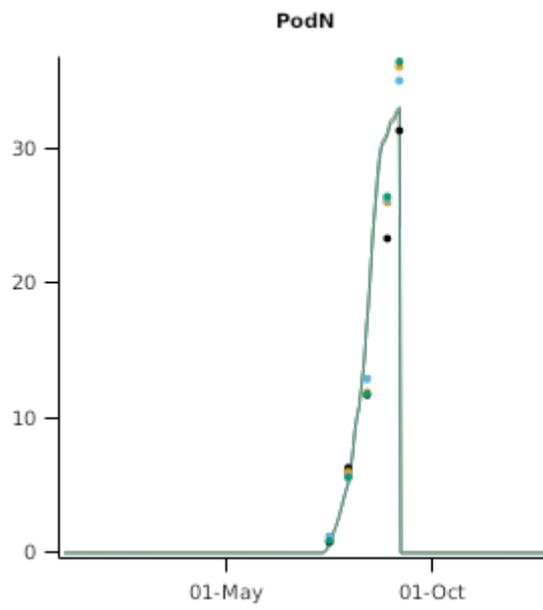
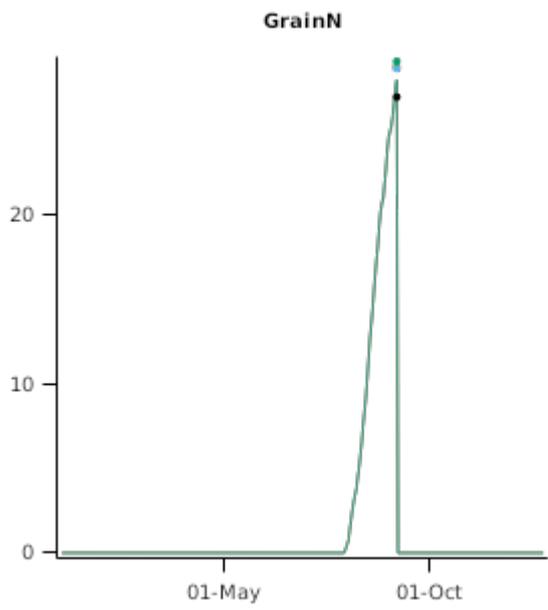


**LeafLiveN**



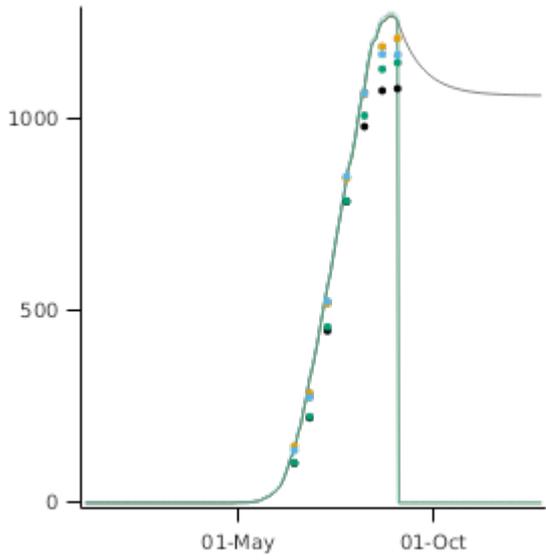
**StemN**



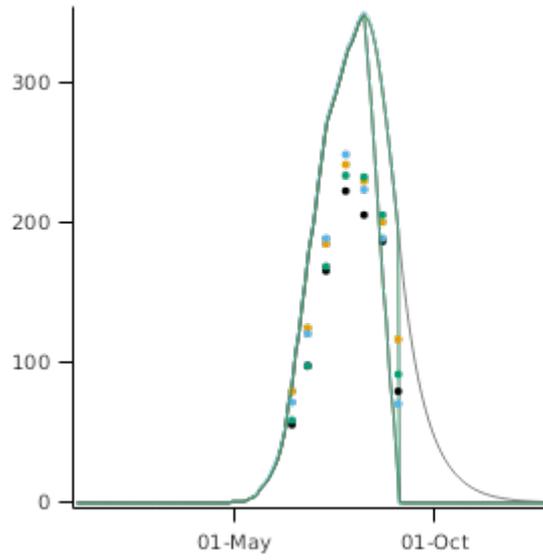


**2.2.5.3 Nebraska2007**

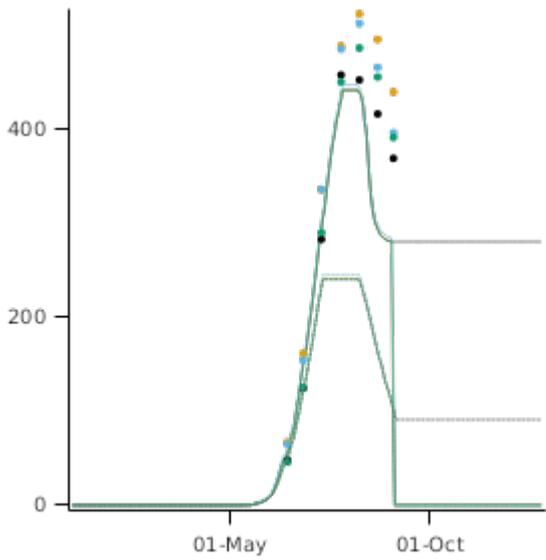
**Biomass**



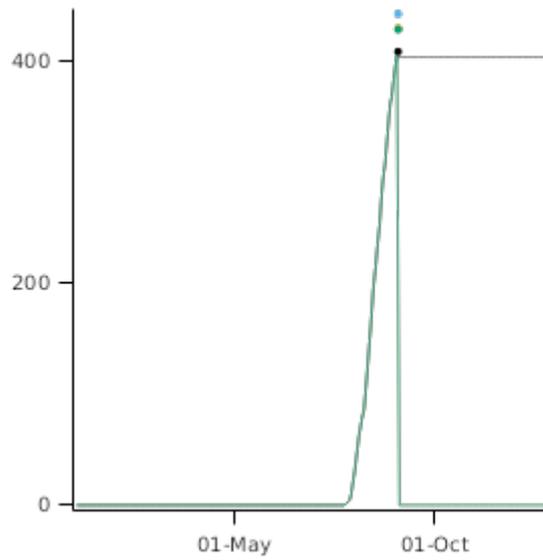
**LeafWt**



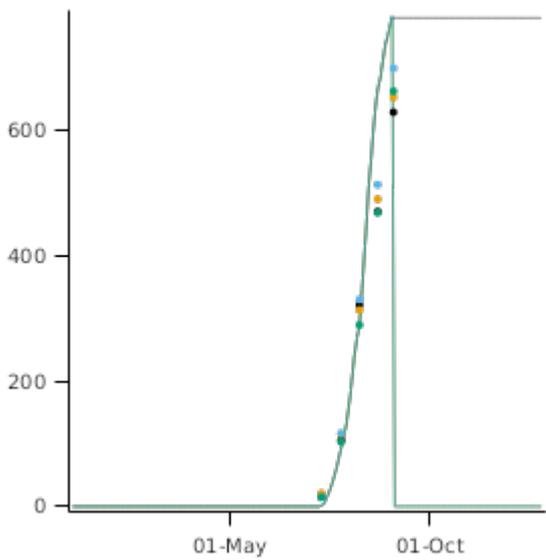
**StemWt**



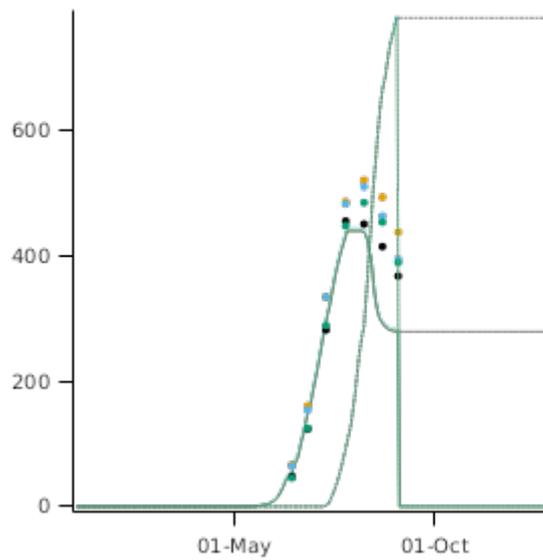
**GrainWt**



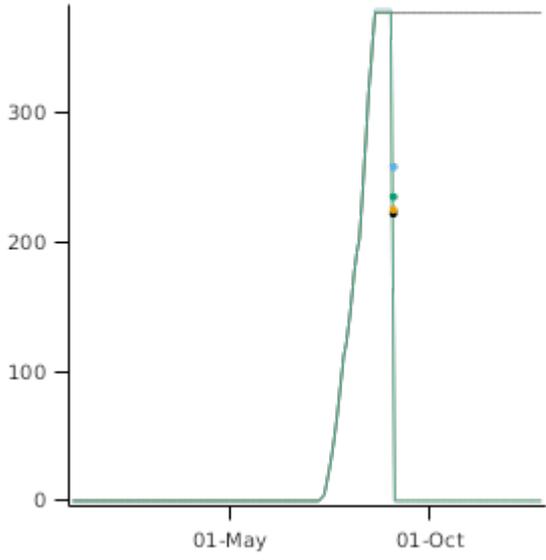
**PodWt**



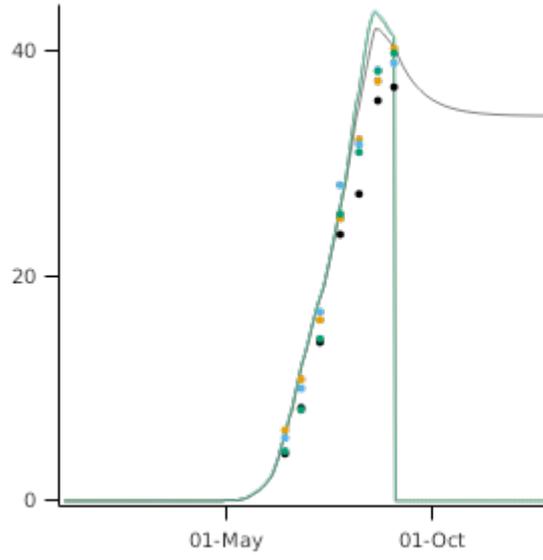
**StemWt and PodWt**



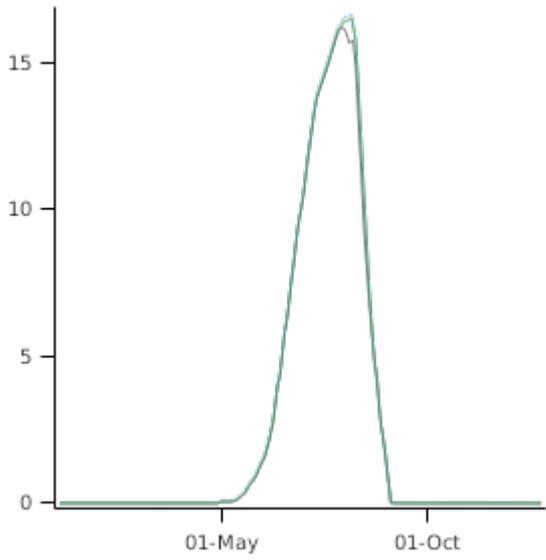
**ShellWt**



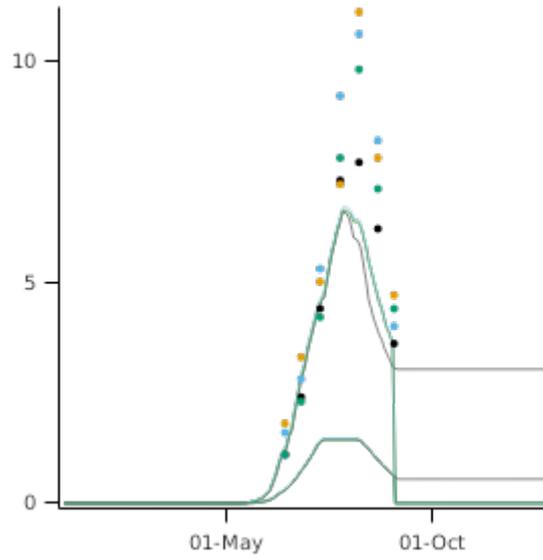
**BiomassN**

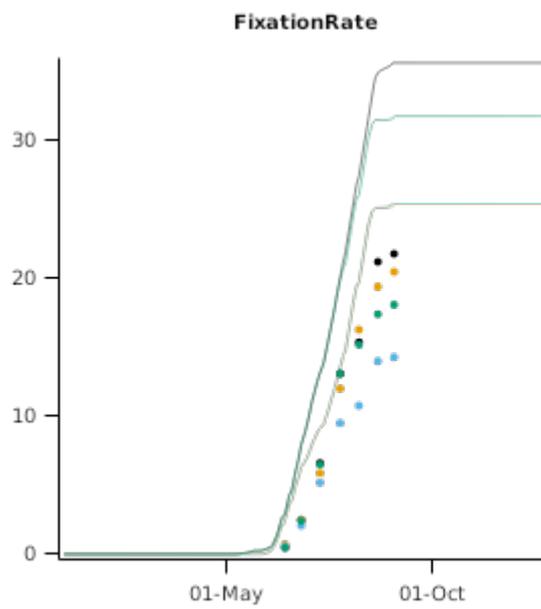
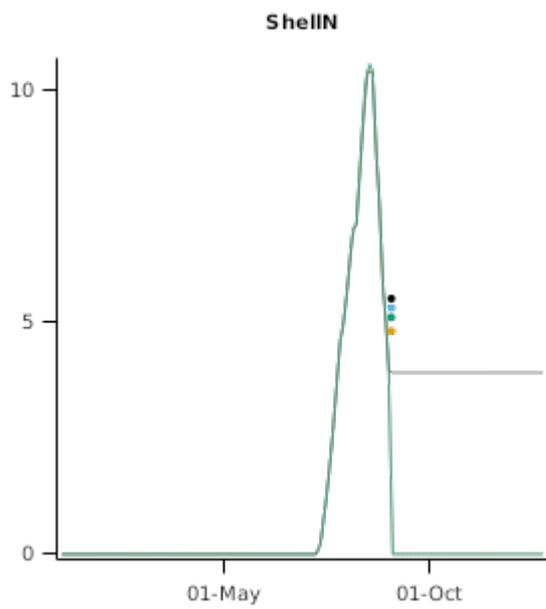
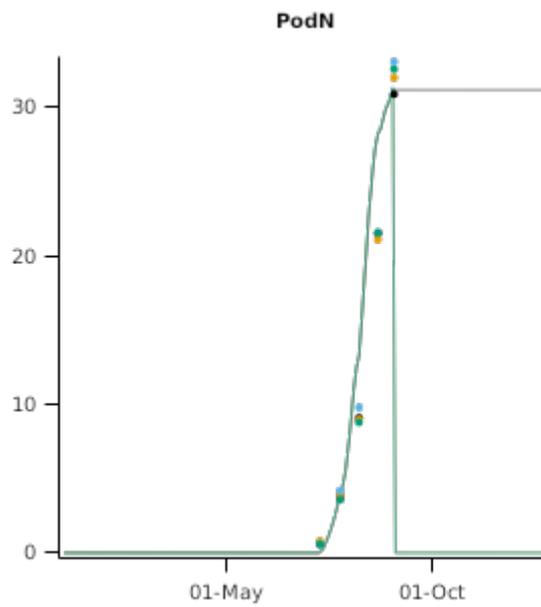
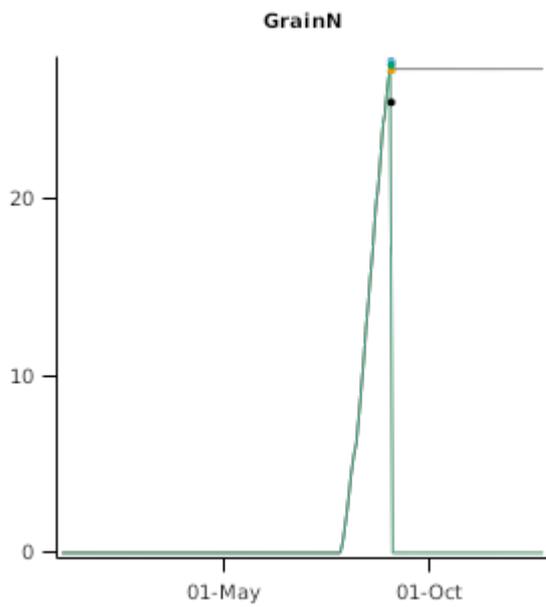


**LeafLiveN**



**StemN**





## 2.3 Australia

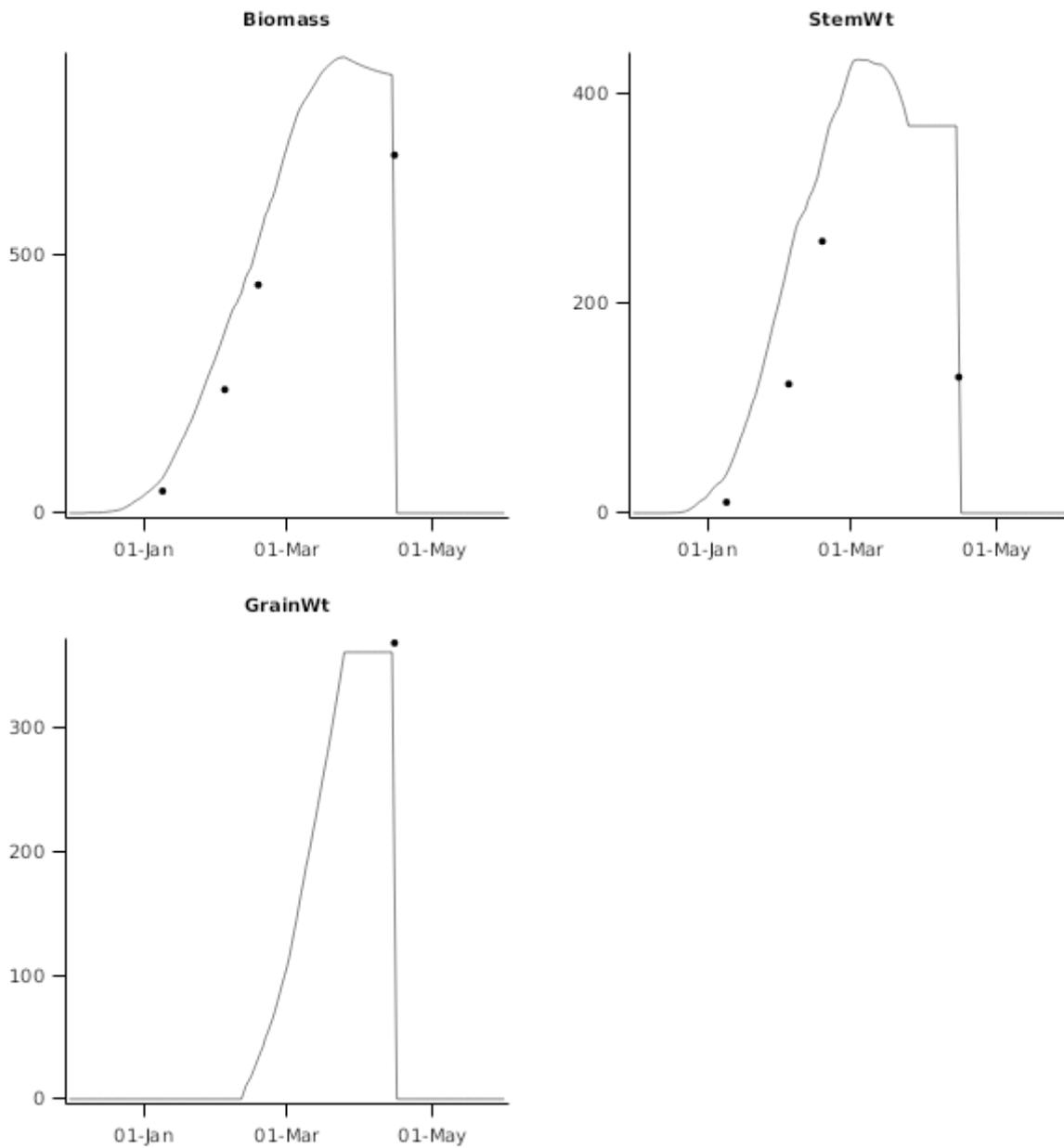
### 2.3.1 Coleambally

#### 2.3.1.1 List of experiments

Experiment Name	Design (Number of Treatments)
Coleambally	Sow (1)

#### 2.3.1.2 Graphs

##### 2.3.1.2.1 Biomass



## 2.3.2 Gatton

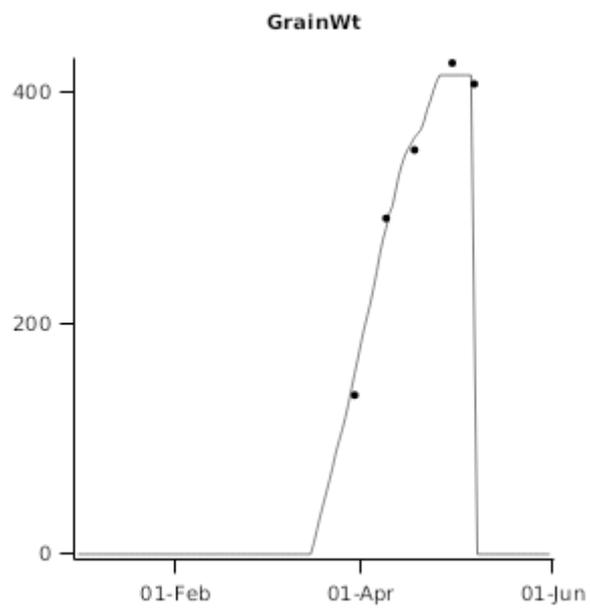
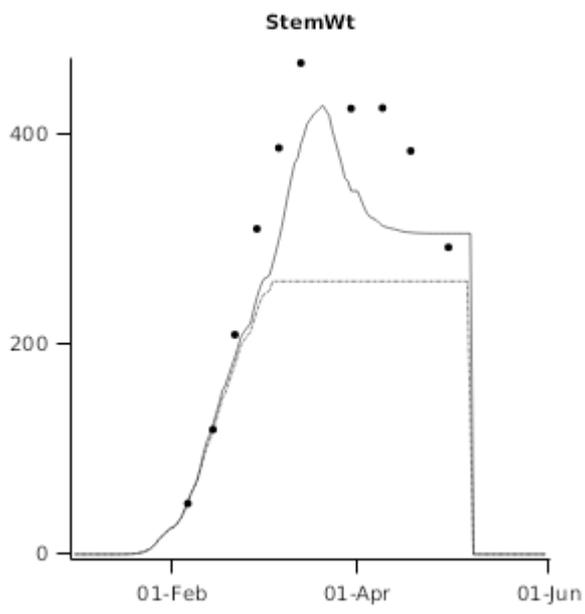
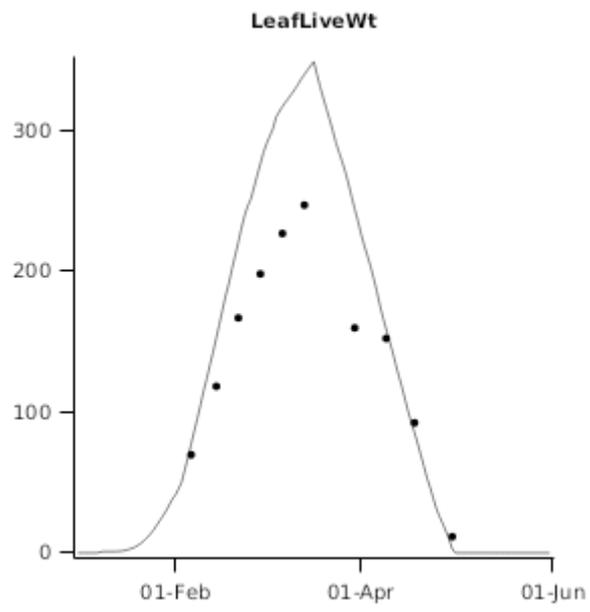
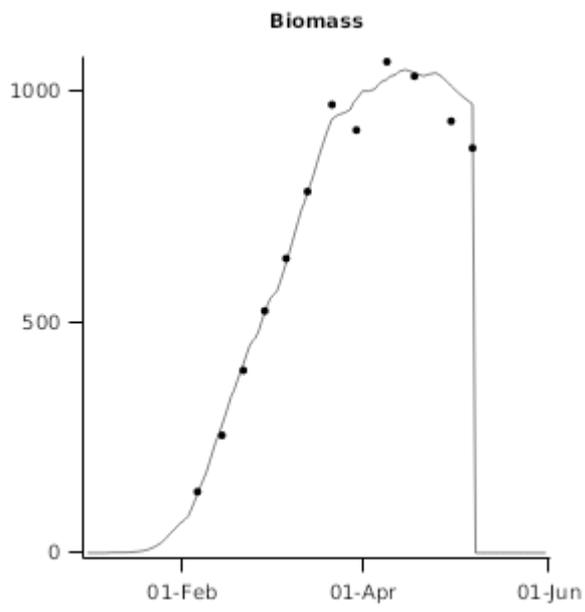
This dataset ([Muchow et al., 1993](#)) includes the cultivar "Davis" grown under irrigated conditions in a subtropical environment at the Gatton Research Station in southeastern Queensland, Australia. Plants were sampled almost weekly for biomass partitioning, nitrogen and plant development.

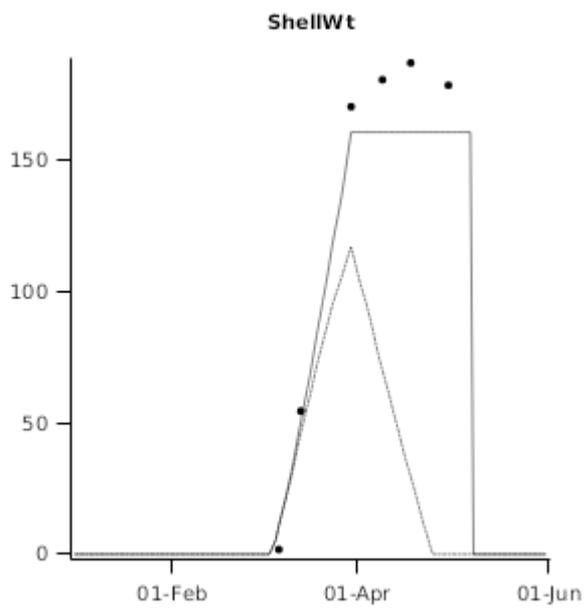
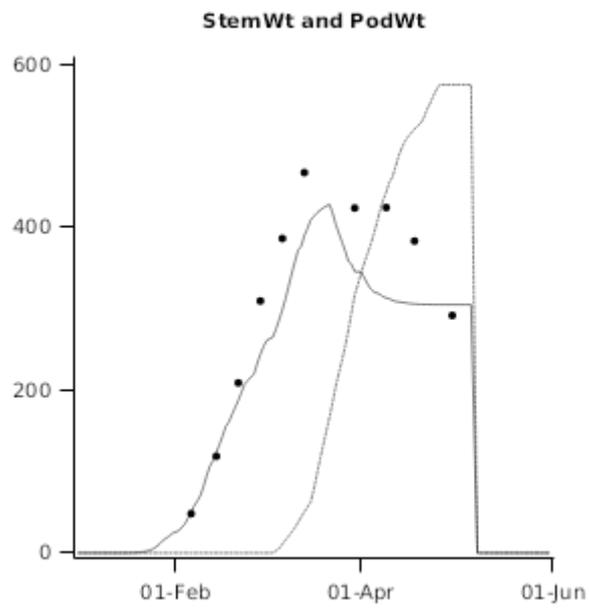
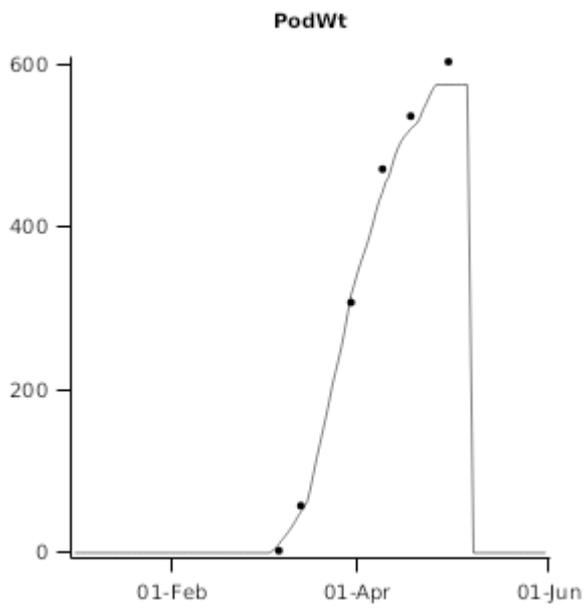
### 2.3.2.1 List of experiments

Experiment Name	Design (Number of Treatments)
Gatton	Sow (1)

### 2.3.2.2 Graphs

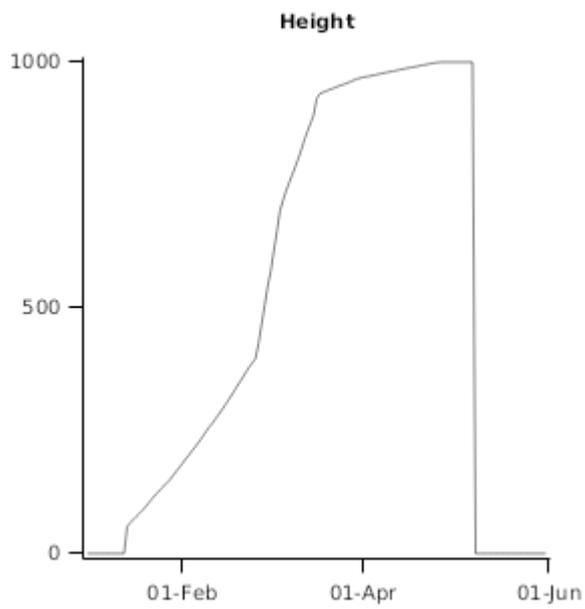
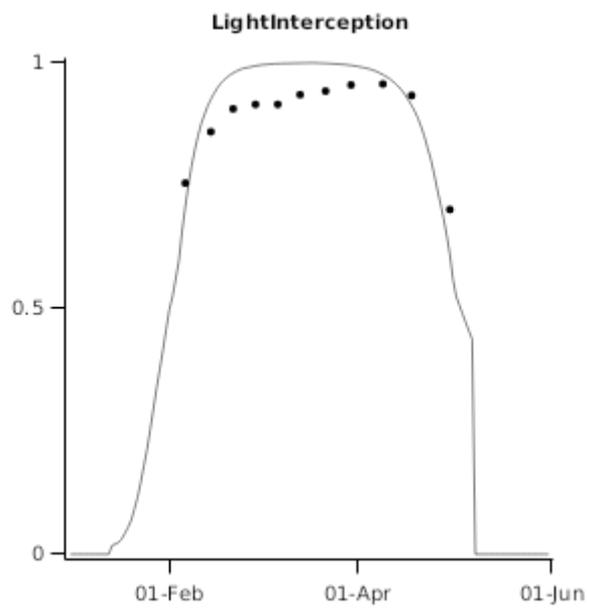
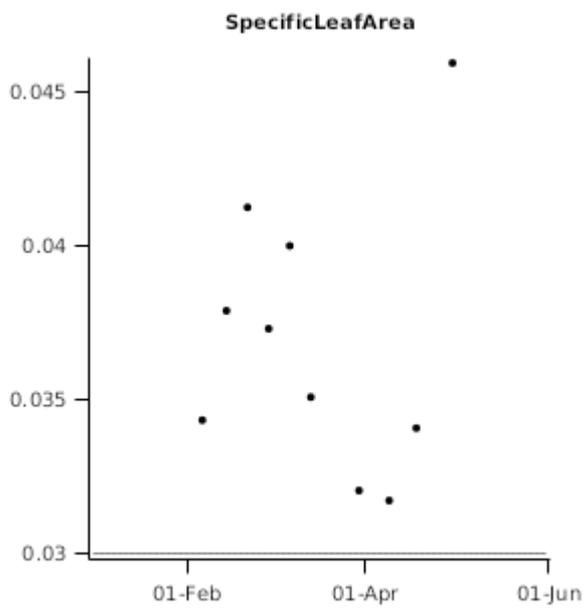
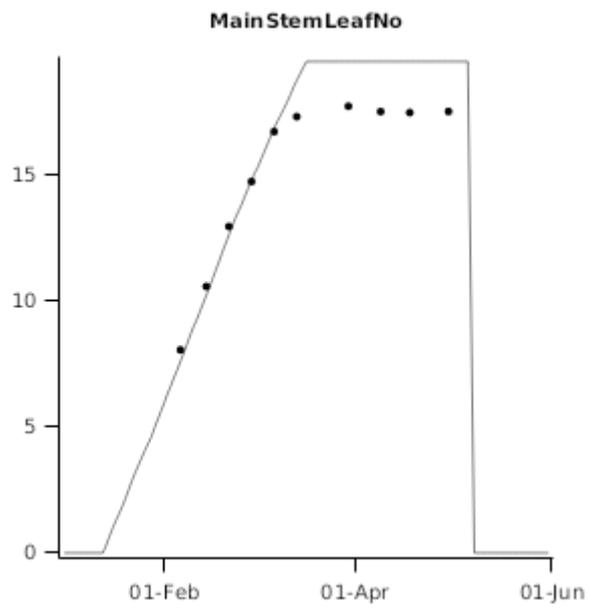
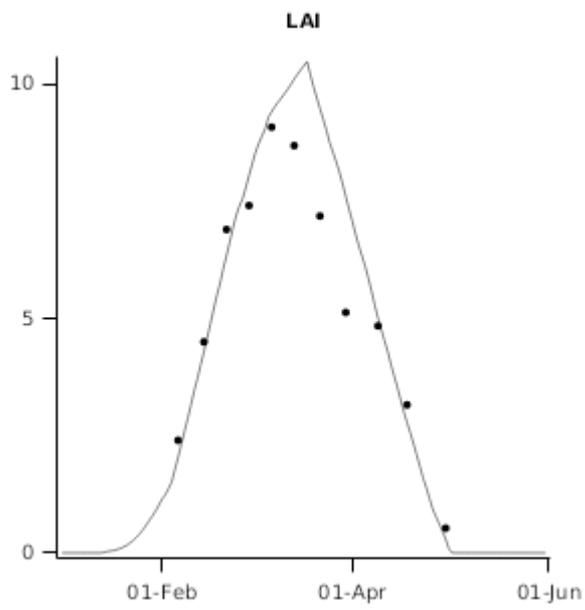
#### 2.3.2.2.1 Biomass



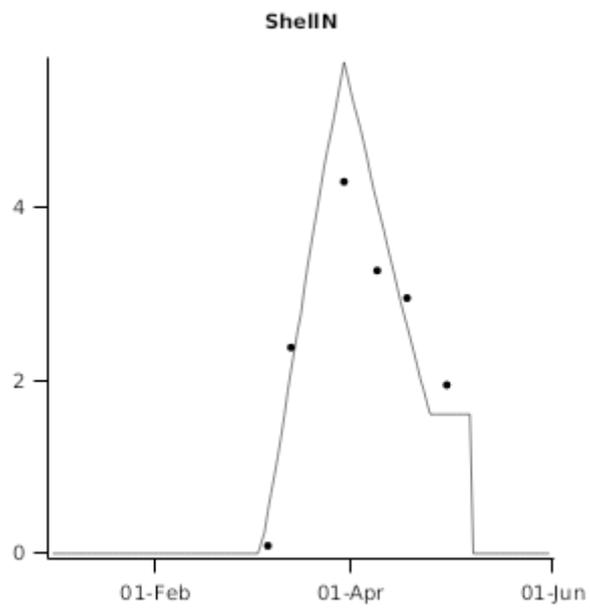
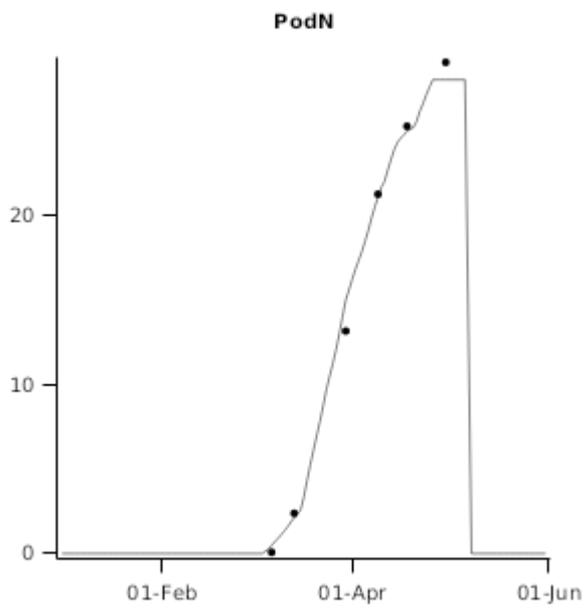
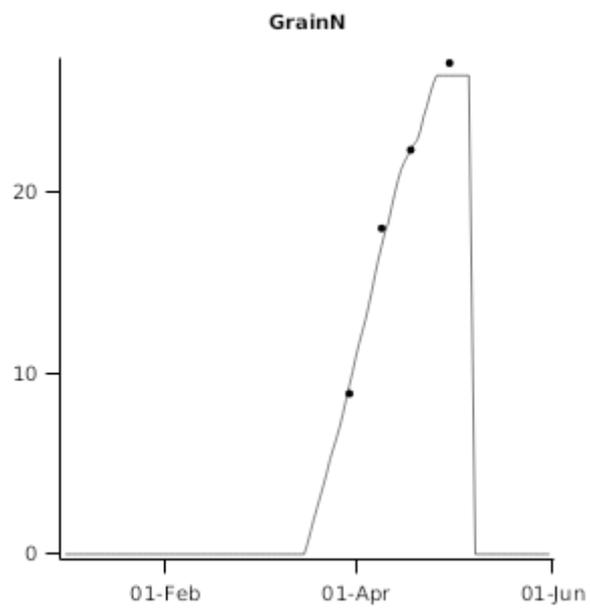
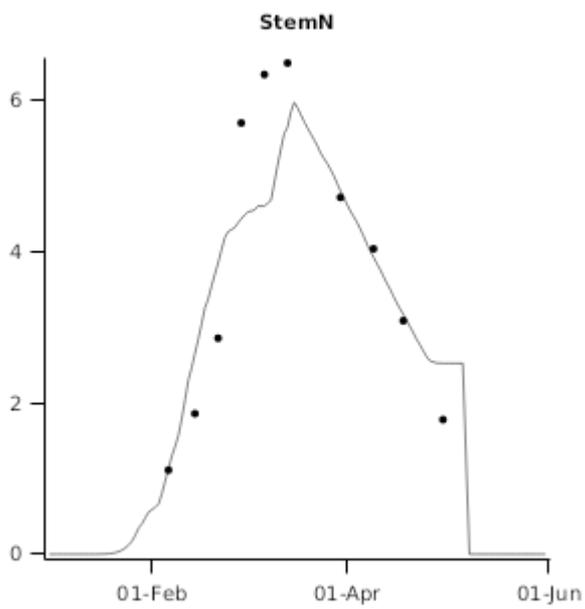
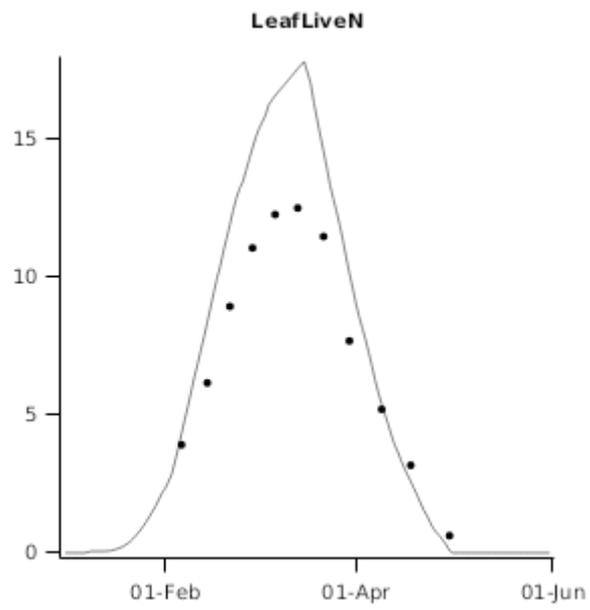
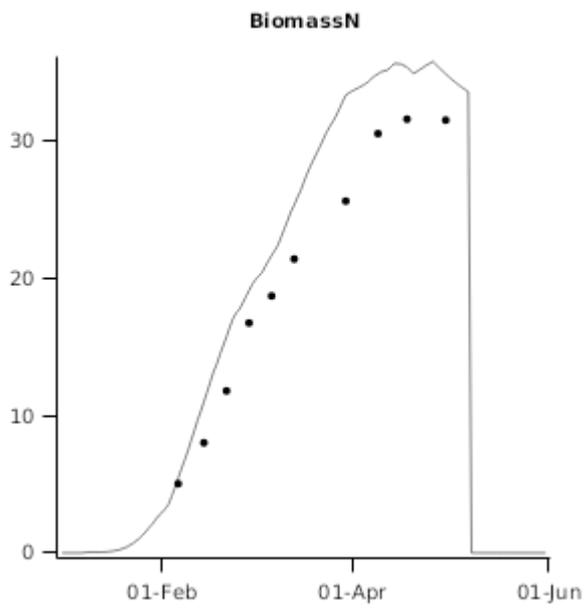


**HarvestIndex**

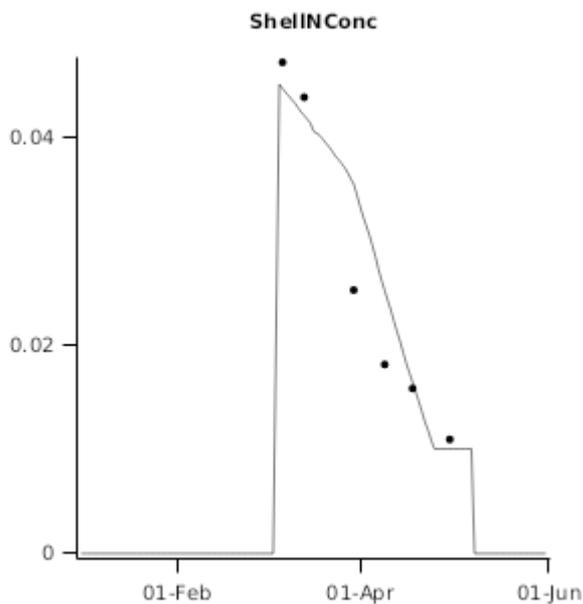
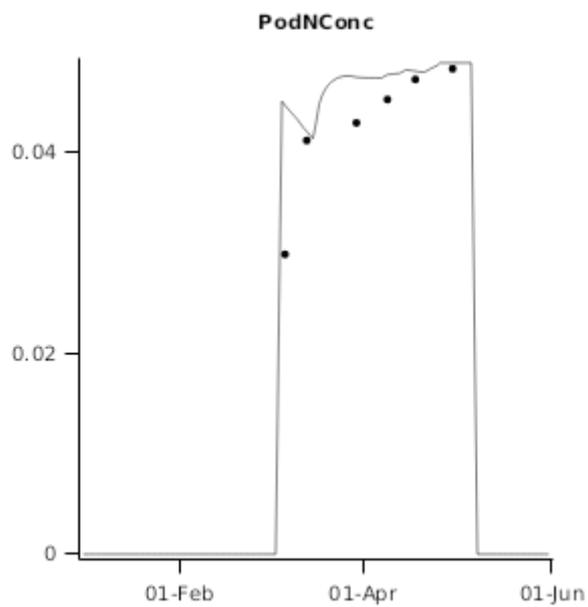
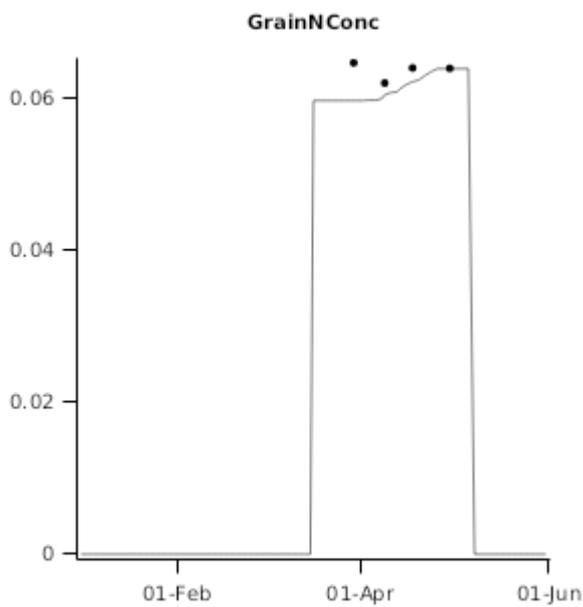
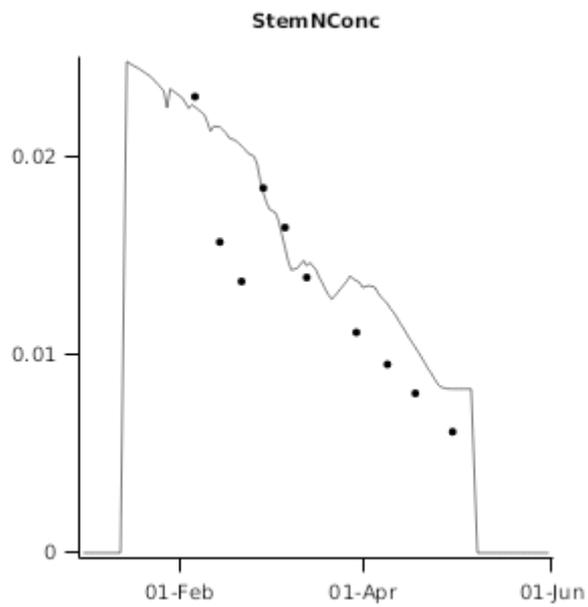
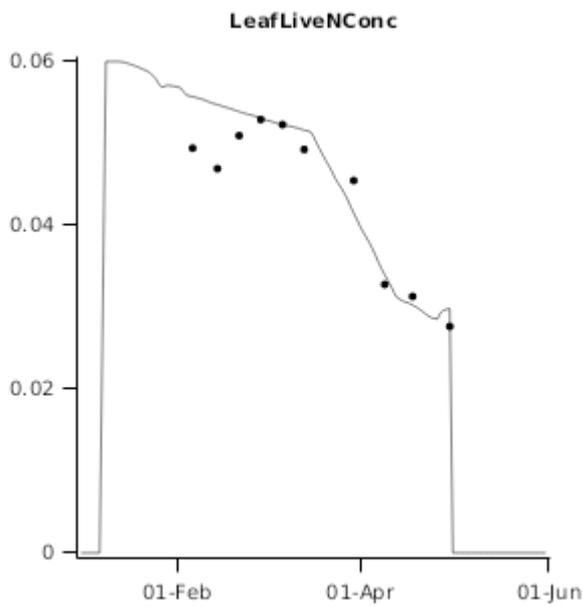
**2.3.2.2.2 Canopy**



**2.3.2.2.3 Nitrogen**



**2.3.2.2.4 NitrogenConcentration**



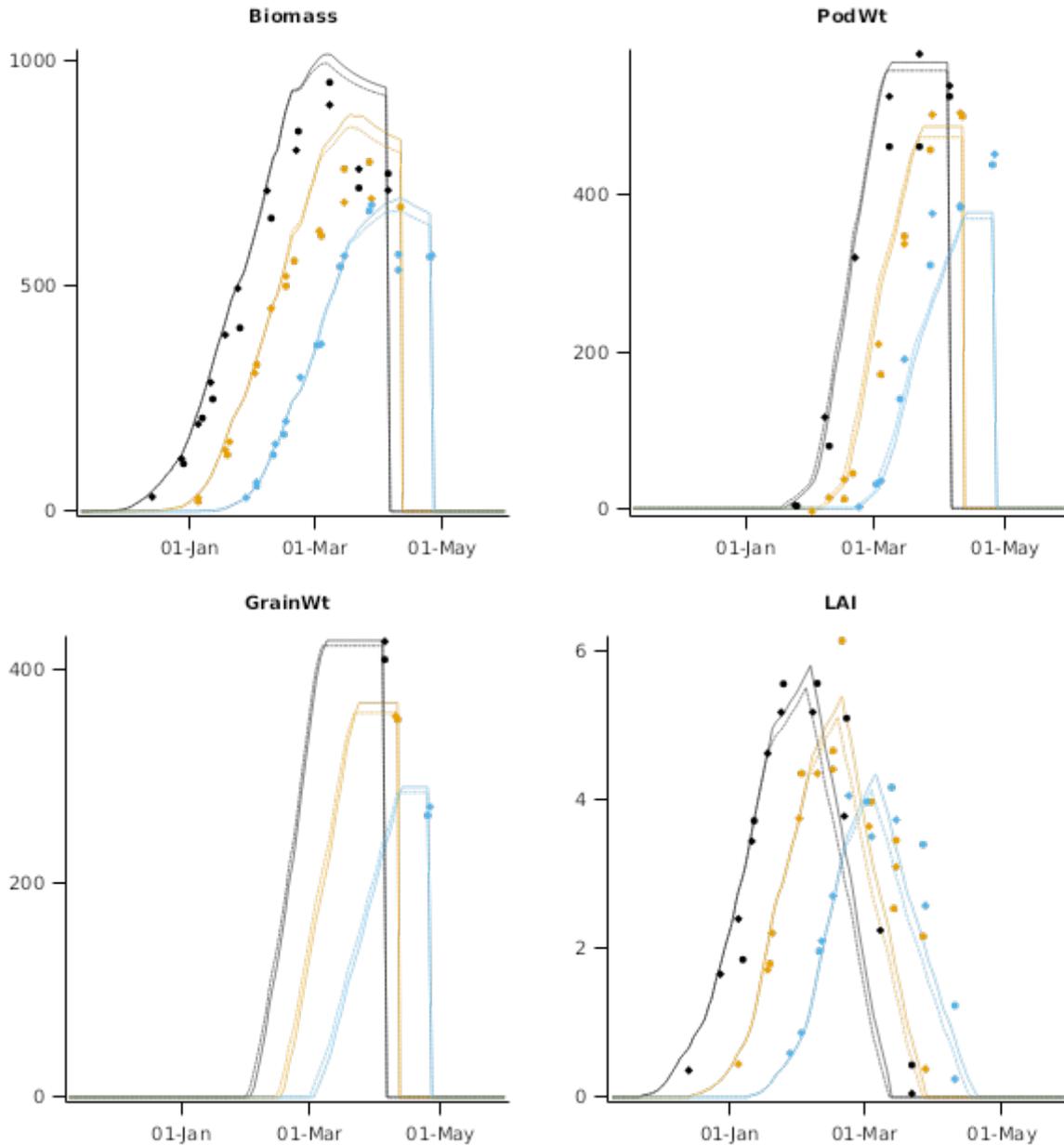
### 2.3.3 Griffith

These data [Timsina et al., 2007](#) were obtained from a field experiment conducted in 1999–2000 on a Hanwood loam soil at CSIRO Land and Water, Griffith, Australia. Two indeterminate soybean cultivars (Hooper and Stephens belonging to late maturity group [MG] 3 or early MG 4) were on 15 November, 8 December, and 6 January.

### 2.3.3.1 List of experiments

Experiment Name	Design (Number of Treatments)
Griffith	Sow x Cv (6)

### 2.3.3.2 Griffith



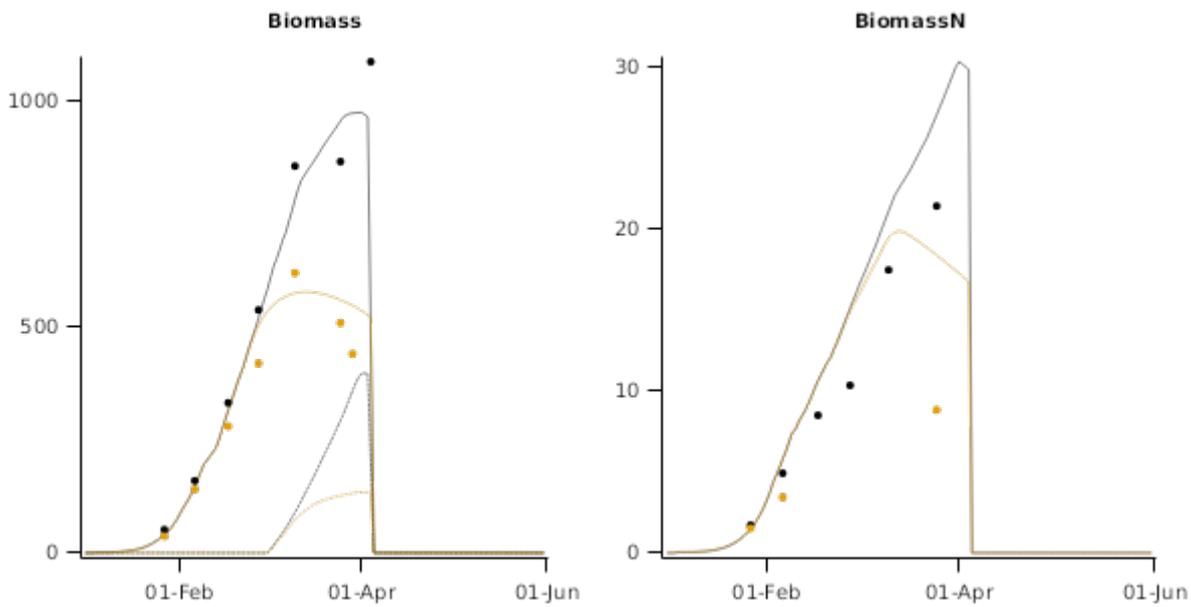
### 2.3.4 Katherine

This dataset (Muchow et al., 1993) includes the cultivar "Buchanan" grown under a range of conditions in a tropical environment at the Katherin Research Station in the Northern Territory, Australia. This includes two irrigated conditions in 1988 and two planting dates in 1989.

#### 2.3.4.1 List of experiments

Experiment Name	Design (Number of Treatments)
Katherine1988	Water (2)
Katherine1989	Sow (2)

#### 2.3.4.2 Katherine1988



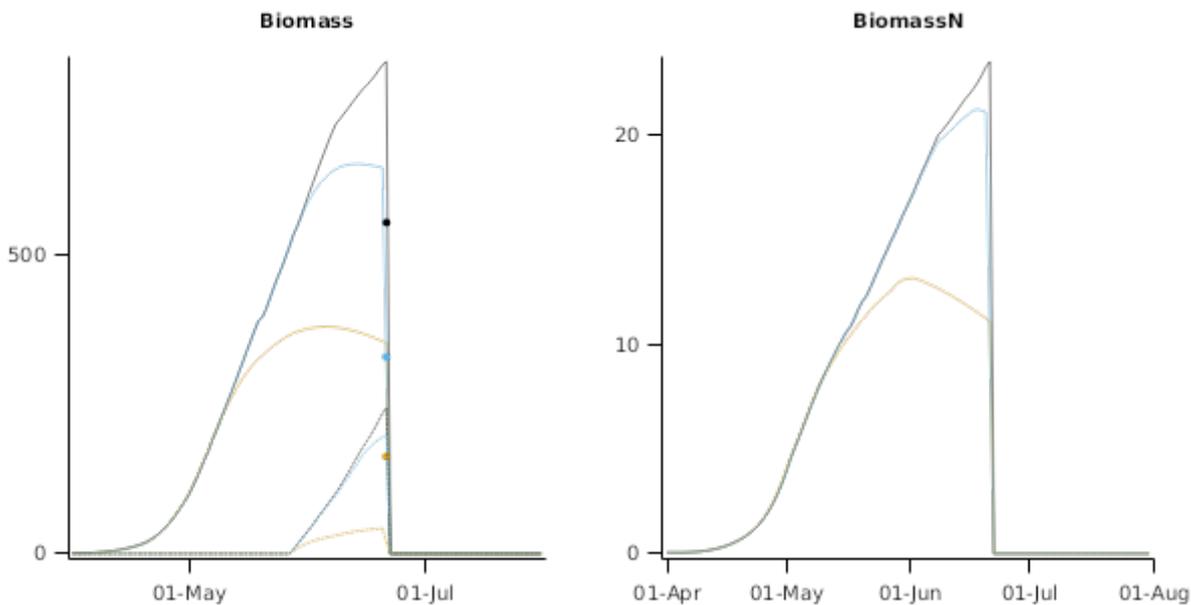
### 2.3.5 Kununurra

This dataset [Muchow et al., 1986](#) includes a short-season and a long-season cultivar grown on two different soil types under both irrigated and water-limited conditions in a semi-arid tropical environment at the Kimberley Research Station (15 ° 38' S, 128°43 ' E) in northern Western Australia. Crops were grown over the winter months because of the tropical location.

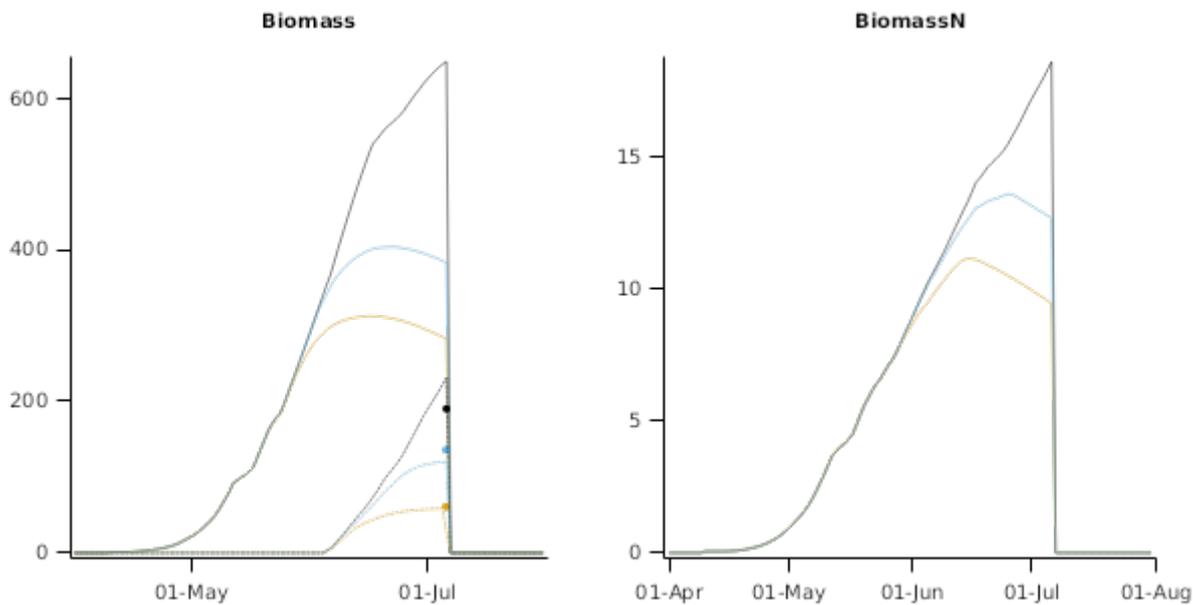
#### 2.3.5.1 List of experiments

Experiment Name	Design (Number of Treatments)
Kununurra1980	Water (3)
Kununurra1979	Water (3)

#### 2.3.5.2 Kununurra1980



#### 2.3.5.3 Kununurra1979

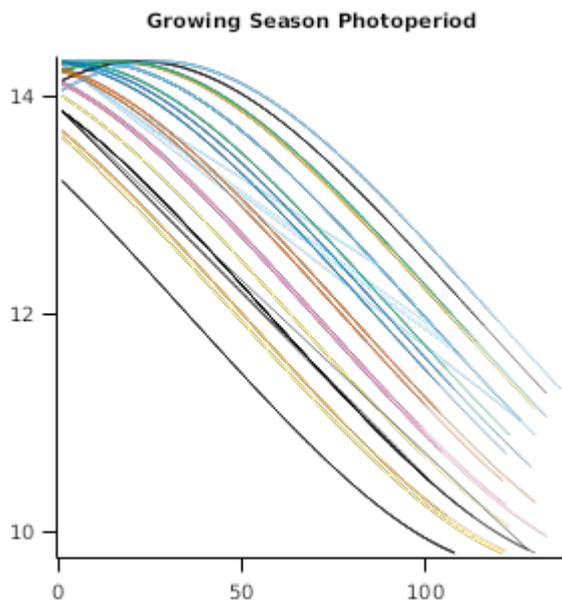


### 2.3.6 Leeton

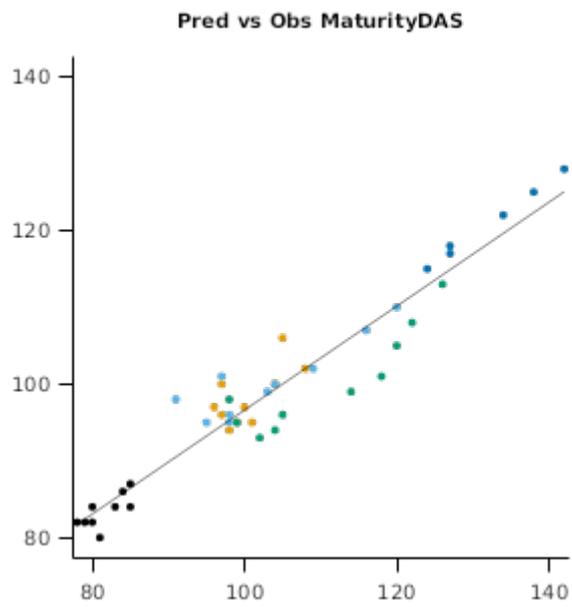
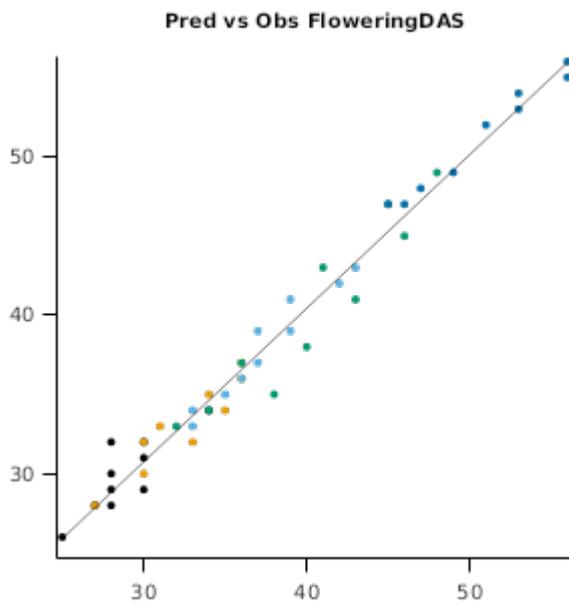
This dataset [Gaynor et al., 2011](#) is derived from a small-plot serial sowing date study were conducted over the summers of 2006–07 and 2007–08, at the NSW Department of Primary Industries' Leeton Field Station, New South Wales, Australia (348280S, 1468250E). The soil was a grey self-mulching clay, described as a Vertosol under the Australian Soil Classification. Ten diverse soybean genotypes ranging from very early to very late maturity were grown with 10 sowing dates in the first season and 9 in the second.

#### 2.3.6.1 List of experiments

Experiment Name	Design (Number of Treatments)
Leeton2006	Sow x Cv (50)
Leeton2007	Sow x Cv (45)



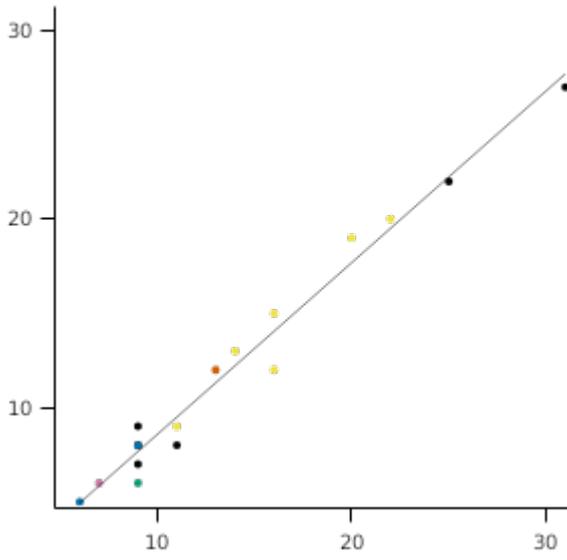
#### 2.3.6.2 Phenology



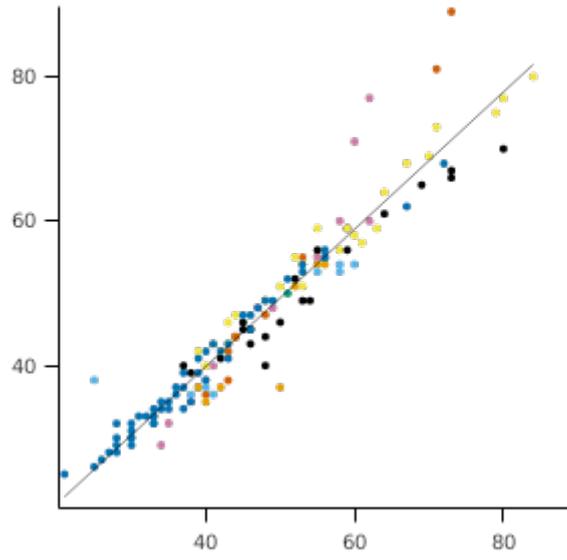
## 2.4 Combined Results

Simulation results for the combined datasets from the various countries are shown in the following graphs. The model is able to adequately capture the influence of growing conditions (soil, climate) and management (population, Nitrogen, irrigation, sowing date).

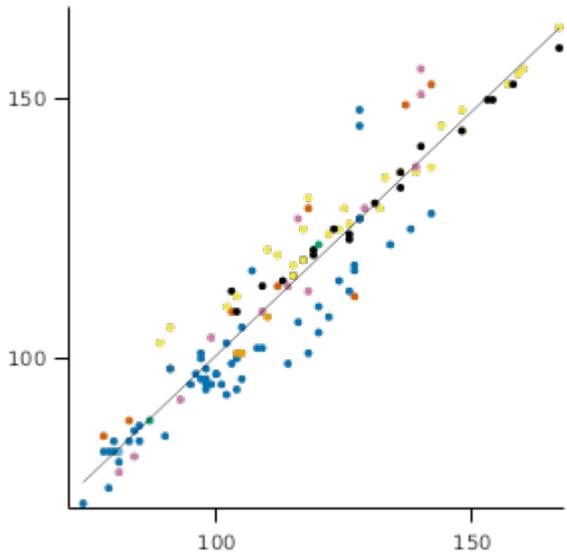
**Pred vs Obs EmergenceDAS**



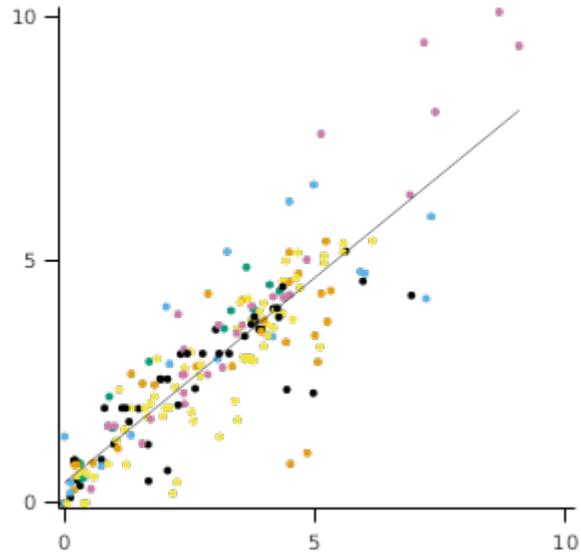
**FloweringDAS**



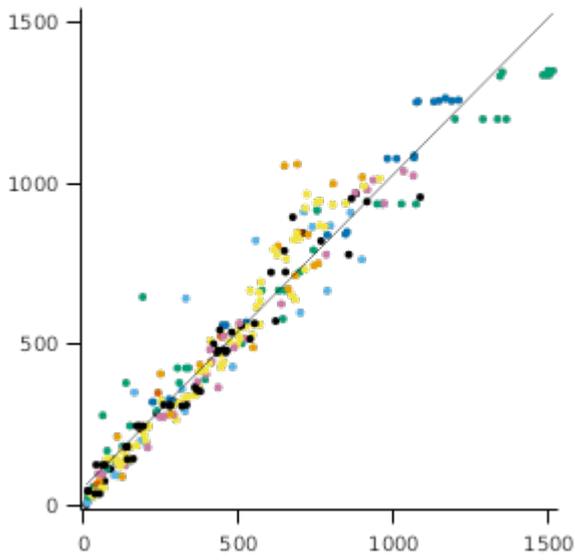
**MaturityDAS**



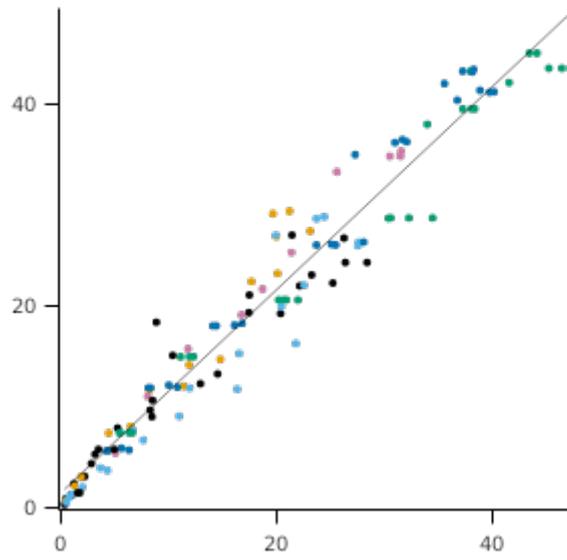
**LAI**

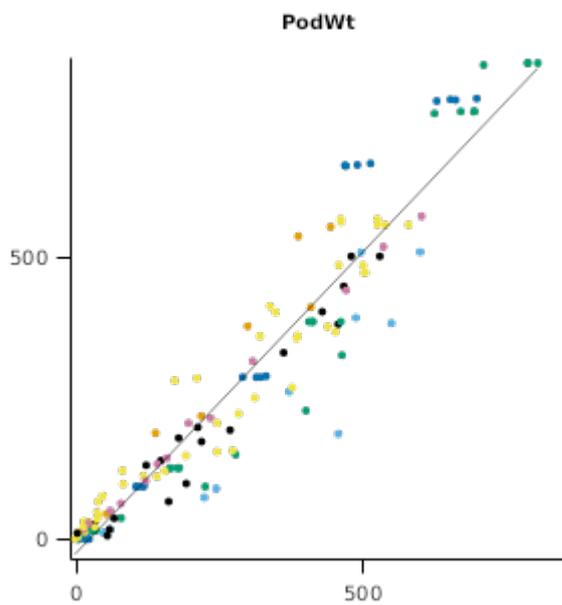
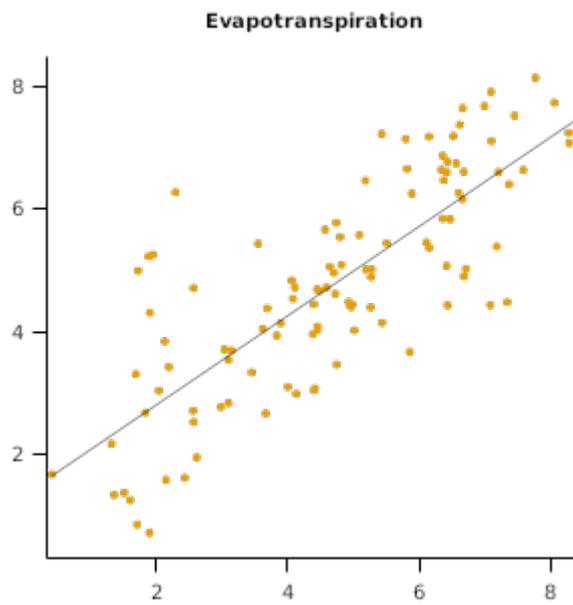
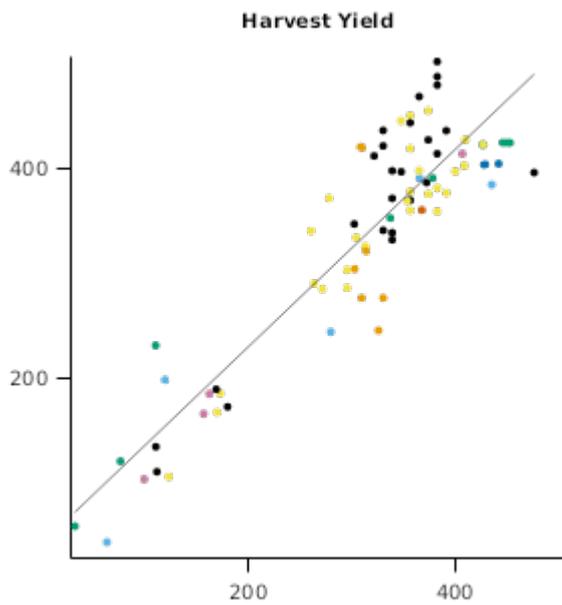


**Biomass**



**BiomassN**





## 2.5 China

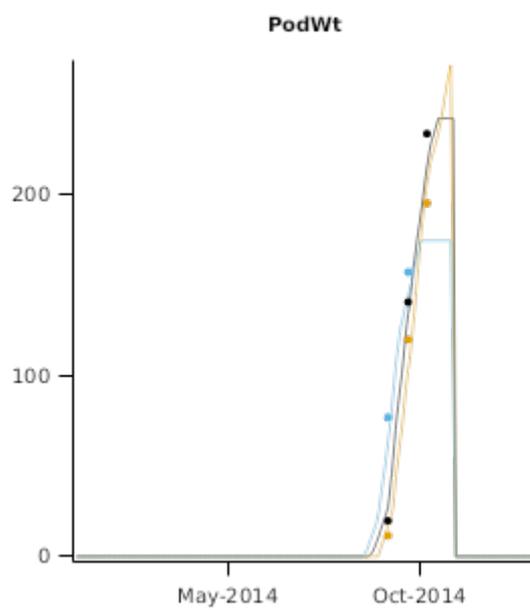
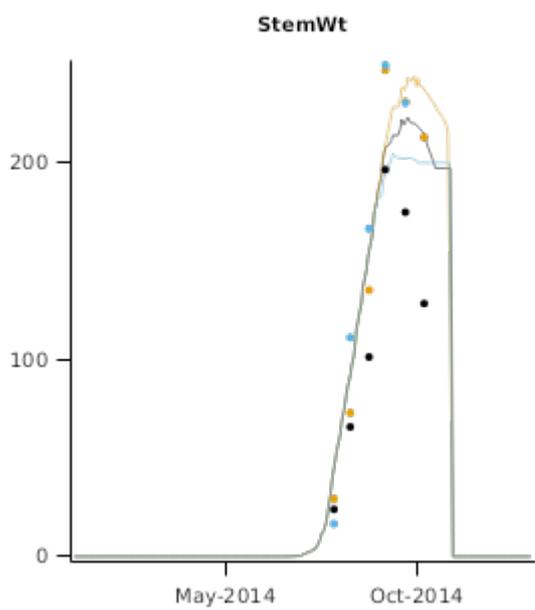
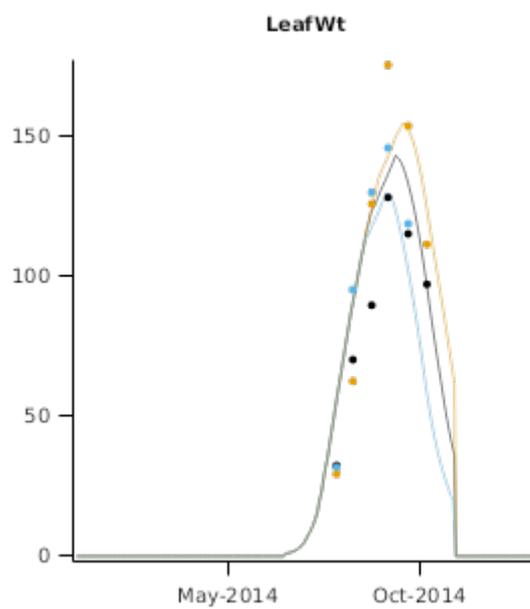
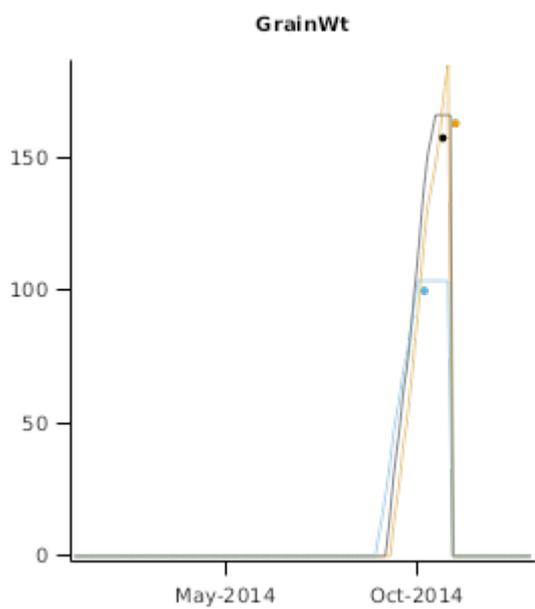
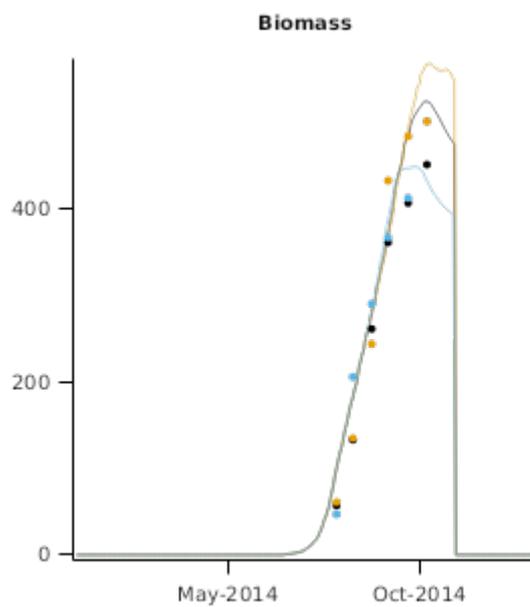
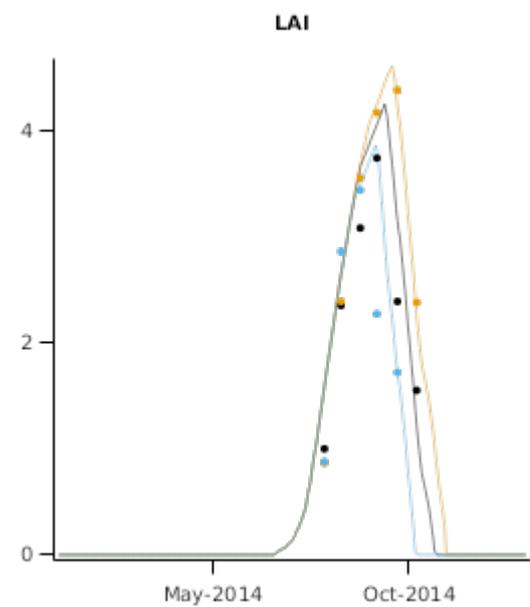
### 2.5.1 Yaan

These data [Wu2019] were obtained from a field experiment conducted in 2014–2016 on a Purple clay loam(XI-Luvic Xerosols, FAO classification) at Sichuan Agricultural University, Yaan, China. Three soybean cultivars (Jiuyuehuang,Nandou12, and Texuan13 belonging to maturity group [MG] 5-7 ) were sown on 15 Jun 2014, 18 Jun 2015, and 18 Jun 2016.

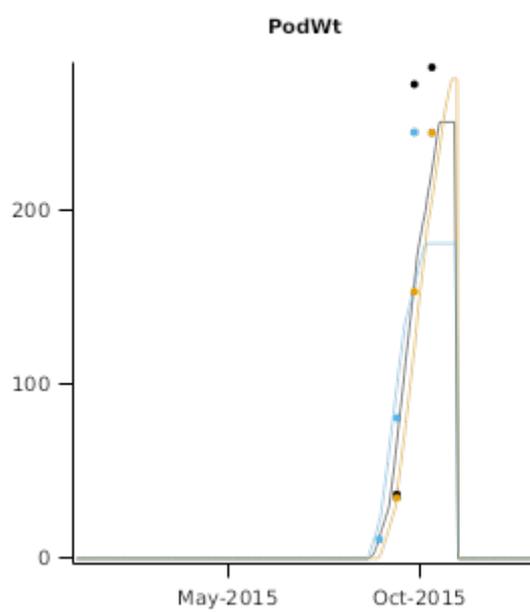
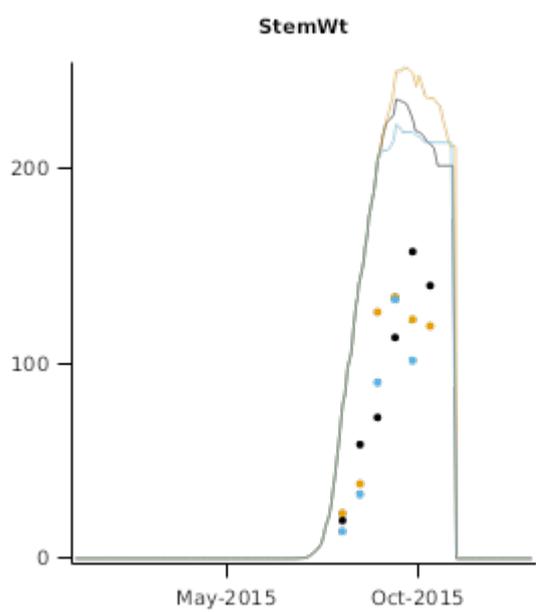
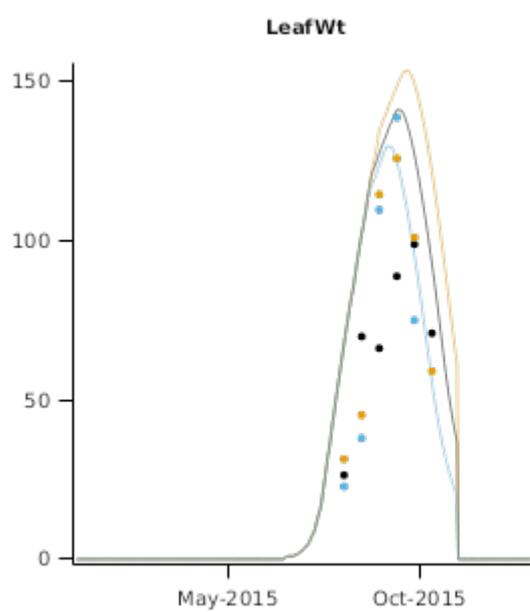
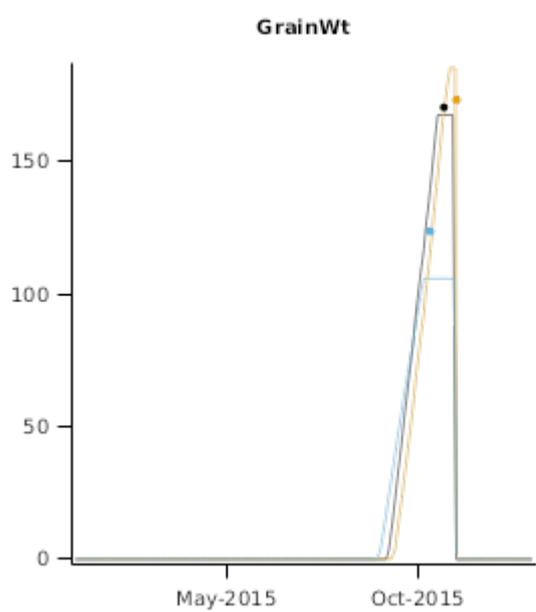
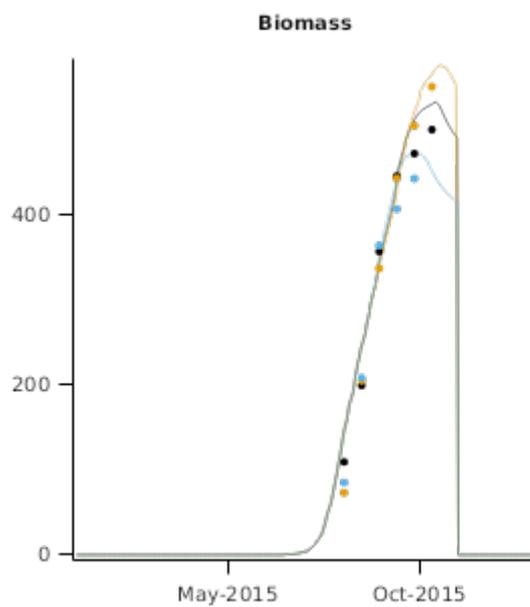
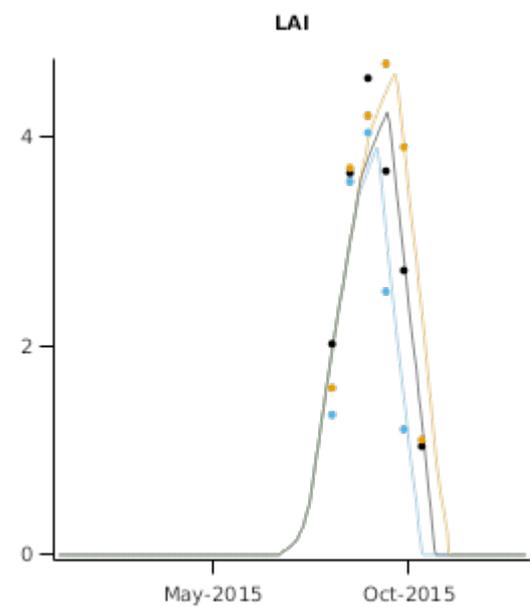
#### 2.5.1.1 List of experiments

Experiment Name	Design (Number of Treatments)
Yaan2014	Cv (3)
Yaan2015	Cv (3)
Yaan2016	Cv (3)

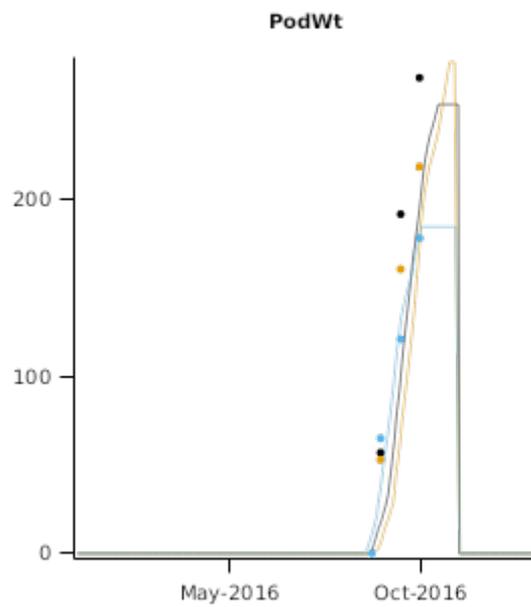
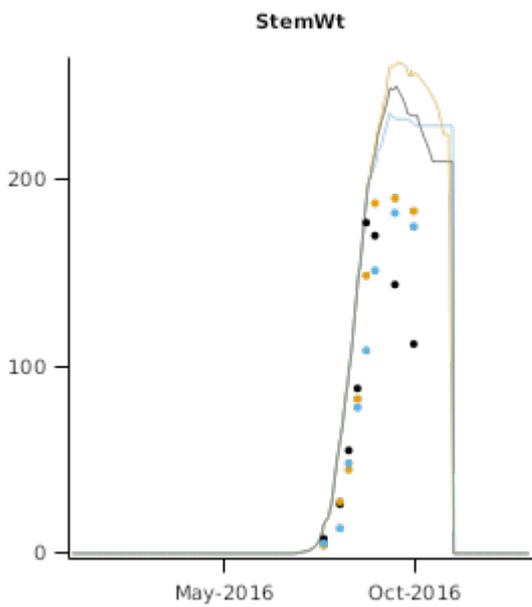
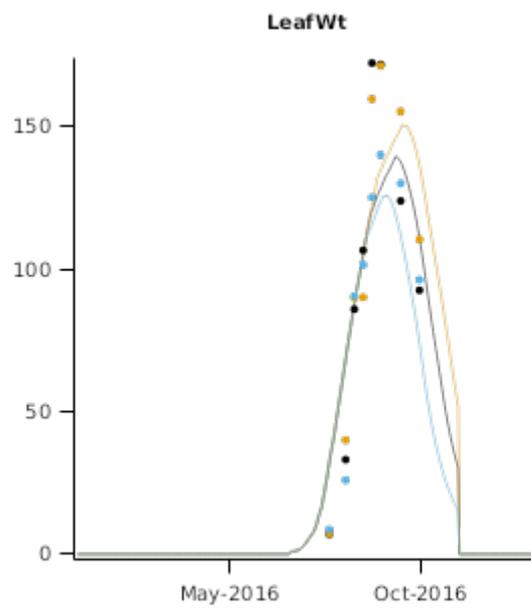
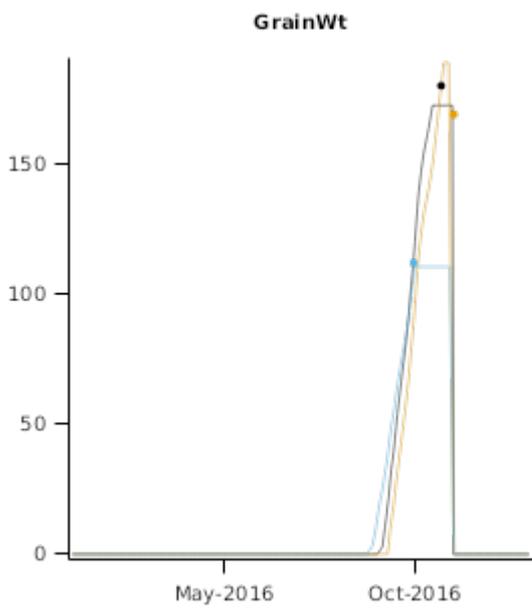
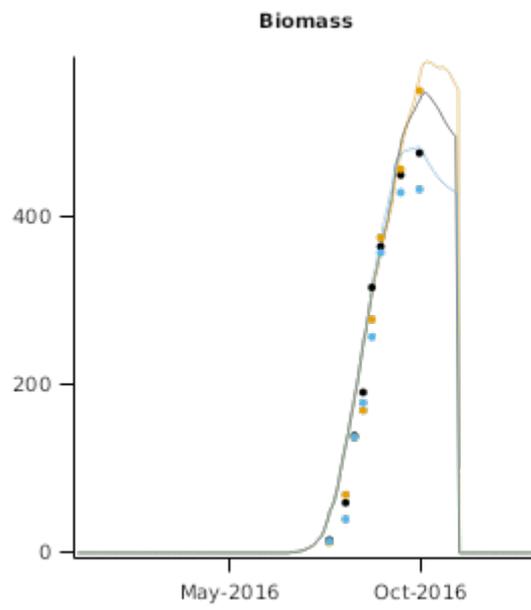
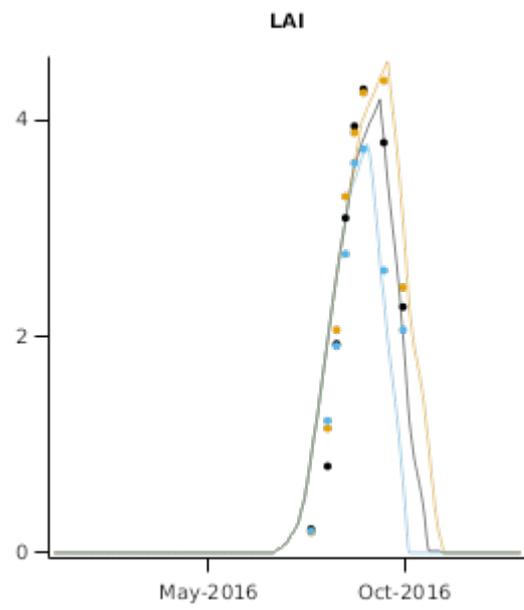
#### 2.5.1.2 Yaan2014



**2.5.1.3 Yaan2015**

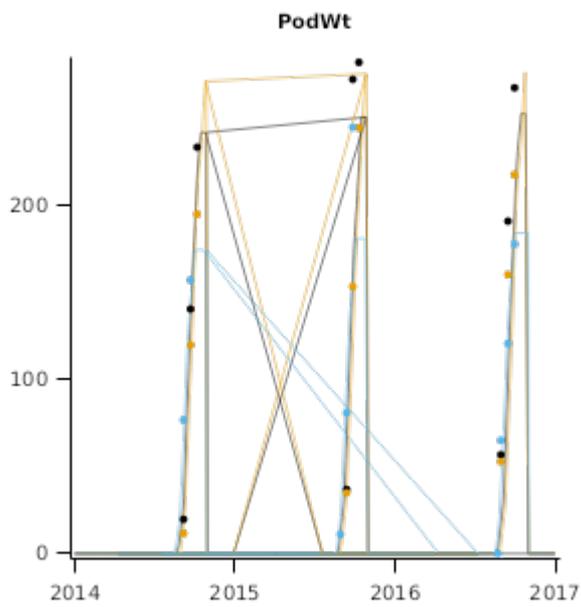
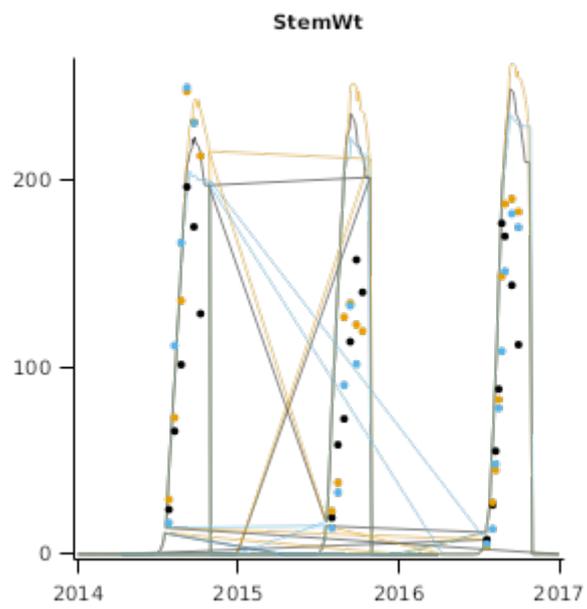
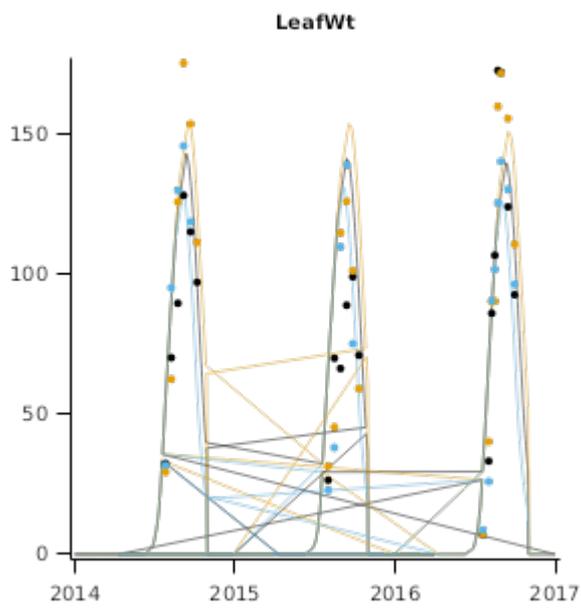
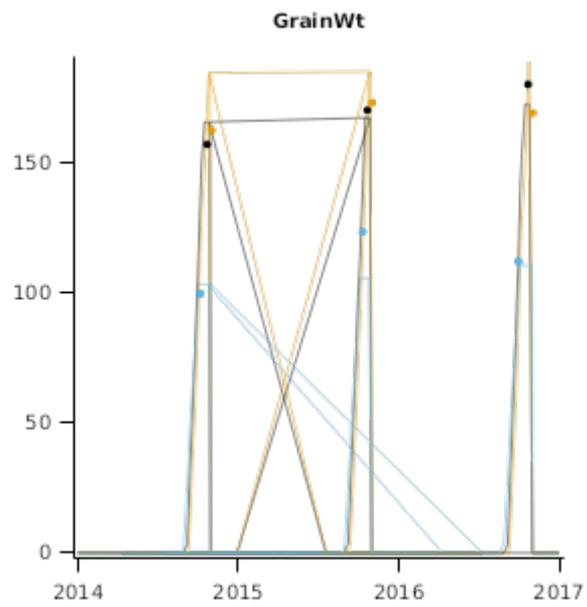
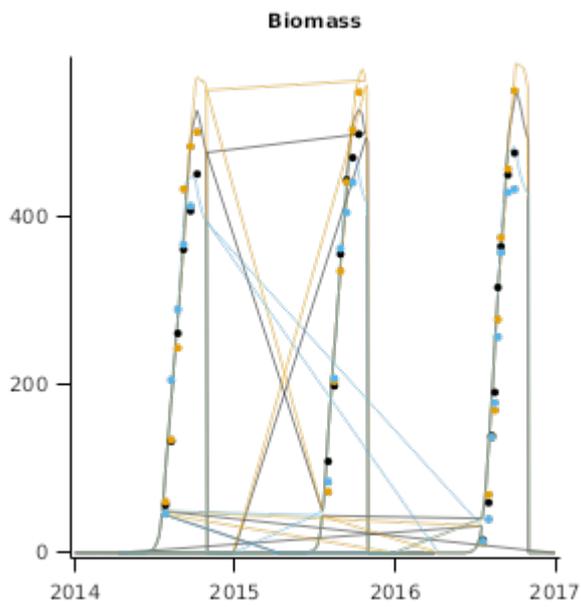


**2.5.1.4 Yaan2016**

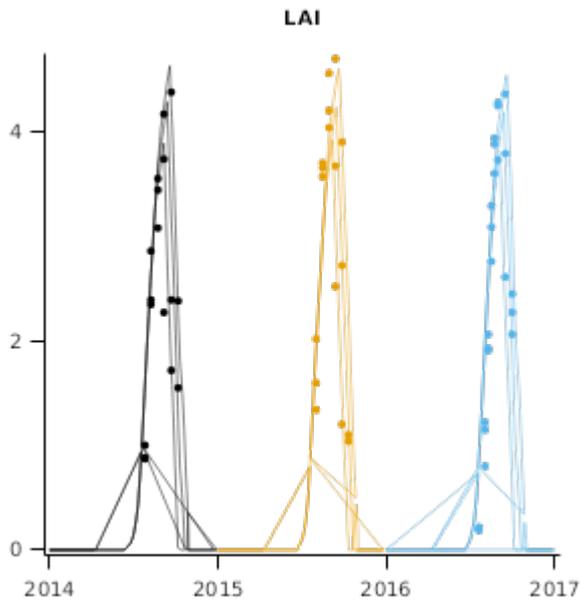


## 2.5.1.5 Graphs

### 2.5.1.5.1 Biomass



**2.5.1.5.2 Canopy**



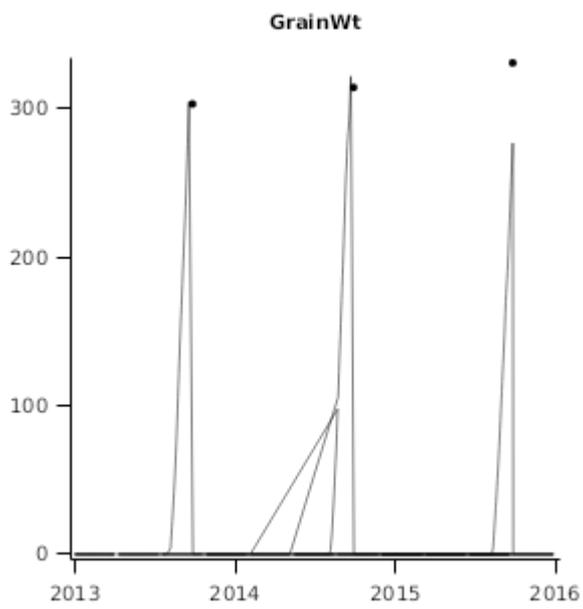
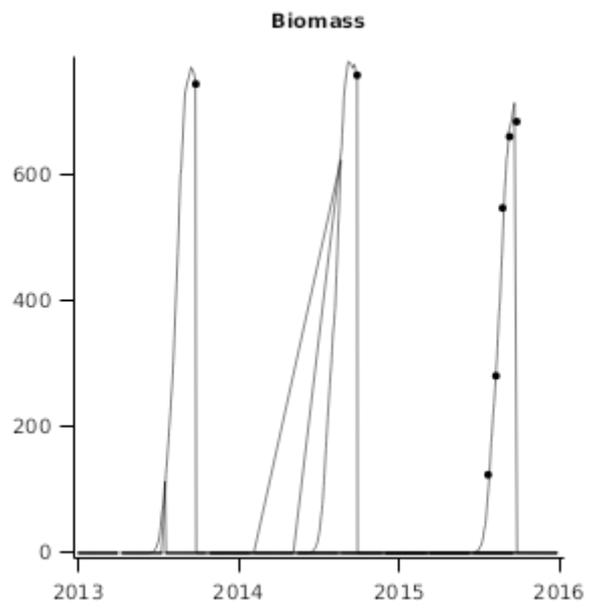
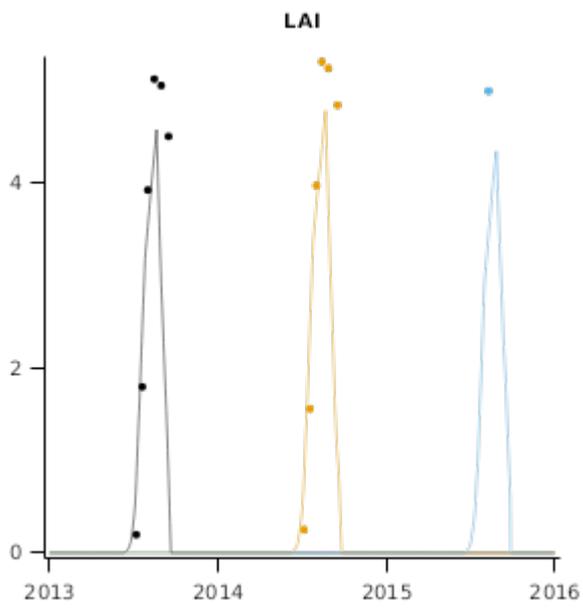
## 2.5.2 Heze

These data [Wu2019] were obtained from a field experiment conducted in 2013–2015 on sandy loam (J-Fluvisols, FAO classification) in the surface 0.5 m, changing to loam at depth with a deep soil profile (> 2 m) in Heze city, China. One soybean cultivar (Hedou19 belonging to maturity group [MG]3) were sown on 15 Jun 2014, 18 Jun 2015, and 18 Jun 2016.

### 2.5.2.1 List of experiments

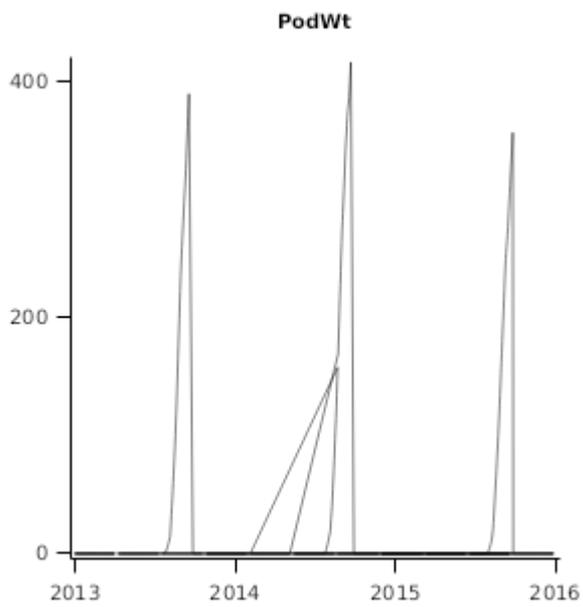
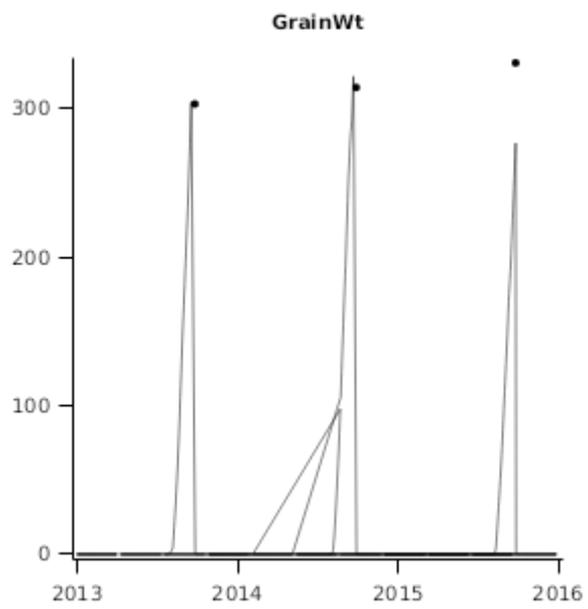
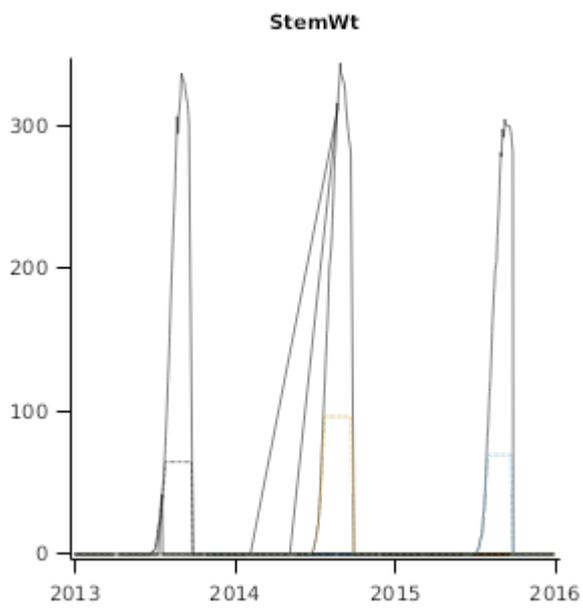
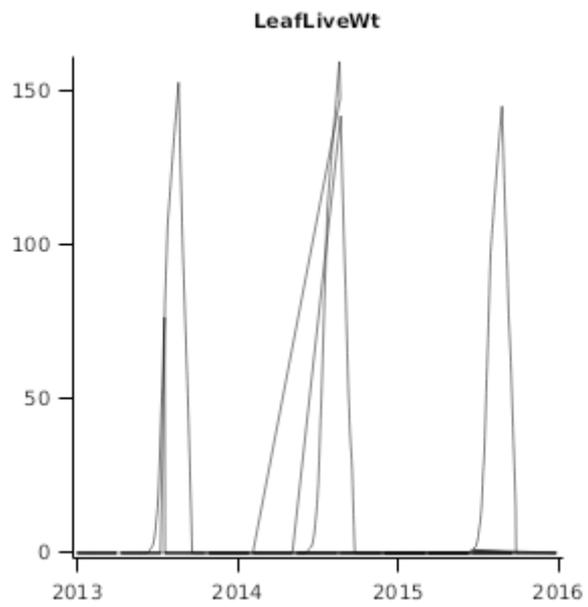
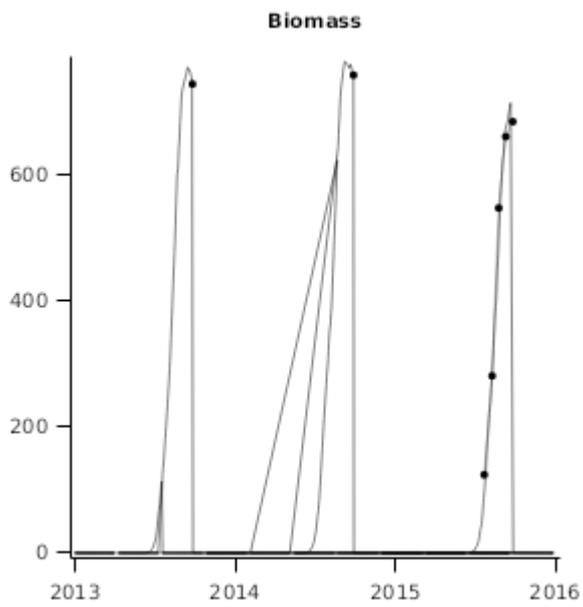
Experiment Name	Design (Number of Treatments)
Hedou19	Sow (3)

### 2.5.2.2 Hedou19



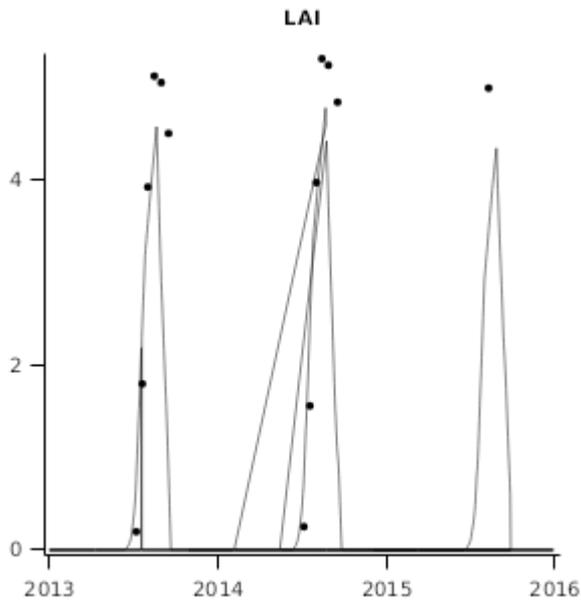
## 2.5.2.3 Graphs

### 2.5.2.3.1 Biomass



**HarvestIndex**

**2.5.2.3.2 Canopy**



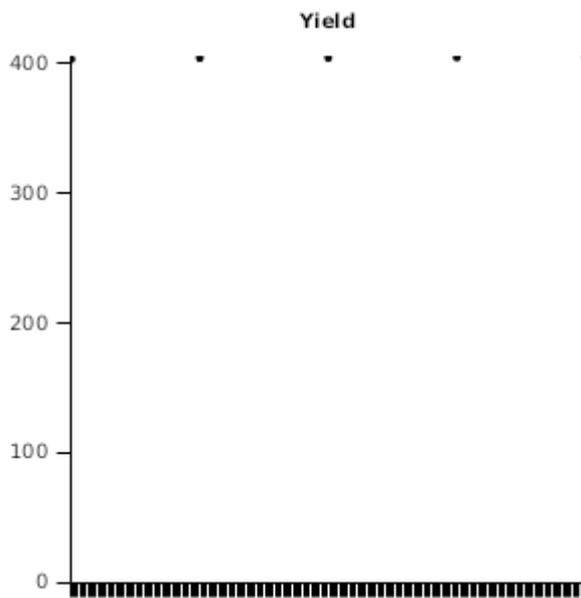
### 3 Sensibility

#### 3.1 FertiliserResponse

This sensibility test checks that Soybean yield response to N fertiliser is modest under normal field conditions. A simulation experiment has been constructed to simulate yield in Nebraska for different rates of N applied at sowing. Yield variation in response to this should be low.

##### 3.1.1 List of experiments

Experiment Name	Design (Number of Treatments)
FertiliserResponse	N (5)

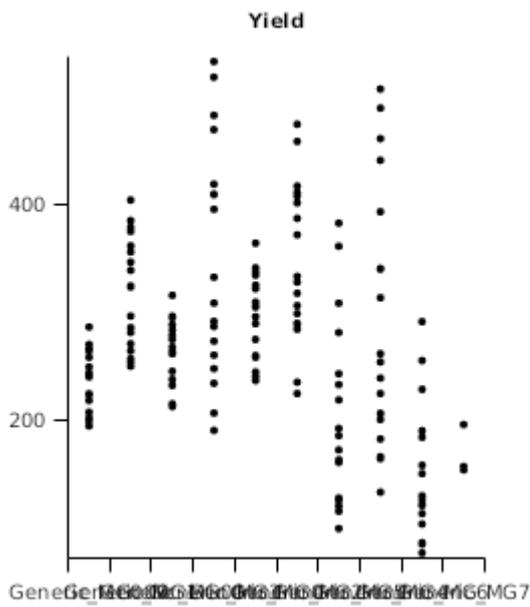


#### 3.2 MaturityGroups

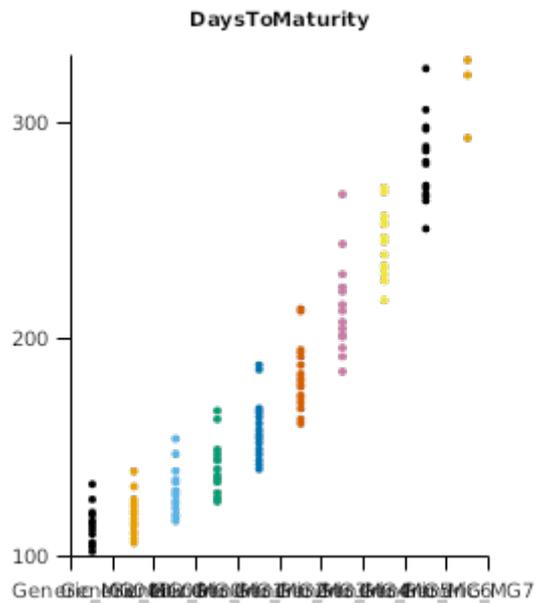
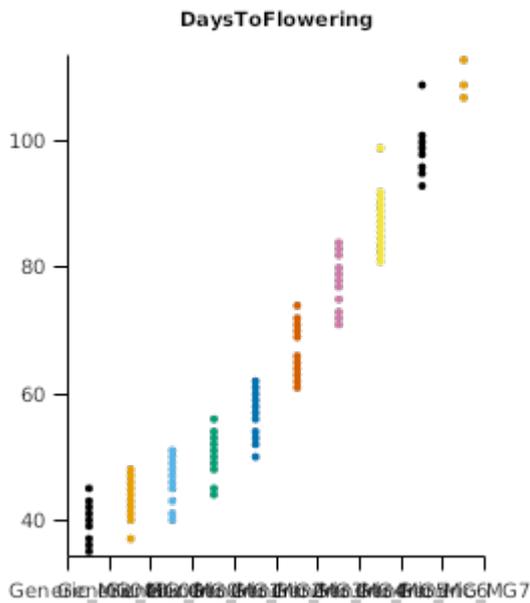
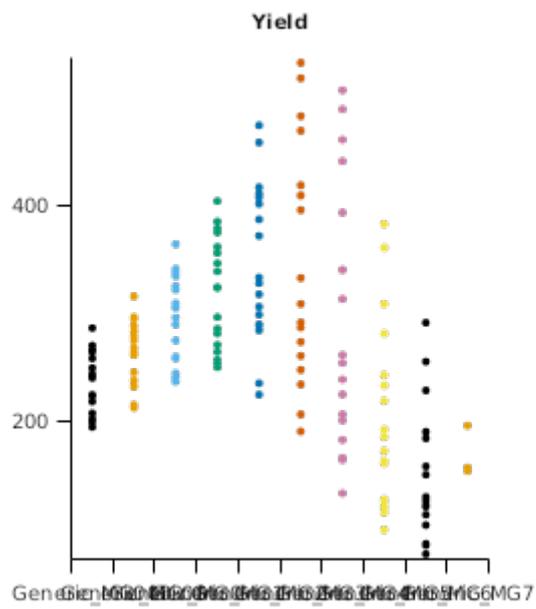
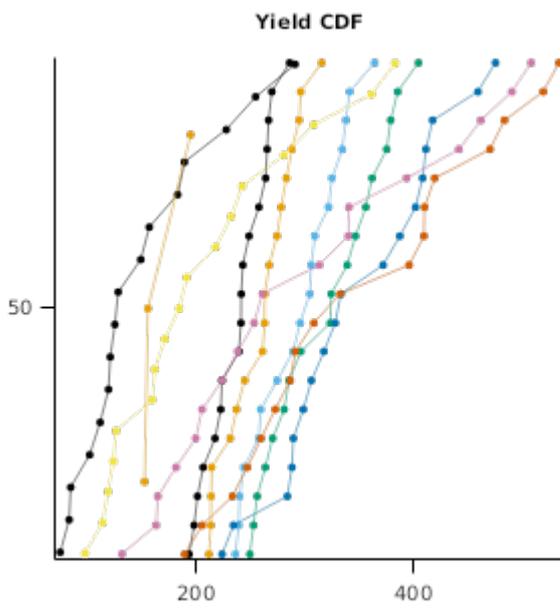
The optimum maturity class for soybean in Iowa should be approximately 2 to 3. Simulations are provided for the entire range of generic cultivars for several years at Ames, Iowa.

##### 3.2.1 List of experiments

Experiment Name	Design (Number of Treatments)
MaturityGroupslowa	Cv (13)



### 3.2.2 MaturityGroupslowa

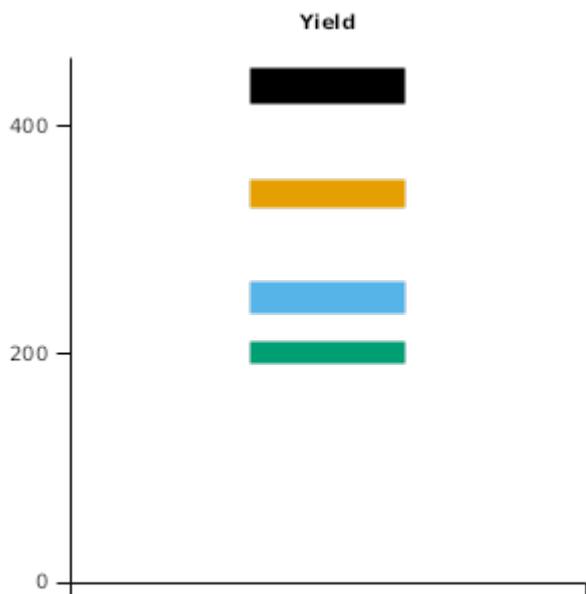


### 3.3 TimeOfSowing

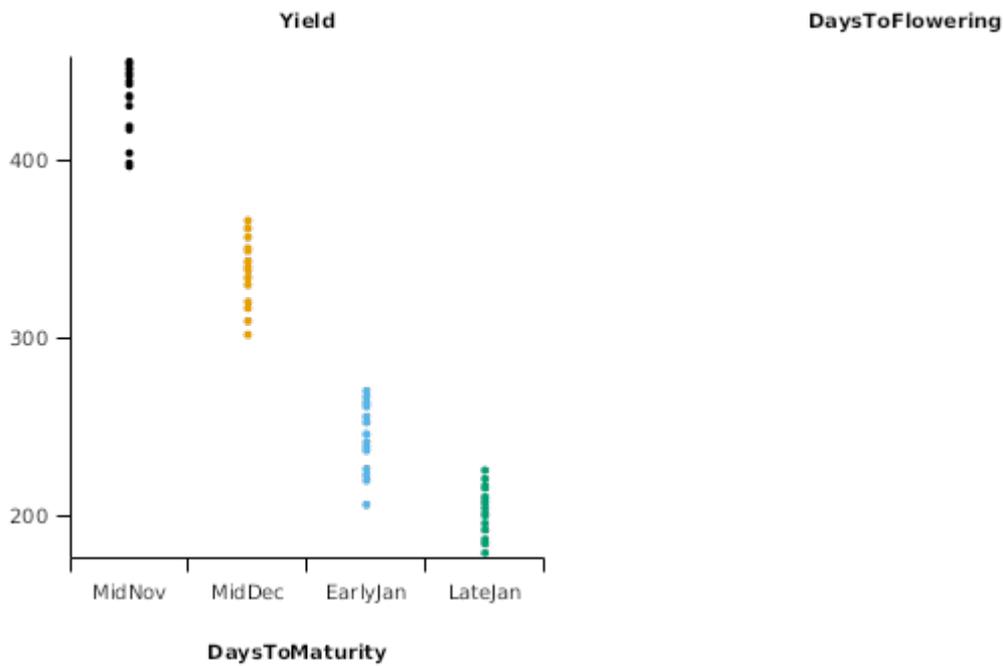
The data of [Gaynor et al., 2011](#) show that Soybean yield should be approximately 4t/ha for early sown soybean (Mid November) in the Australian Riverina region and decrease across the growing season to lower values (1.5-2t/ha) by late January.

### 3.3.1 List of experiments

Experiment Name	Design (Number of Treatments)
TimeOfSowingGriffith	TOS (4)



### 3.3.2 TimeOfSowingGriffith



### 3.4 DetailedDynamics

#### 3.4.1 List of experiments

Experiment Name	Design (Number of Treatments)
DetailedDynamics	Sow (1)

## 4 References

Archontoulis, S. V., Miguez, F. E., Moore, K. J., 2014. A methodology and an optimization tool to calibrate phenology of short-day species included in the APSIM PLANT model: Application to soybean. *Environmental Modelling & Software* 62, 465 - 477.

Brown, Hamish E., Huth, Neil I., Holzworth, Dean P., Teixeira, Edmar I., Zyskowski, Rob F., Hargreaves, John N. G., Moot, Derrick J., 2014. Plant Modelling Framework: Software for building and running crop models on the APSIM platform. *Environmental Modelling and Software* 62, 385-398.

Edwards, J.T., Purcell, L.C., 2005. Soybean yield and biomass responses to increasing plant population among diverse maturity groups: I. Agronomic characteristics. *Crop Science* 45, 1770–1777.

Gaynor, L.G., Lawn, R.J., James, A.T., 2011. Agronomic studies on irrigated soybean in southern New South Wales. I. Phenological adaptation of genotypes to sowing date. *Crop & Pasture Science* 62, 1056–1066.

Muchow, R.C., Robertson, M.J., Pengelly, B.C., 1993. Accumulation and partitioning of biomass and nitrogen by soybean, mungbean and cowpea under contrasting environmental conditions. *Field Crop Research* 33, 13–36.

- Muchow, R.C., Sinclair, T.R., 1986. Agronomic studies on irrigated soybean in southern New South Wales. I. Phenological adaptation of genotypes to sowing date. *Field Crops Research* 15, 143-156.
- Robinson, A.P., Conley, S.P., Volenec, J.J., Santini, J.B., 2009. Analysis of high yielding, early-planted soybean in Indiana. *Agronomy Journal* 101, 131–139.
- Salvagiotti, F., Specht, J.E., Cassman, K.G., Walters, D.T., Weis, A., Dobermann, A., 2009. Growth and N fixation in high yielding soybean: impact if N fertilization. *Agronomy Journal* 101, 958-970.
- Timsina, J., Boote, K.J., Duffield, S., 2007. Evaluating the CROPGRO Soybean Model for Predicting Impacts of Insect Defoliation and Depodding. *Agronomy Journal* 99, 148–157.
- Zhang, L., Zhang, J., Kyei-Boahen, S., 2004. Developing phenological prediction tables for soybean.. *Crop Management*.