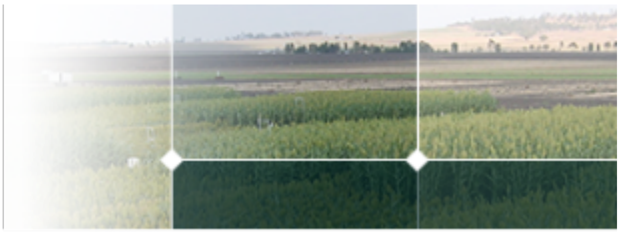

1 The APSIM Wheat Model

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.

Brown, H.E., Huth, N.I. and Holzworth, D.P.

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The wheat model consists of:

* a phenology model to simulate development through sequential developmental 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

This work builds upon earlier APSIM Wheat models such as NWheat (S Asseng et al., 2002, BA Keating, 2001), NWheatS (S Asseng et al., 1998), Cropmod-Wheat (Wang et al., 2002), and the earlier versions developed in Plant (APSIM Wheat 7.5") and then within the Plant Modelling Framework (Brown et al., 2014).

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

1.1 Plant Model Components

Component Name	Component Type
Arbitrator	Models.PMF.OrganArbitrator
Phenology	Models.PMF.Phen.Phenology
Structure	Models.PMF.Struct.Structure
Grain	Models.PMF.Organs.ReproductiveOrgan
Root	Models.PMF.Organs.Root
Leaf	Models.PMF.Organs.Leaf
Spike	Models.PMF.Organs.GenericOrgan
Stem	Models.PMF.Organs.GenericOrgan
MortalityRate	Models.Functions.Constant
SeedMortalityRate	Models.Functions.Constant

1.2 Composite Biomass

Component Name	Component Type
AboveGround	Models.PMF.CompositeBiomass
AboveGroundLive	Models.PMF.CompositeBiomass
AboveGroundDead	Models.PMF.CompositeBiomass
BelowGround	Models.PMF.CompositeBiomass
Total	Models.PMF.CompositeBiomass
TotalLive	Models.PMF.CompositeBiomass
TotalDead	Models.PMF.CompositeBiomass
Ear	Models.PMF.CompositeBiomass
StemPlusSpike	Models.PMF.CompositeBiomass

1.3 Cultivars

Cultivar Name	Alternative Name(s)
Amarok	Amarok
BattenWinter	BattenWinter
BattenSpring	BattenSpring
Claire	Claire
Conquest	Conquest
CRWT153	CRWT153
Discovery	Discovery
Exceed	Exceed
Option	Option
Otane	Otane
Regency	Regency
Robigus	Robigus
Rongotea	Rongotea
Sage	Sage
Saracen	Saracen
Solstice	Solstice
Tribute	Tribute
Wakanui	Wakanui
Voltron	Voltron
Sorrial	Sorrial
Cesario	Cesario
Stockade	Stockade
CRW247	CRW247

Cultivar Name	Alternative Name(s)
Zyatt	Zyatt
Graham	Graham
Kerrin	Kerrin
Axe	Axe
Bolac	Bolac
Cunningham	Cunningham
Derrimut	Derrimut
Gregory	Gregory
Gamenya	Gamenya
Gauntlet	Gauntlet
Gladius	Gladius
Gutha	Gutha
H45	H45
H46	H46
Hartog	Hartog
Wills	Wills
Mercury	Mercury
Batavia	Batavia
Egret	Egret
Janz	Janz
Kellalac	Kellalac
Kennedy	Kennedy
Lang	Lang
Livingston	Livingston
Lincoln	Lincoln
Mace	Mace
MacKellar	MacKellar
Matong	Matong
McCubbin	McCubbin
Ruby	Ruby
Spear	Spear
Sunbri	Sunbri
Sunco	Sunco
Ventura	Ventura

Cultivar Name	Alternative Name(s)
Eaglehawk	Eaglehawk
Wedgetail	Wedgetail
Wilgoyne	Wilgoyne
Wyalkatchem	Wyalkatchem
Yitpi	Yitpi
Young	Young
Scepter	Scepter
Cutlass	Cutlass
Longsword	Longsword
CSIROW007	CSIROW007
CSIROW023	CSIROW023
CSIROW073	CSIROW073
Konya	Konya
Keyu13	Keyu13
Yecora	Yecora
Rex	Rex
Nugaines	Nugaines
Hyslop	Hyslop
Stephens	Stephens
Dekan	Dekan
Rosario	Rosario
Ararat	Ararat
Tybalt	Tybalt
HAR1685	HAR1685
Gorgan	Gorgan
Adv08_0008	Adv08_0008
Bennett	Bennett
Scythe	Scythe
Beaufort	Beaufort
Braewood	Braewood
Calingiri	Calingiri
Catalina	Catalina
Condo	Condo
Crusader	Crusader

Cultivar Name	Alternative Name(s)
CSIROW002	CSIROW002
CSIROW003	CSIROW003
CSIROW005	CSIROW005
CSIROW011	CSIROW011
CSIROW018	CSIROW018
CSIROW021	CSIROW021
CSIROW027	CSIROW027
CSIROW029	CSIROW029
CSIROW077	CSIROW077
CSIROW087	CSIROW087
CSIROW102	CSIROW102
CSIROW105	CSIROW105
Hume	Hume
Ellison	Ellison
Emu_Rock	Emu_Rock
Forrest	Forrest
Grenade	Grenade
Kittyhawk	Kittyhawk
Lancer	Lancer
Nighthawk	Nighthawk
Magenta	Magenta
Manning	Manning
Merinda	Merinda
Mitch	Mitch
Ouyen	Ouyen
Peake	Peake
Revenue	Revenue
Rosella	Rosella
Scout	Scout
Spitfire	Spitfire,Drysdale
Strzelecki	Strzelecki
Sunbee	Sunbee
Sunlamb	Sunlamb
Sunstate	Sunstate

Cultivar Name	Alternative Name(s)
Suntop	Suntop
Trojan	Trojan
Illabo	Illabo
Whistler	Whistler
Suneca	Suneca

1.4 Child Components

1.4.1 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 DoPotentialDMAllocation() 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, DoActualDMAllocation 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.

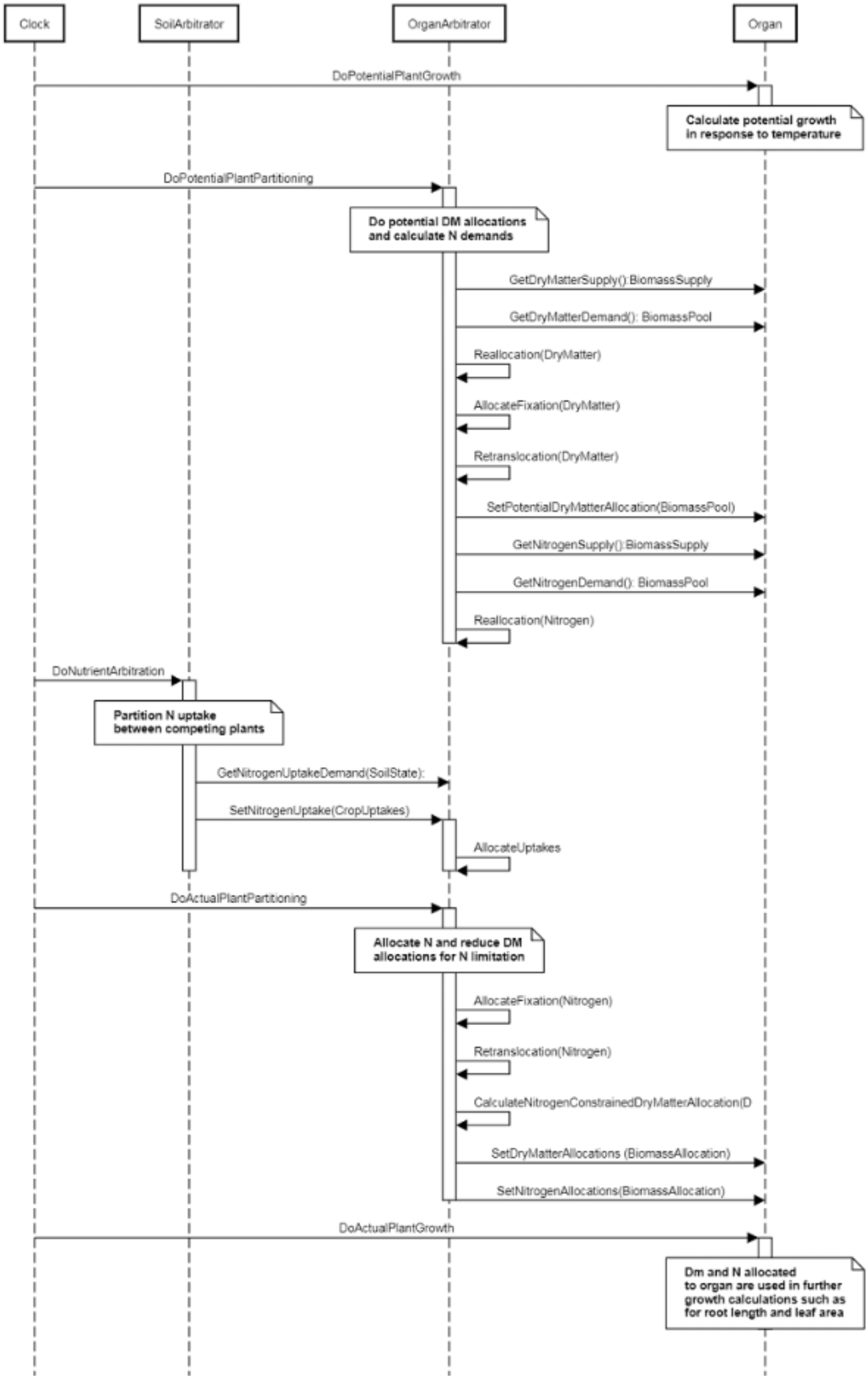


Figure 1: Schematic showing the procedure for arbitration of biomass partitioning. Pink boxes represent events that occur every day and their numbering shows the order of calculations. Blue boxes represent the methods that are called when these events occur. Orange boxes contain properties that make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

1.4.2 Phenology

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

Wheat exhibits a range of developmental responses to environment and these are strongly influenced by genotype characteristics. Temperature is the primary driver of development, increasing development rates and decreasing phase durations as it increases. These affects are captured by thermal time. However, wheat also exhibits cold and photoperiod sensitivities in its Vernalisaing phase and further photoperiod sensitivity in the SpikeletDifferenation and HeadEmergence phases. Photoperiod responses are seen as a reduction in the length of a phase for a photoperiod sensitive genotype in response to a longer photoperiod. Vernalisation responses are more complicated as they are driven by cool temperature but interact with photoperiod. For vernalisation sensitive varieties (Winter types), exposure to cool temperatures and/or short photoperiods during the Vernalising phase may reduce its thermal time duration.

APSIM wheat implements the Cereal Anthesis Molecular Phenology (CAMP) model to simulate development. It is based on the Kirby Framework which assumes the timing of anthesis is a result of the timing of flag leaf and an additional thermal time passage from there to heading then anthesis. It also assumes the timing of flag leaf is a result of the Final Leaf Number (which sets a target) and leaf appearance rate (which sets the rate of progress toward the target). Leaf appearance rate is a function of Thermal time and a genotype specific Phyllochron which changes with Haun stage as described by Jamieson et al., 1995.

Final Leaf Number (FLN) is set on the day that terminal spikelet occurs as:

FLN = 2.85 + 1.1 * TSHS

Where TSHS is the Haun stage on the day terminal spikelet stage occurs. Terminal spikelet is at the end of the SpikeletDifferentaiation phase which is preceeded by the Emerging and Vernalising phases. The mechanisums for progress through each of these phase are described below

1.4.3 Structure

The structure model simulates morphological development of the plant to inform the Leaf class when and how many leaves and branches appear and provides an estimate of height.

1.4.4 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).

1.4.5 Root

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

1.4.6 Leaf

The leaves are modelled as a set of leaf cohorts and the properties of each of these cohorts are summed to give overall values for the leaf organ.
A cohort represents all the leaves of a given main stem node position including all of the branch leaves appearing at the same time as the given main stem leaf (Lawless et al., 2005).
The number of leaves in each cohort is the product of the number of plants per m^2 and the number of branches per plant.
The *Structure* class models the appearance of main stem leaves and branches. Once cohorts are initiated the *Leaf* class models the area and biomass dynamics of each.
It is assumed all the leaves in each cohort have the same size and biomass properties. The modelling of the status and function of individual cohorts is delegated to *LeafCohort* classes.

1.4.7 Spike

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.

1.4.8 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.

1.4.9 MortalityRate

A constant function (name=value)

1.4.10 SeedMortalityRate

A constant function (name=value)

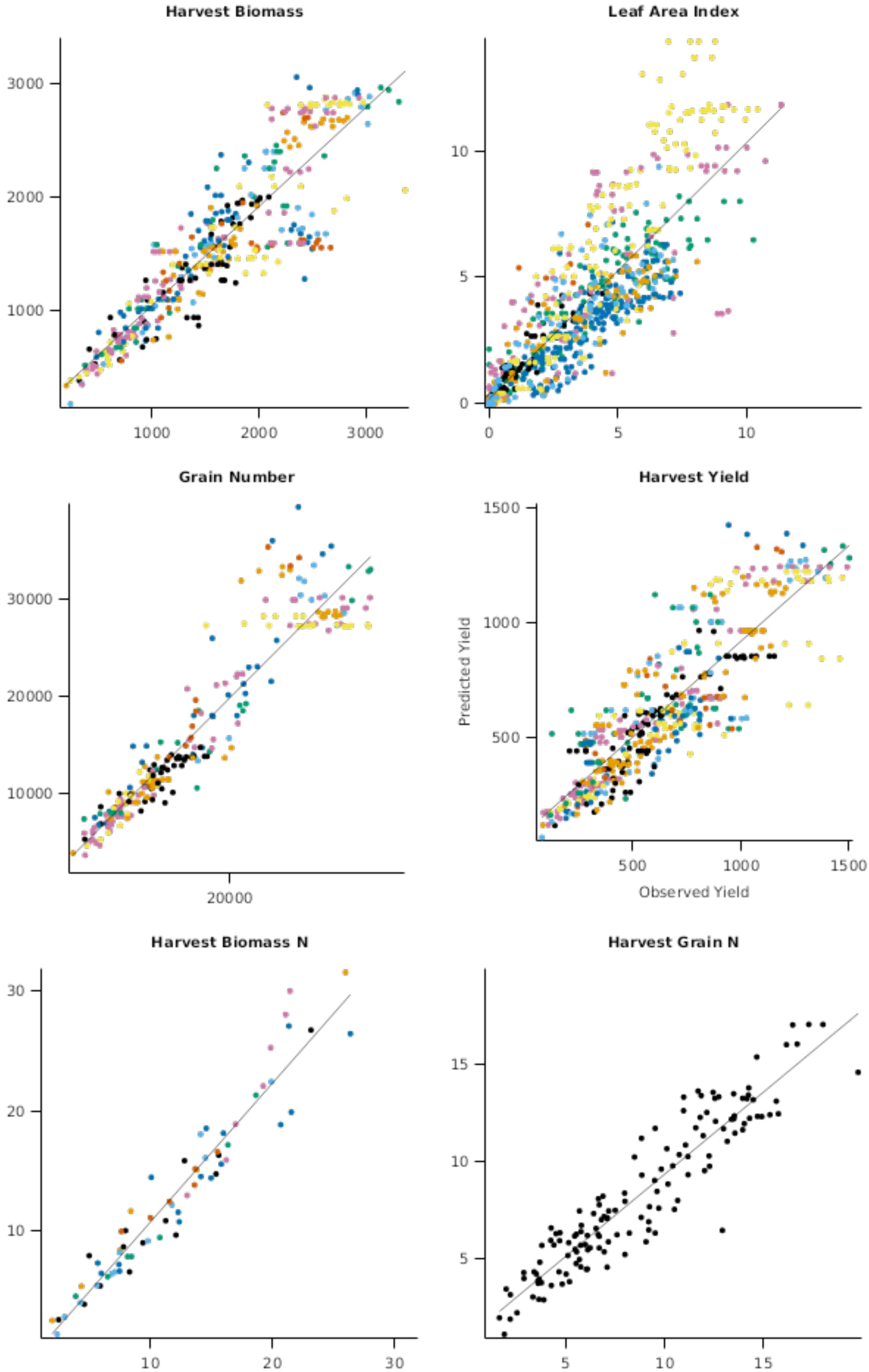
2 Validation

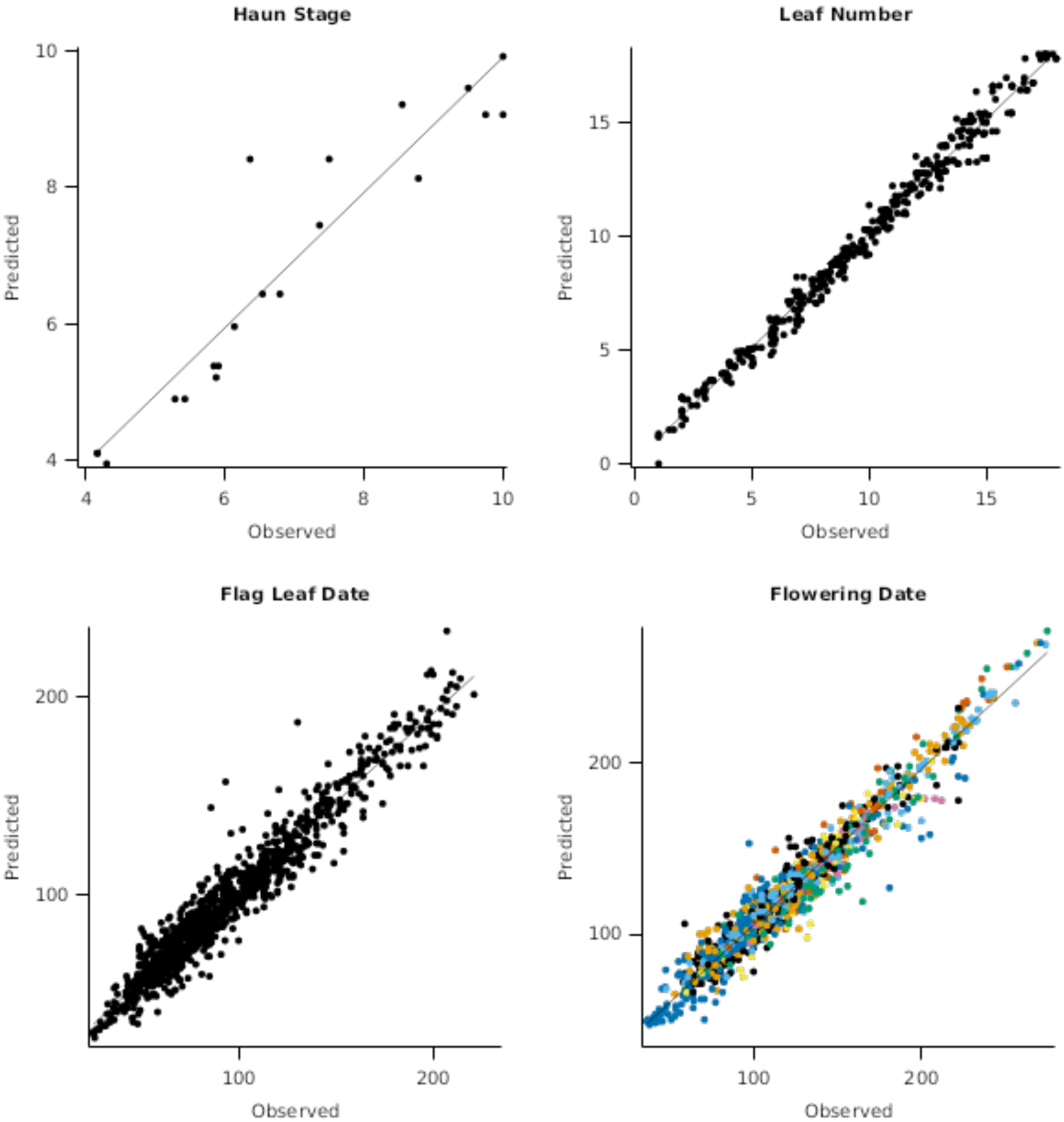
A test dataset has been developed to test the APSIM Wheat model for a range of environmental (soil and climate) conditions, management options (sowing dates, populations, nitrogen rates, row spacing, irrigation), genetic backgrounds (different regions, cultivar types) and for special considerations such as crop damage. These tests have been grouped into various geographical regions to allow the user to evaluate the suitability of the model for their particular region of interest. Graphs of model performance are provided for yield, biomass production, canopy development, phenological development, water and nitrogen uptake, and grain yield components.

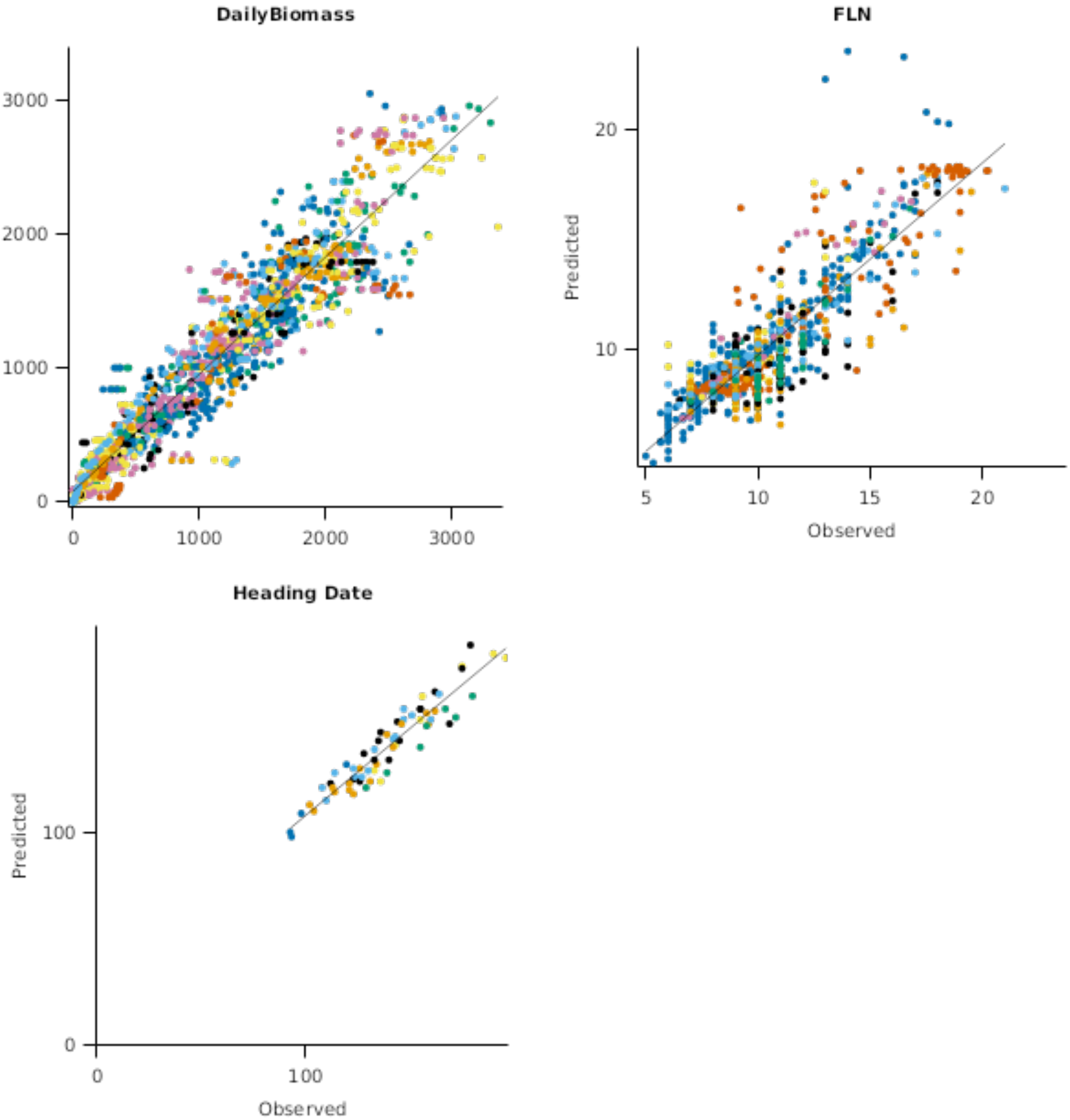
2.1 Map

2.2 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).


Harvest Biomass
1000
2000
3000
1000
2000
3000
Leaf Area Index
0
5
10
0
5
10
Grain Number
10000
20000
30000
20000
Harvest Yield
Predicted Yield
500
1000
1500
Observed Yield
500
1000
1500
Harvest Biomass N
10
20
30
10
20
30
Harvest Grain N
5
10
15
5
10
15


Haun Stage
Predicted
Observed
Leaf Number
Predicted
Observed
Flag Leaf Date
Predicted
Observed
Flowering Date
Predicted
Observed



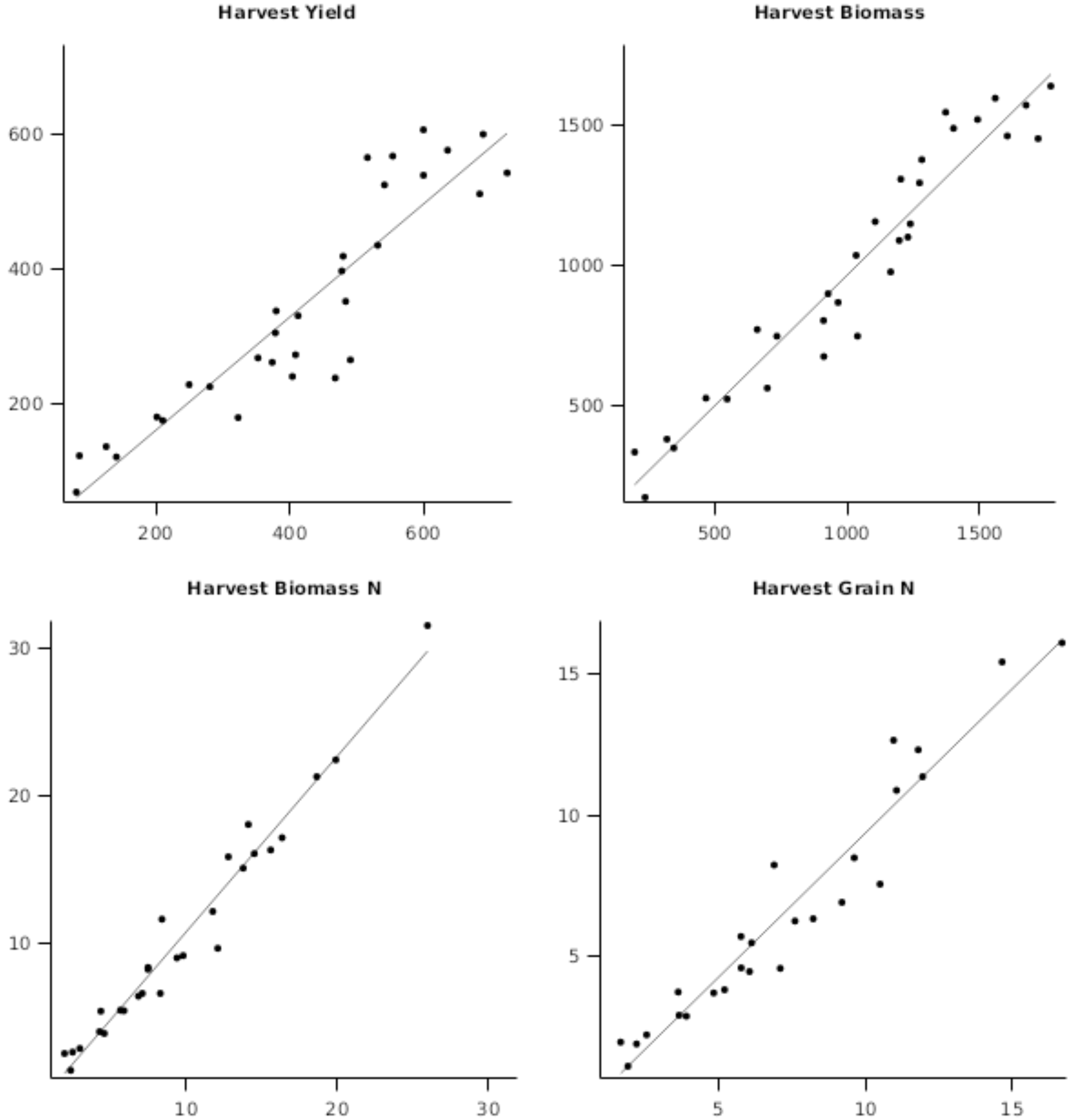
2.3 SE Queensland

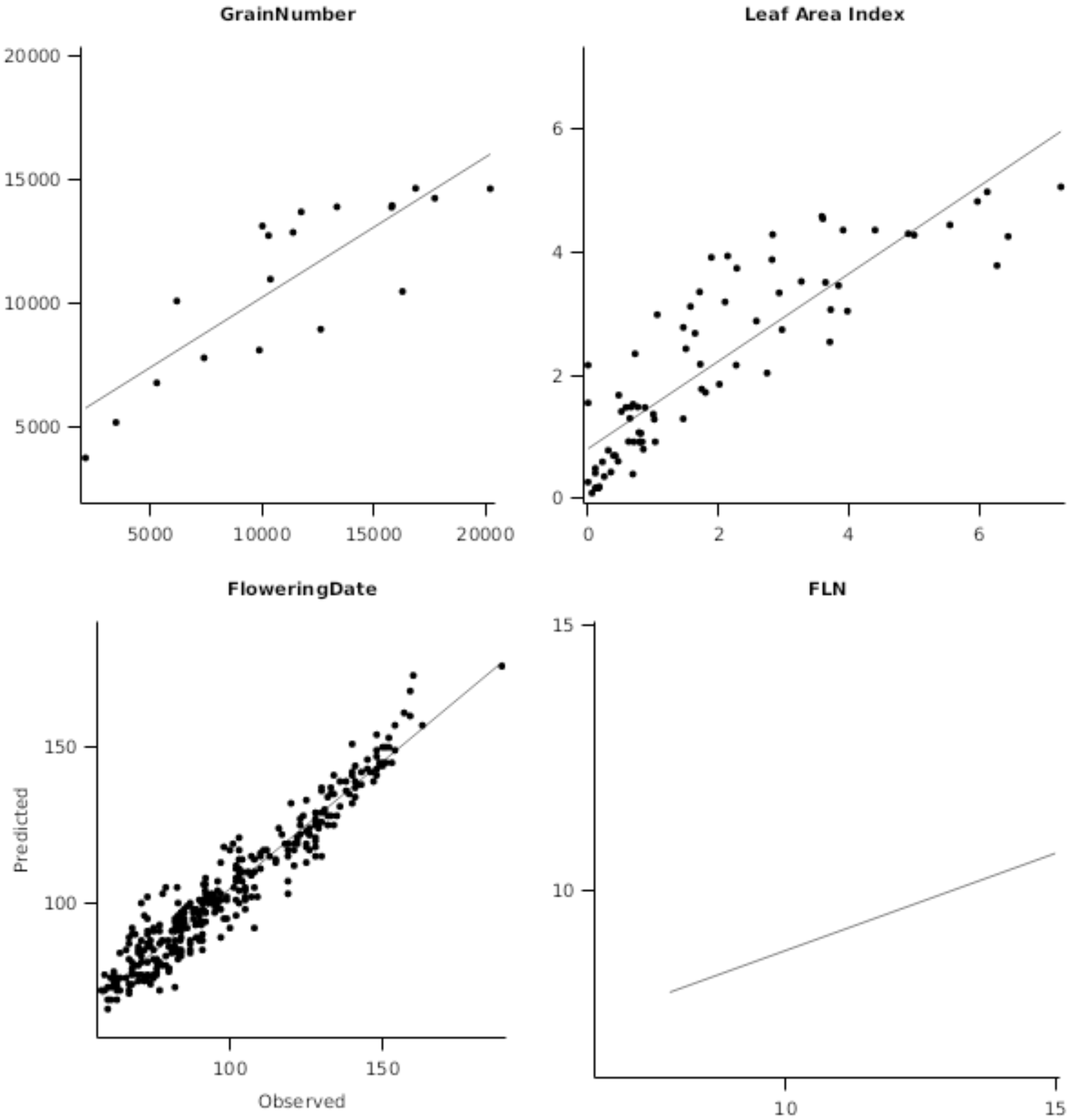
South-eastern Queensland has a warm subtropical environment. Daytime temperatures are moderate due to the relatively low latitudes for wheat growing in Australia, but inland continental conditions can provide cool nights with occaisional frosts. Many of the datasets used here have been published as part of previous APSIM Wheat model tests. Further datasets have been added to provide information on phenological development of modern cultivars.

2.3.1 List of experiments

Experiment Name	Design (Number of Treatments)
APS26	NRate x Water (8)
APS6	NRate (6)
APS14	Stubble x NRate (12)
APS2	TOS (2)
GattonRowSpacing	RowSpace (3)
Gatton94	Cv x TOS (12)
Gatton2009	TOS x Cv (48)

Experiment Name	Design (Number of Treatments)
Gatton2011	TOS x Cv (15)
Gatton2014	TOS x Cv (148)
Gatton2014AE	V x P x Cv (148)
TraitMod2015	TOS x Cv (10)
TraitMod2016	TOS x Cv (5)



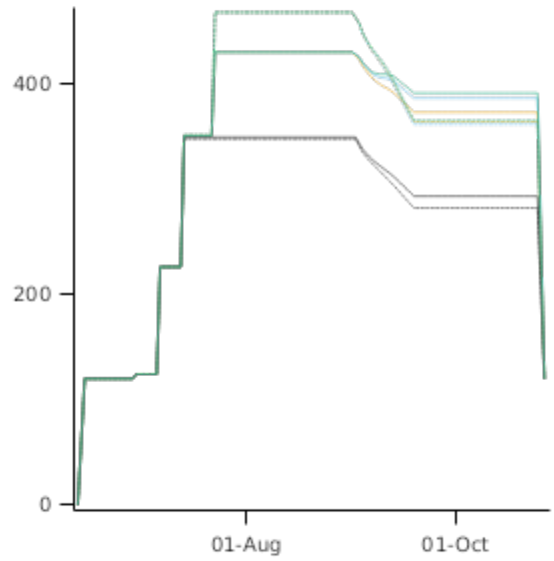


2.3.2 APS26

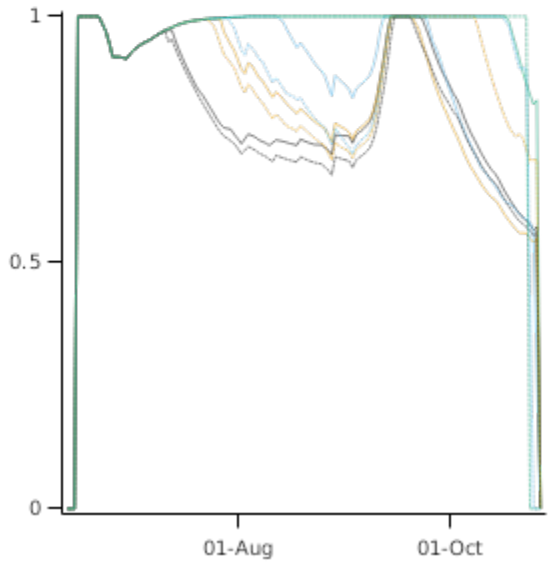
This trial was conducted at Gatton in 1995 using the local variety, Hartog. It consisted of 4 Nitrogen rates (0,40,80,160) with two irrigation rates (minimal amount for establishment, fully irrigated). Yields ranged from 1.4 t/ha to 5.4 t/ha.

FW photo

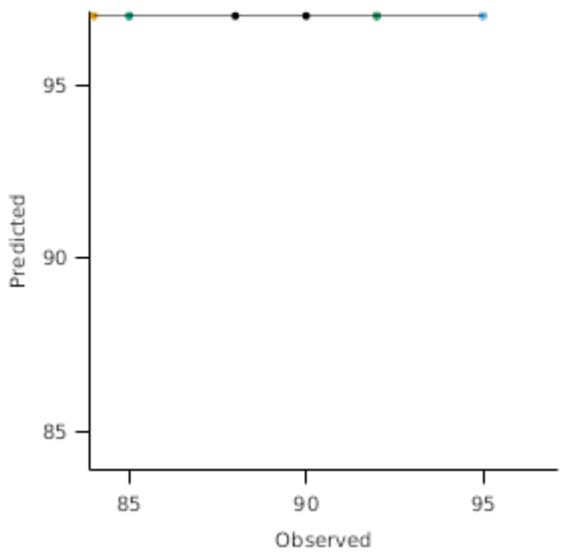
StemNumber



Leaf Fn

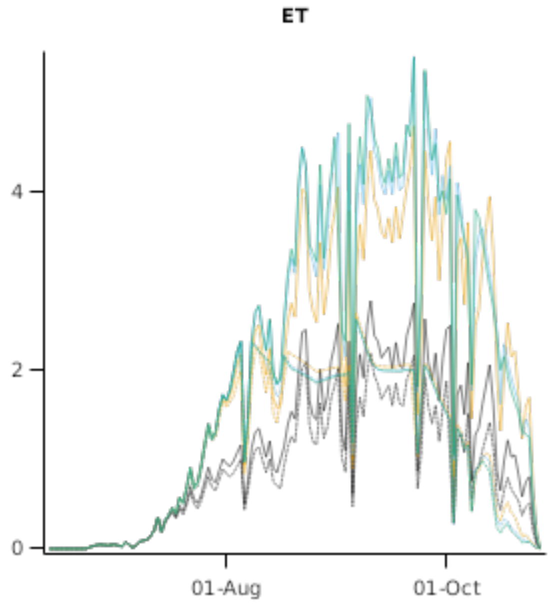


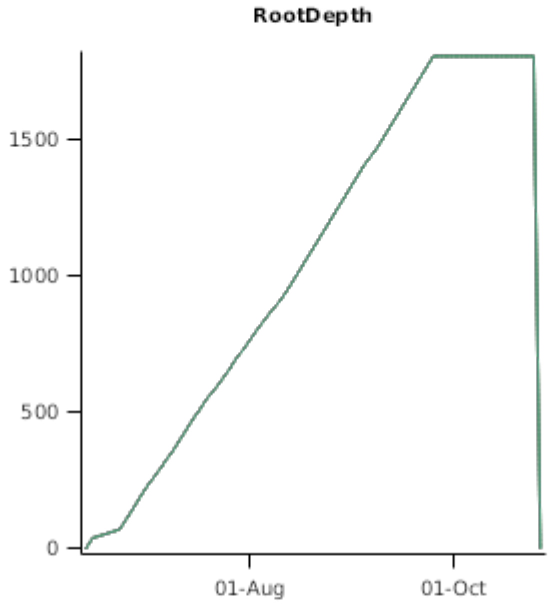
FloweringDate

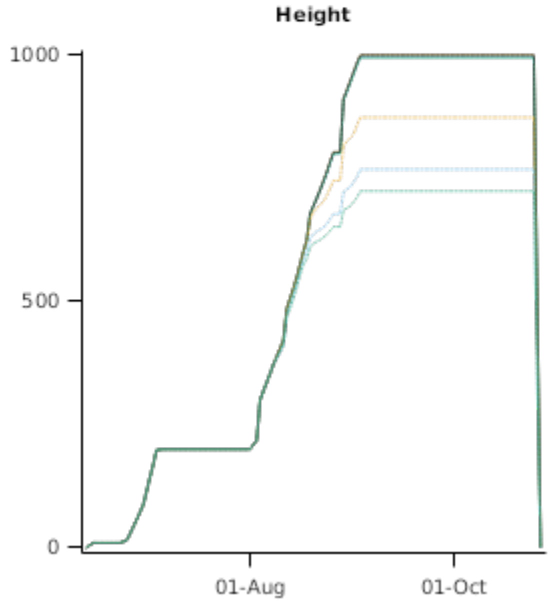


WaterPotential

C Supply and Demand



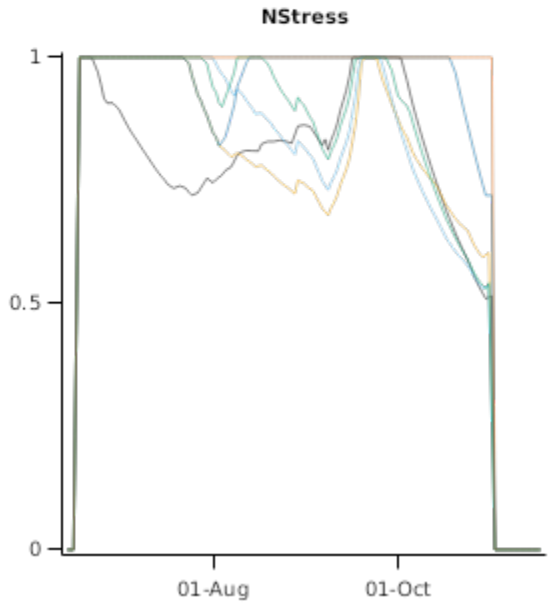




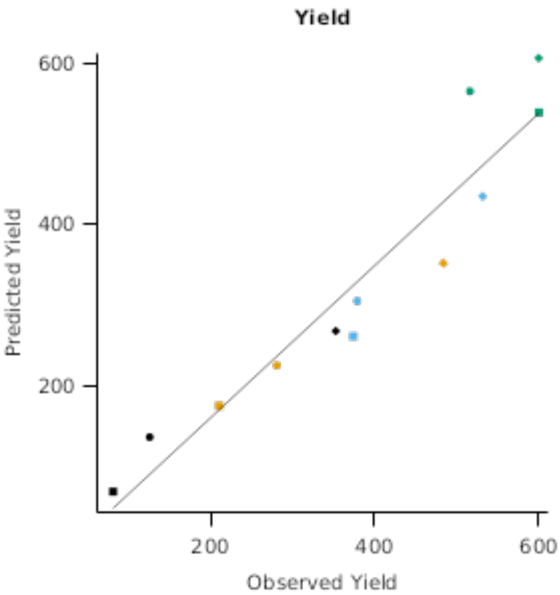
RootLengthDensity

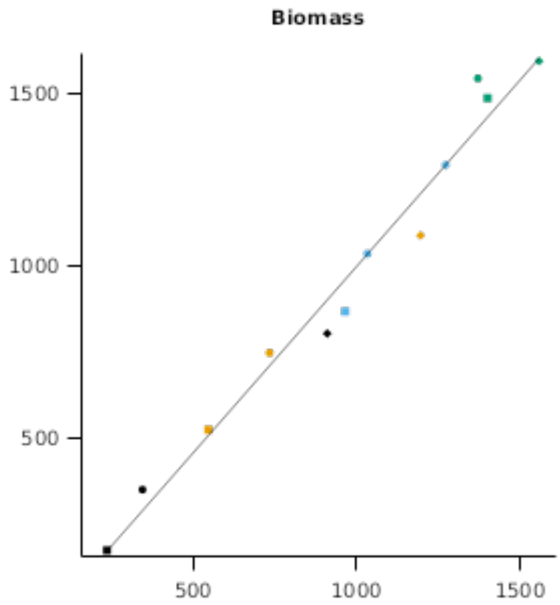
2.3.3 APS6

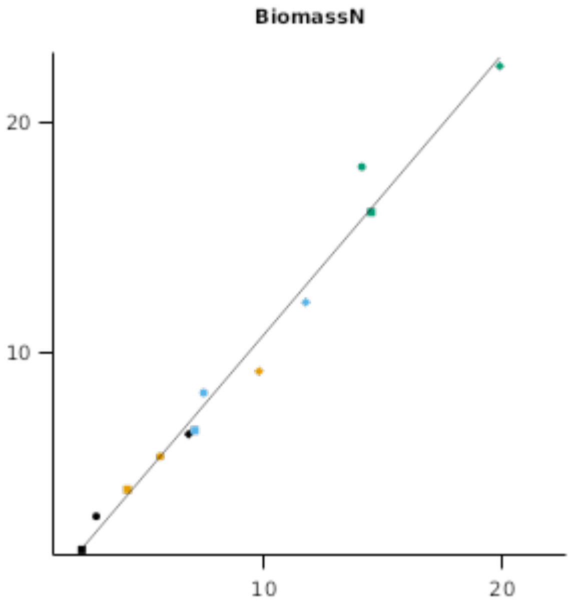
NOTE: High N treatment logdged. Final grain sizes were less than expected.



2.3.4 APS14

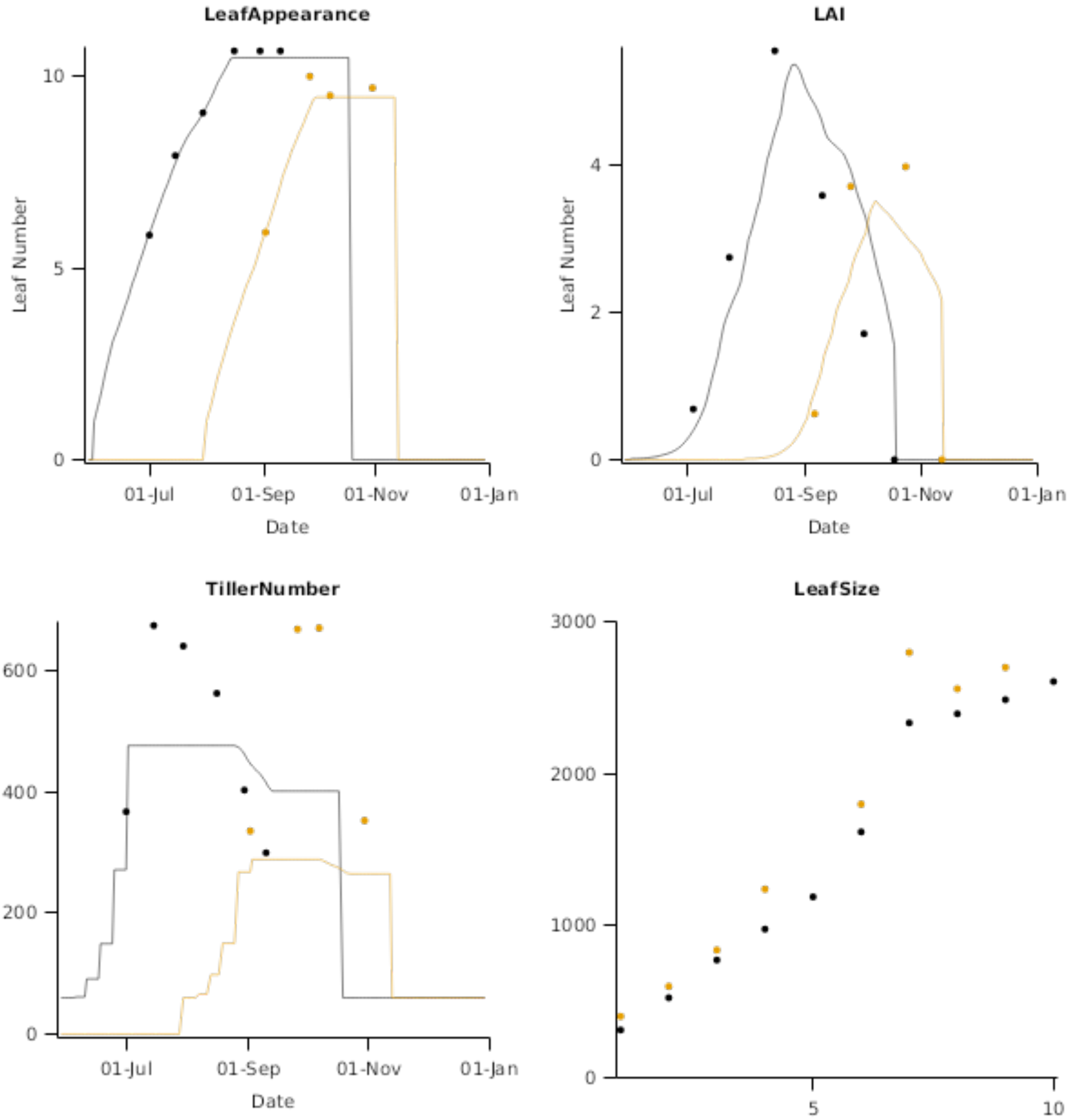






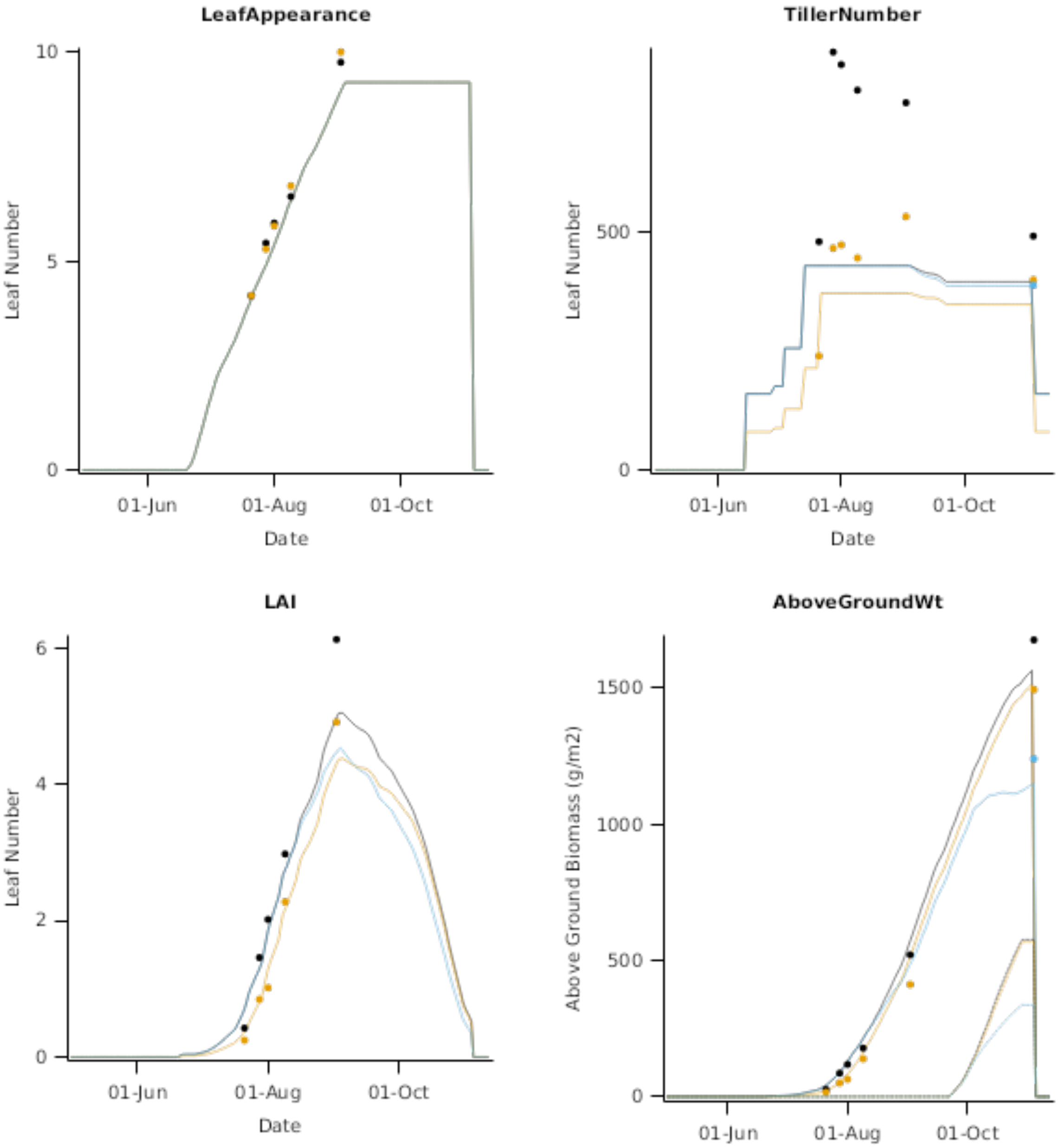
2.3.5 APS2

This simple experiment was conducted to investigate the impact of time of sowing on canopy development and growth of wheat. Wheat (cv. Hartog) was sown at Gatton on 30th of May and 30th of July in 1991. Data were collected on canopy development, biomass accumulation and yield.



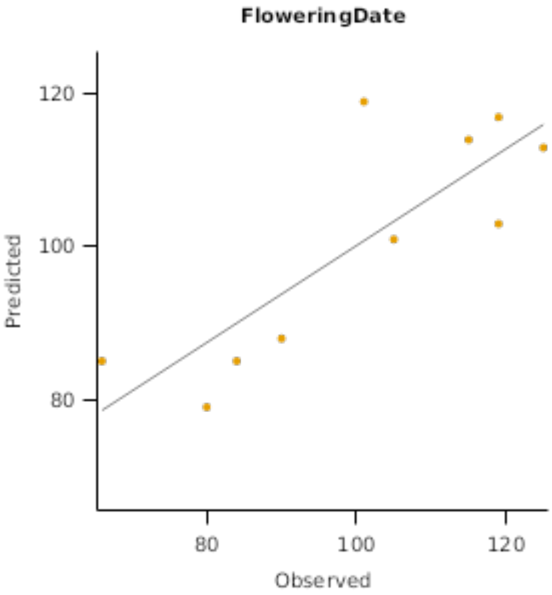
2.3.6 GattonRowSpacing

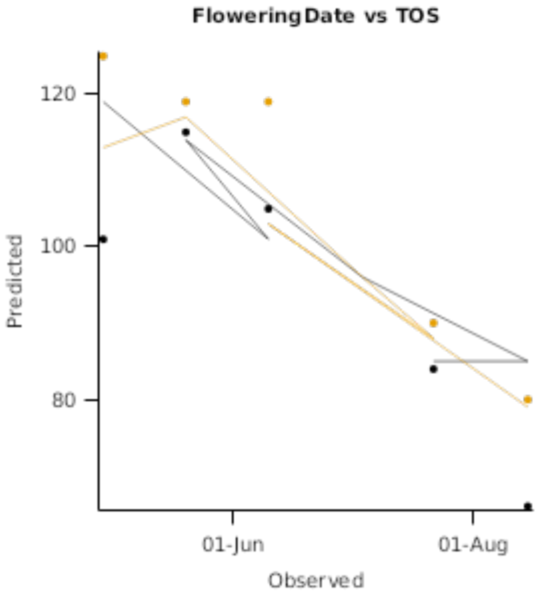
This simple experiment was conducted to investigate the light interception and subsequent growth of wheat under different populations invoked using row spacing. Wheat was sown at Gatton on 15th of June 2011 at 25cm row spacing. Soon after emergence, alternate rows were removed from selected plots to produce half populations at 50cm row spacing. A zero N treatment was used to identfy the inherent fertility of the site to assist in model parameterisation. Data were collected on light interception, canopy development, biomass accumulation and yield.



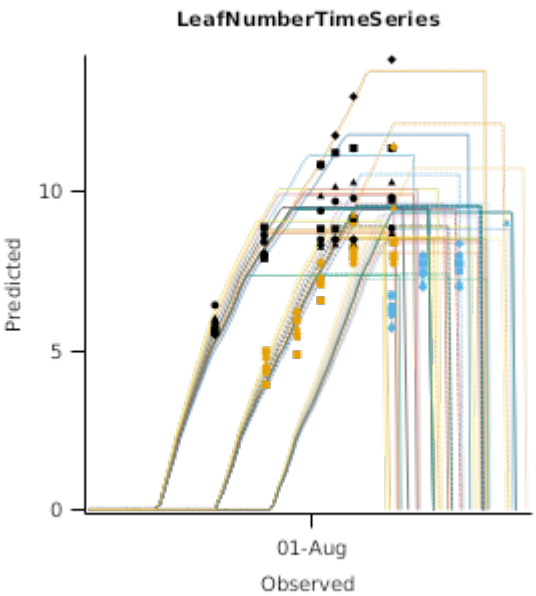
2.3.7 Gatton94

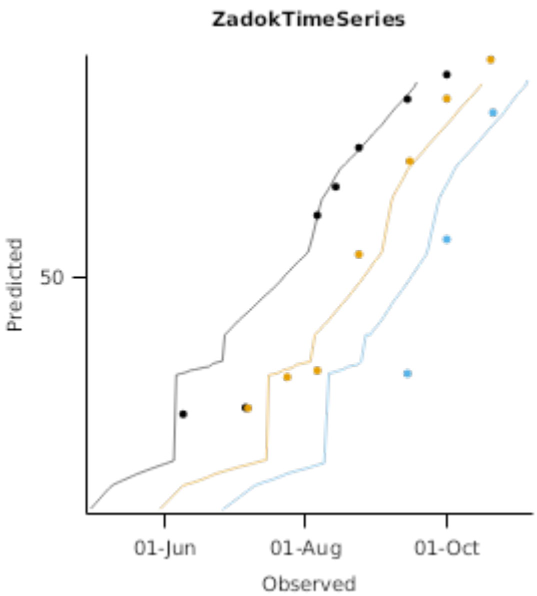
This simple experiment was conducted to investigate the impact of time of sowing on wheat. Wheat (cv. Hartog and Batavia) was sown at Gatton on six dates during 1994. Various data were collected. However final growth data was compromised by mouse damage. The dataset is used here to study the impact of sowing time on phenological development.





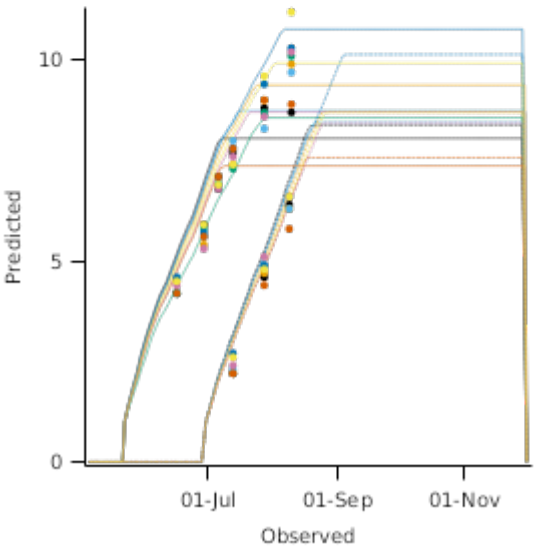
2.3.8 Gatton2009



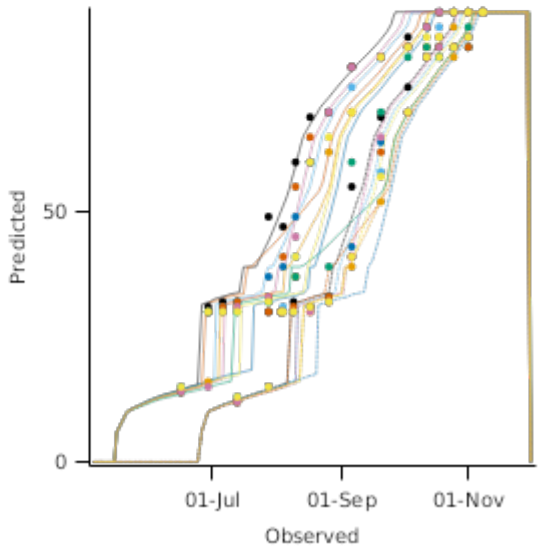


2.3.9 Gatton2011

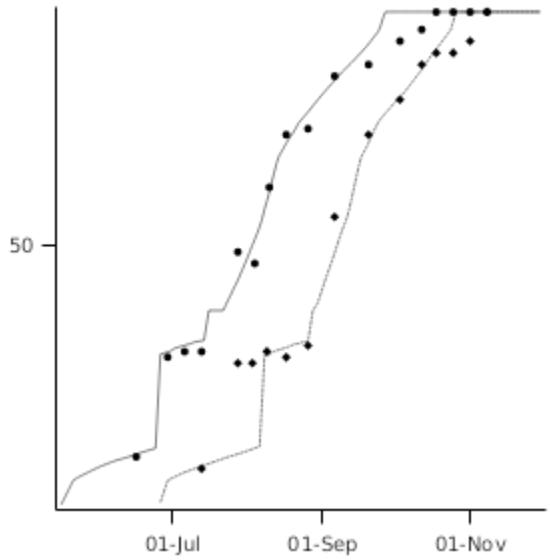
LeafNumberTimeSeries



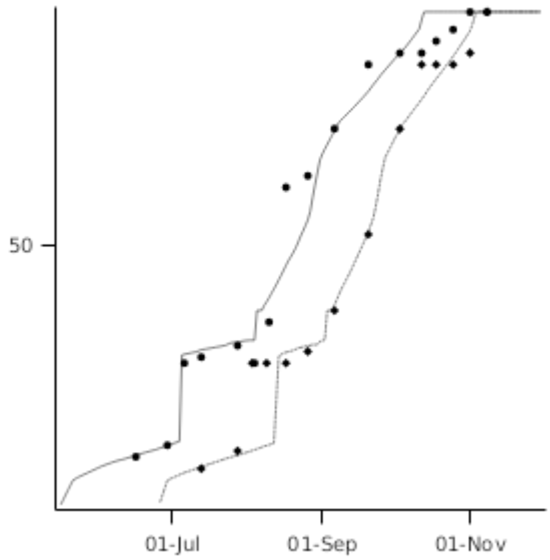
ZadokTimeSeries



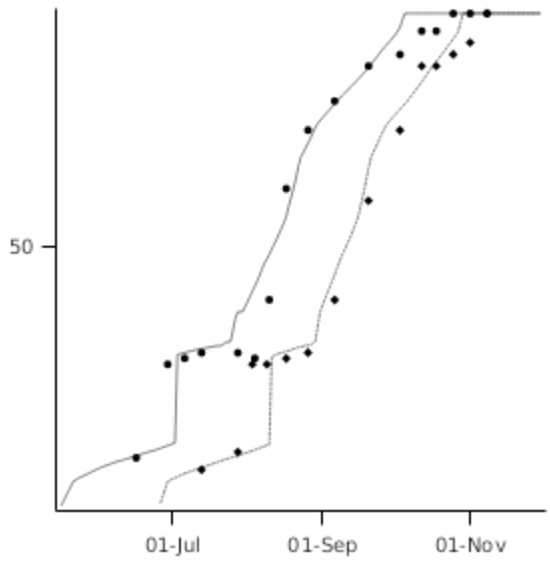
Axe



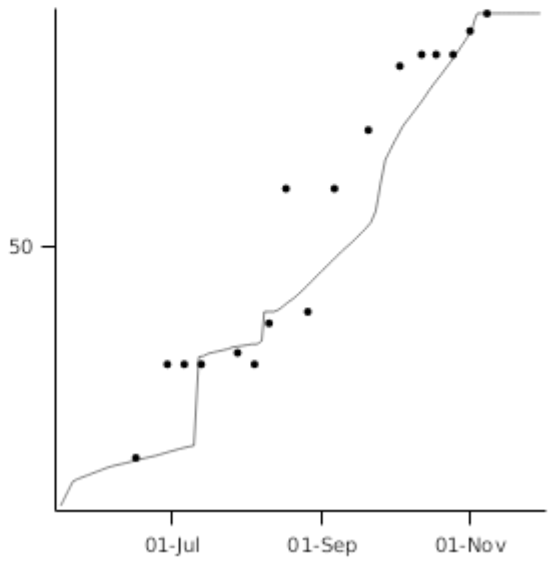
Bolac

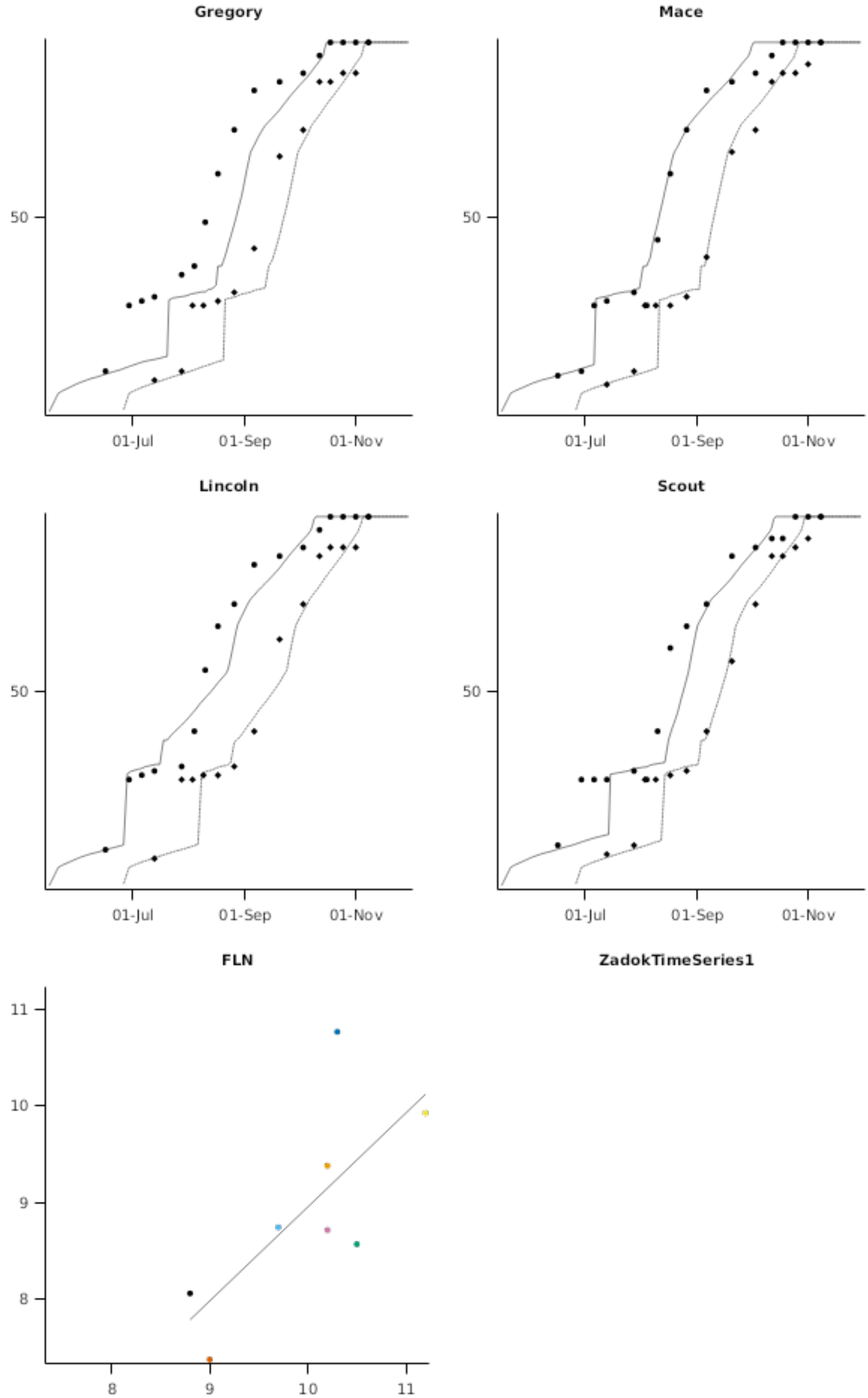


Derrimut

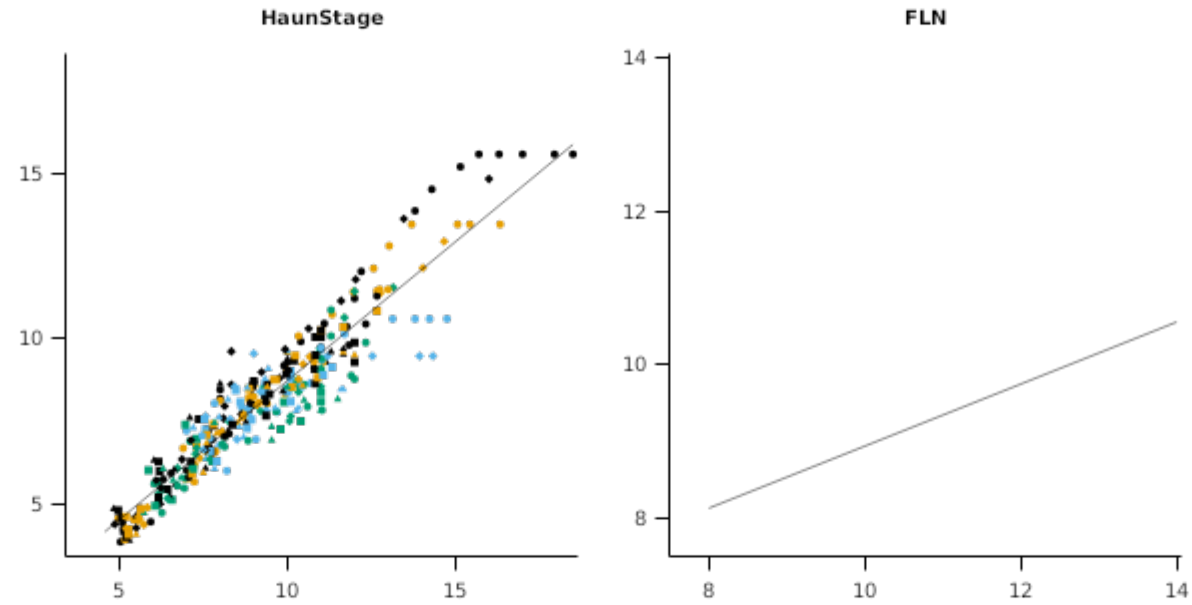


EagleHawk

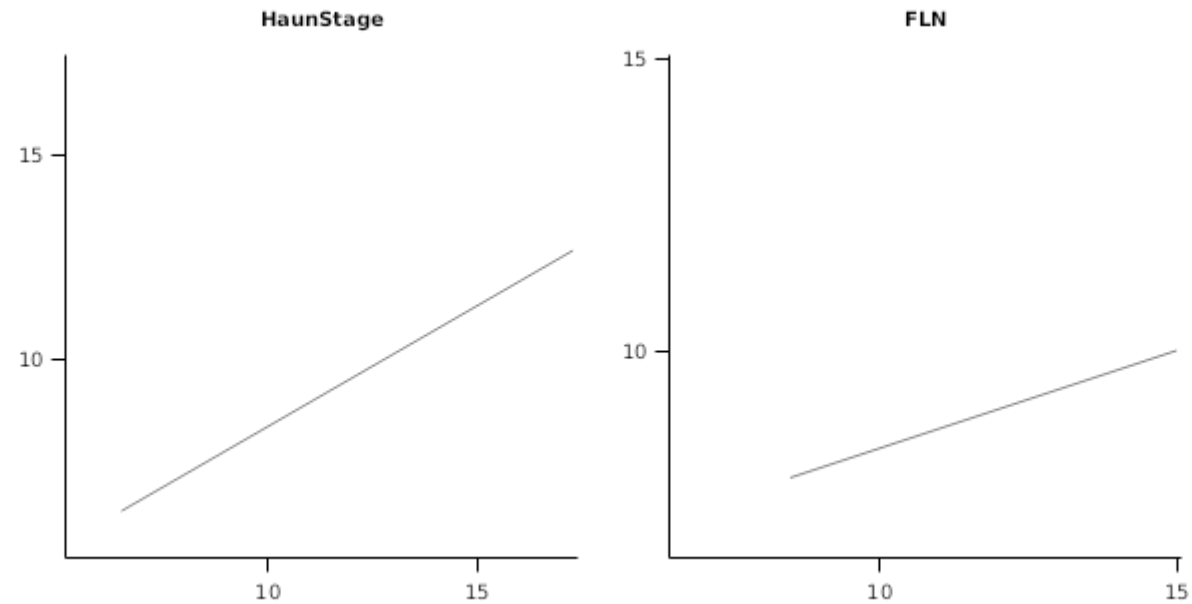




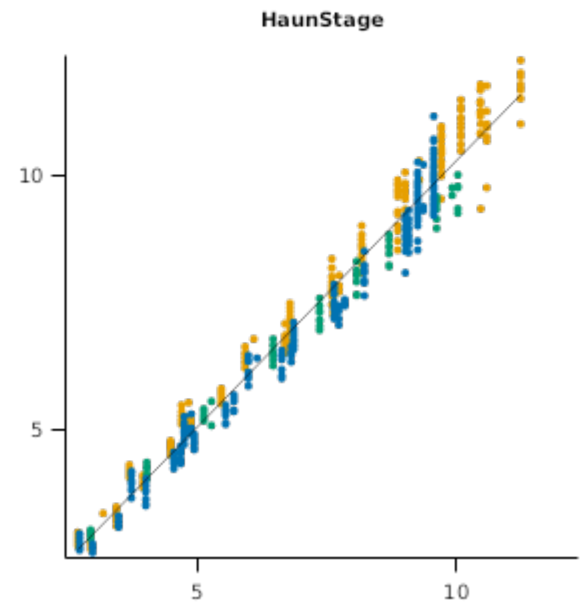
2.3.10 Gatton2014



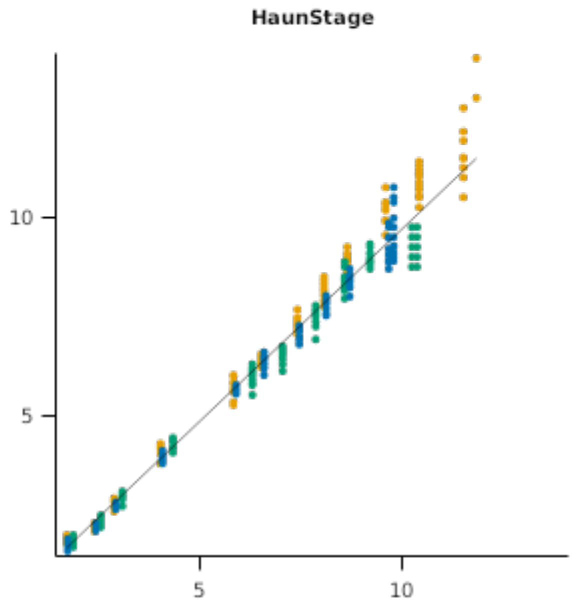
2.3.11 Gatton2014AE



2.3.12 TraitMod2015



2.3.13 TraitMod2016



2.3.14 AddingValueToNVT

The "Adding Value to the National Variety Trials" project aimed to use measurement and modelling to explain GeneXEnvironmentXManagement interactions for Australian Wheat cultivars. A description of this national trial can be found in R.A. Lawes et al., 2016. Here we include some of the data from south-eastern Queensland.

2.3.14.1 List of experiments

Experiment Name	Design (Number of Treatments)
Goondiwindi2011	Cv x TOS (9)
Nagwee2012	Cv x TOS (9)
Bungunya2012	Cv x TOS (9)

2.3.14.2 Nagwee2012

INSERT TEXT HERE

2.3.14.3 Bungunya2012

INSERT TEXT HERE

2.3.15 Phenology1996

This dataset includes observed heading date for six cultivars (Batavia, Cunningham, Hartog, Janz, Sunbri, Suneca) for a range of locations and planting dates in the northern grain-growing region of Australia.

2.3.15.1 List of experiments

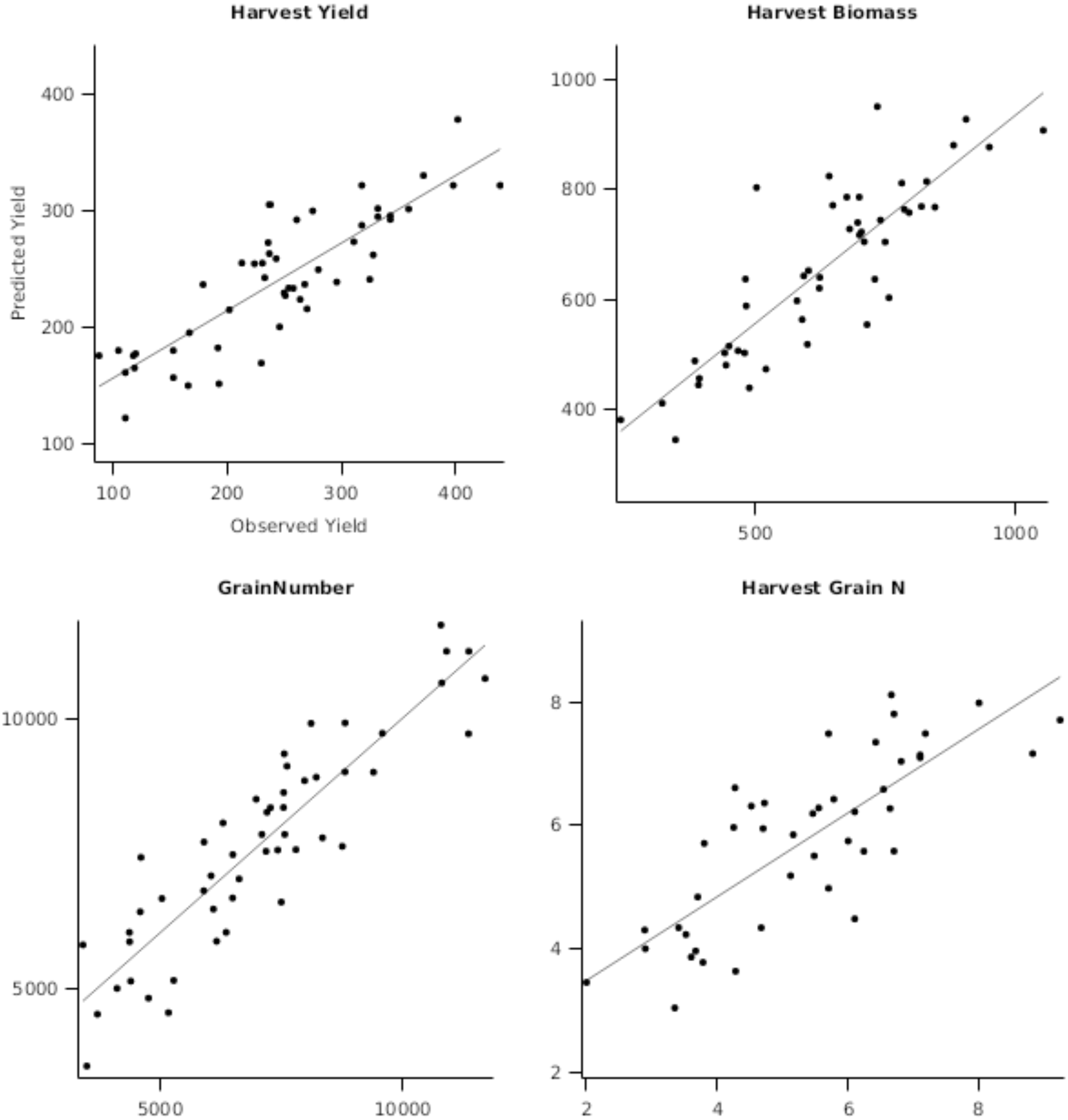
Experiment Name	Design (Number of Treatments)
Goondiwindi1996	Cv x TOS (18)
Miles1996	Cv x TOS (30)
Emerald1996	Cv x TOS (24)
Biloela1996	Cv x TOS (30)
Moree1996	Cv x TOS (18)

2.4 Western Australia

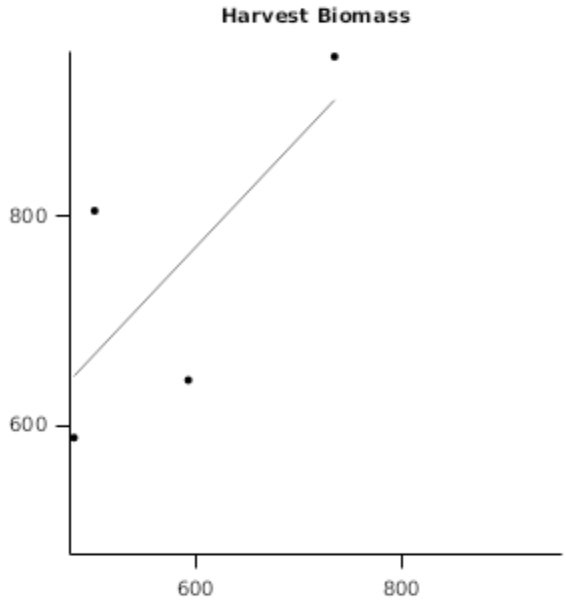
The wheat belt of Western Australia has a Mediteranean climate (winter dominant rainfall patterns) with mostly sandy soils. Data from S Asseng et al., 1998. and some more recent studies have been included to extend the range of conditions studied and to include more modern cultivars.

2.4.1 List of experiments

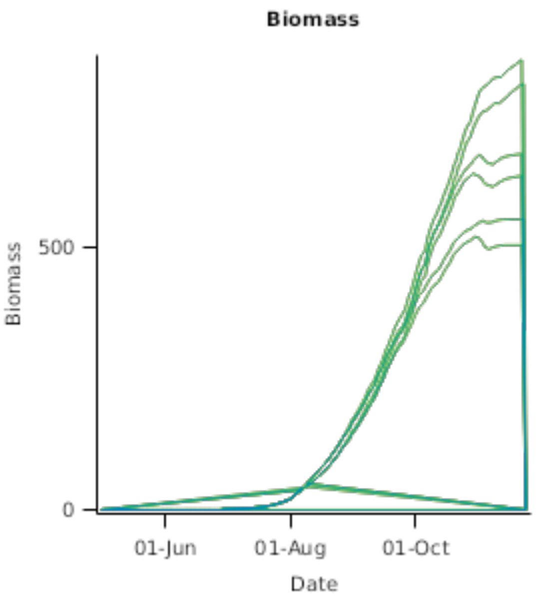
Experiment Name	Design (Number of Treatments)
Mer86	NRate x Water (4)
Mer73	NRate x Water (6)
Cunderdin97	Sow x SowN x TopN x Irr (40)
Wongan83	Soil x N (10)

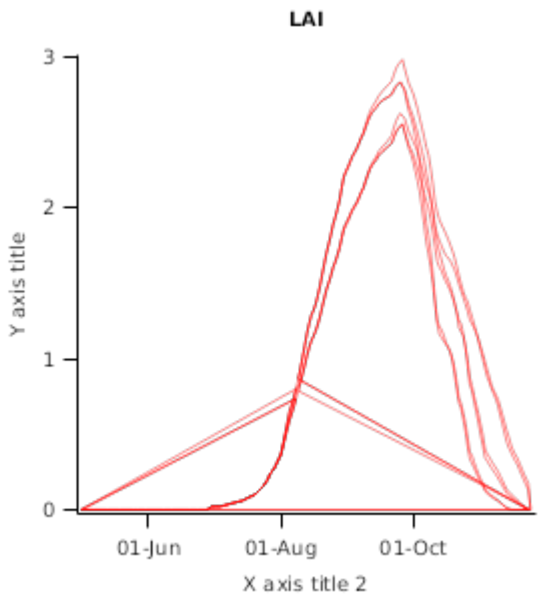


2.4.2 Mer86

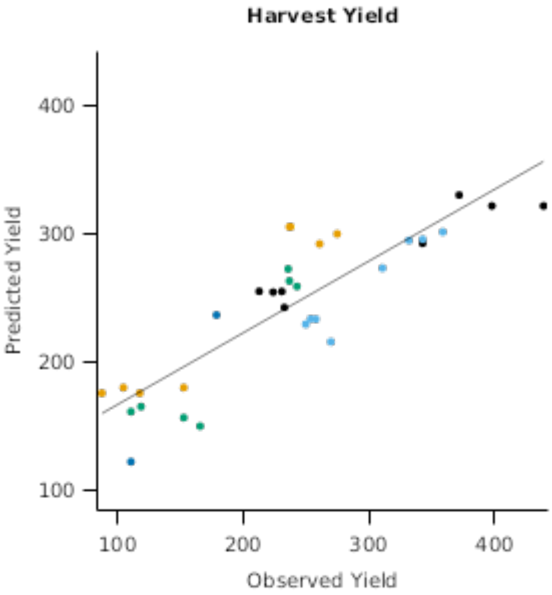


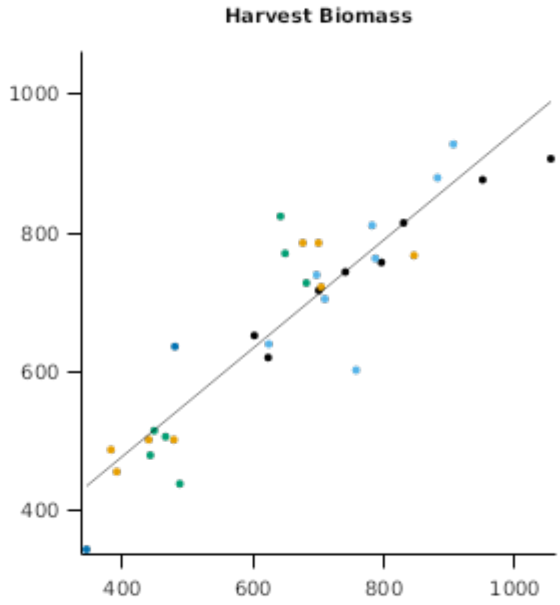
2.4.3 Mer73

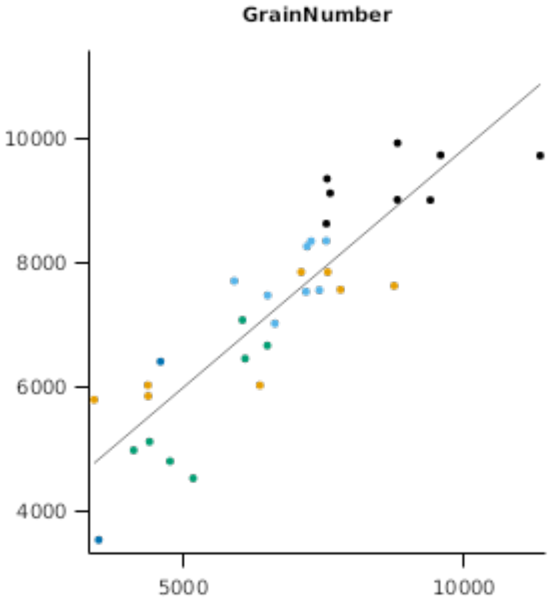




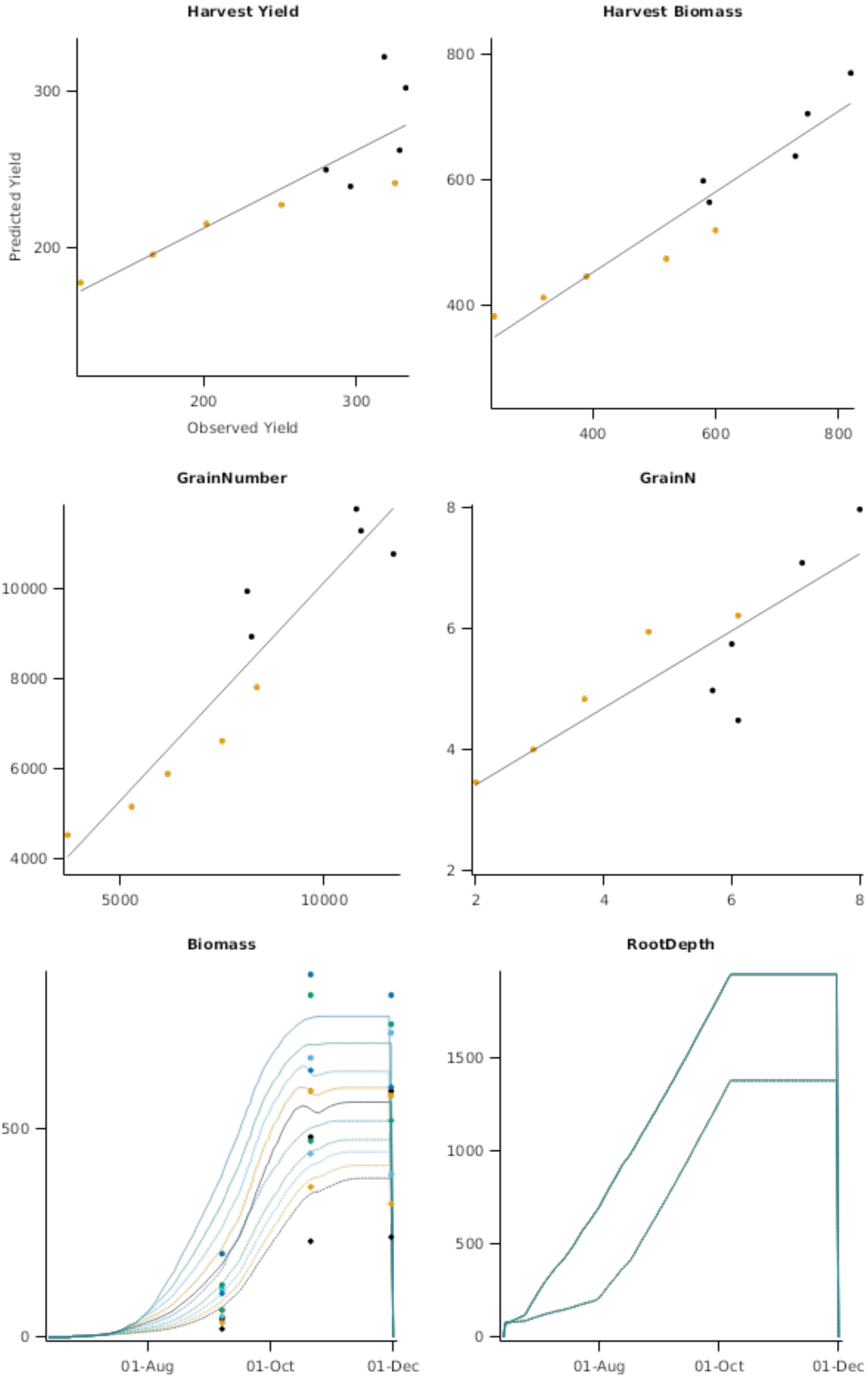
2.4.4 Cunderdin97

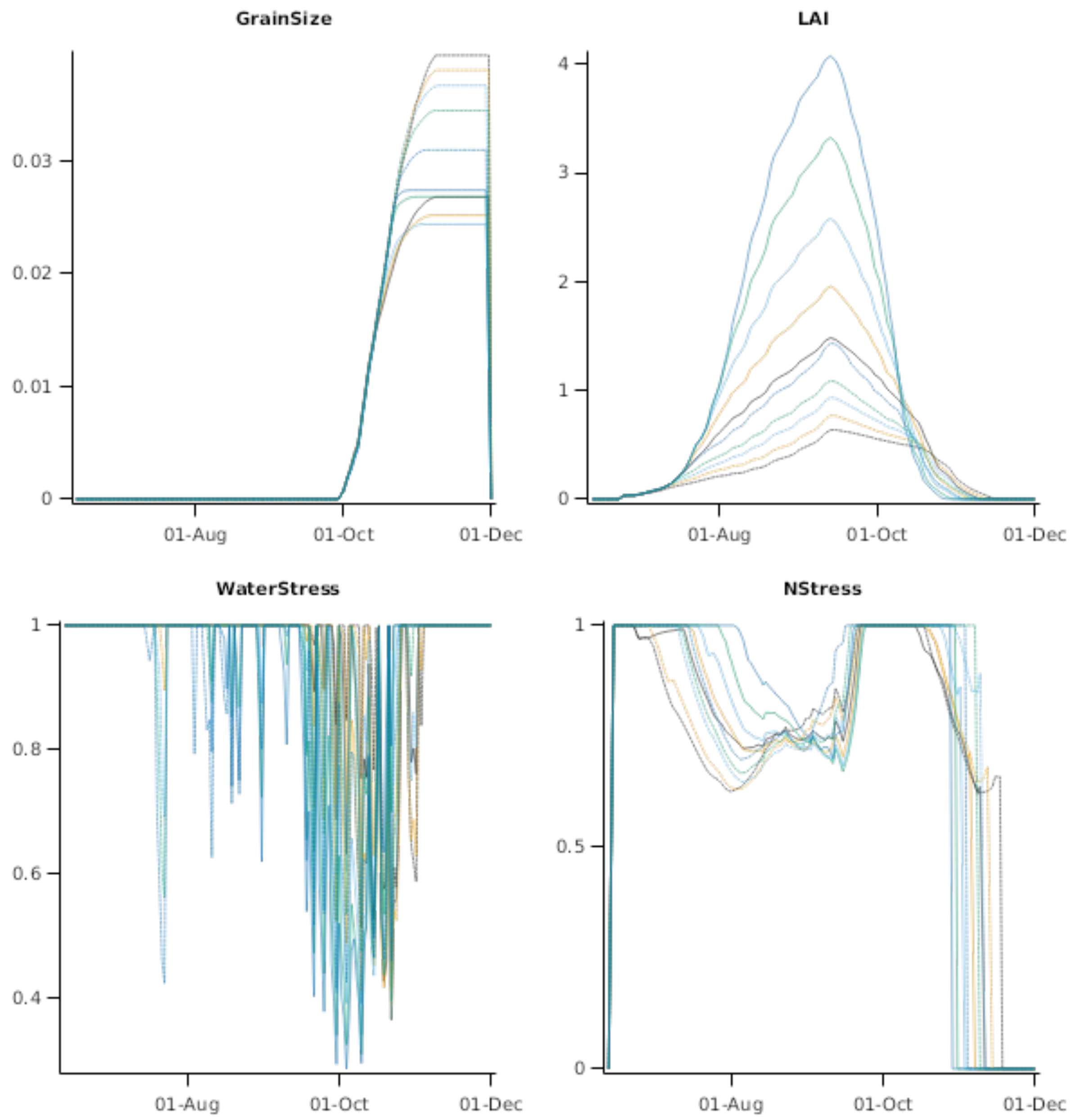






2.4.5 Wongan83


Harvest Yield
Predicted Yield
Observed Yield
300
200
200
300
Harvest Biomass
800
600
400
400
600
800
GrainNumber
10000
8000
6000
4000
5000
10000
GrainN
8
6
4
2
2
4
6
8
Biomass
500
0
01-Aug
01-Oct
01-Dec
RootDepth
1500
1000
500
0
01-Aug
01-Oct
01-Dec

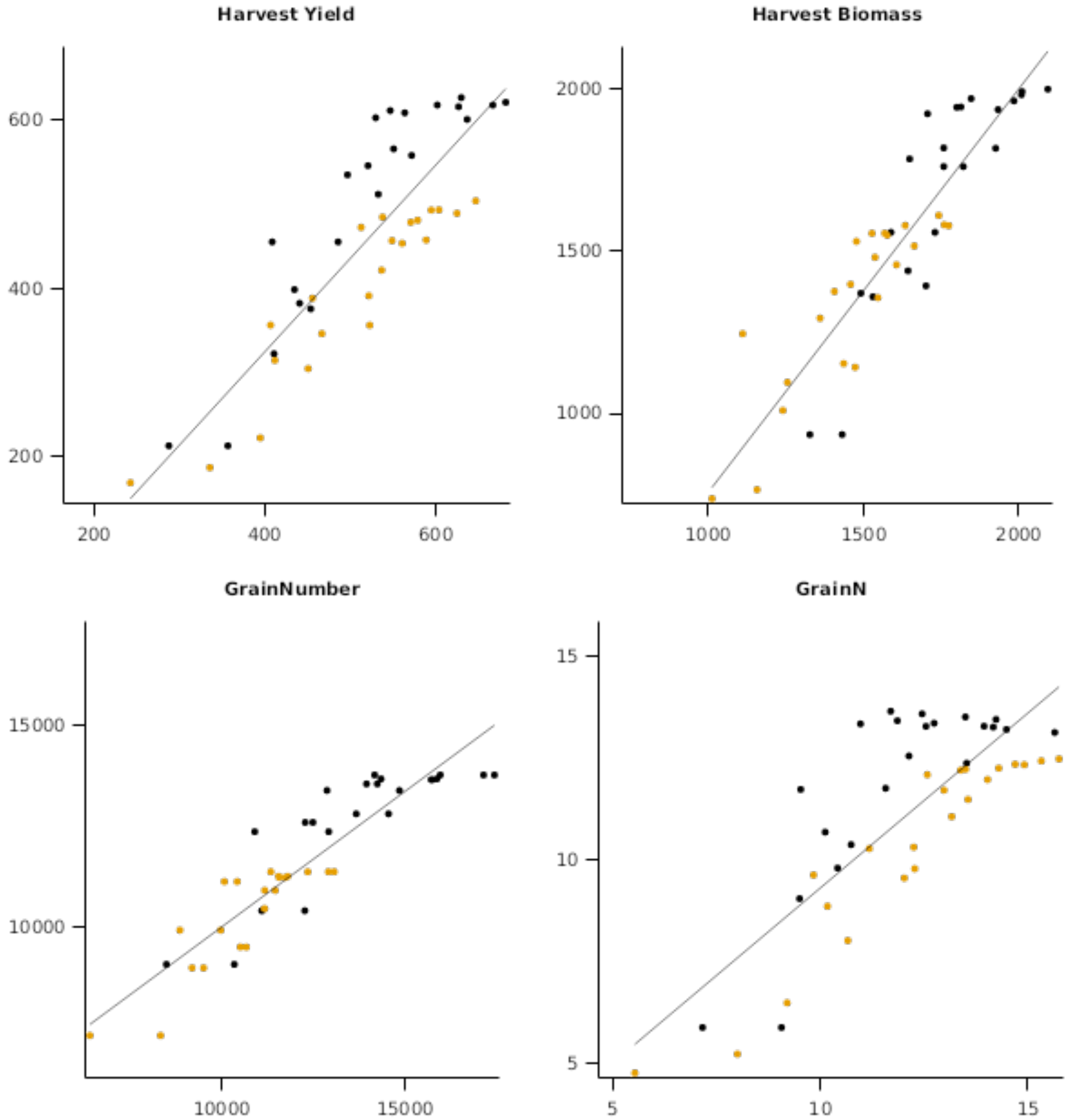


2.5 Turkey

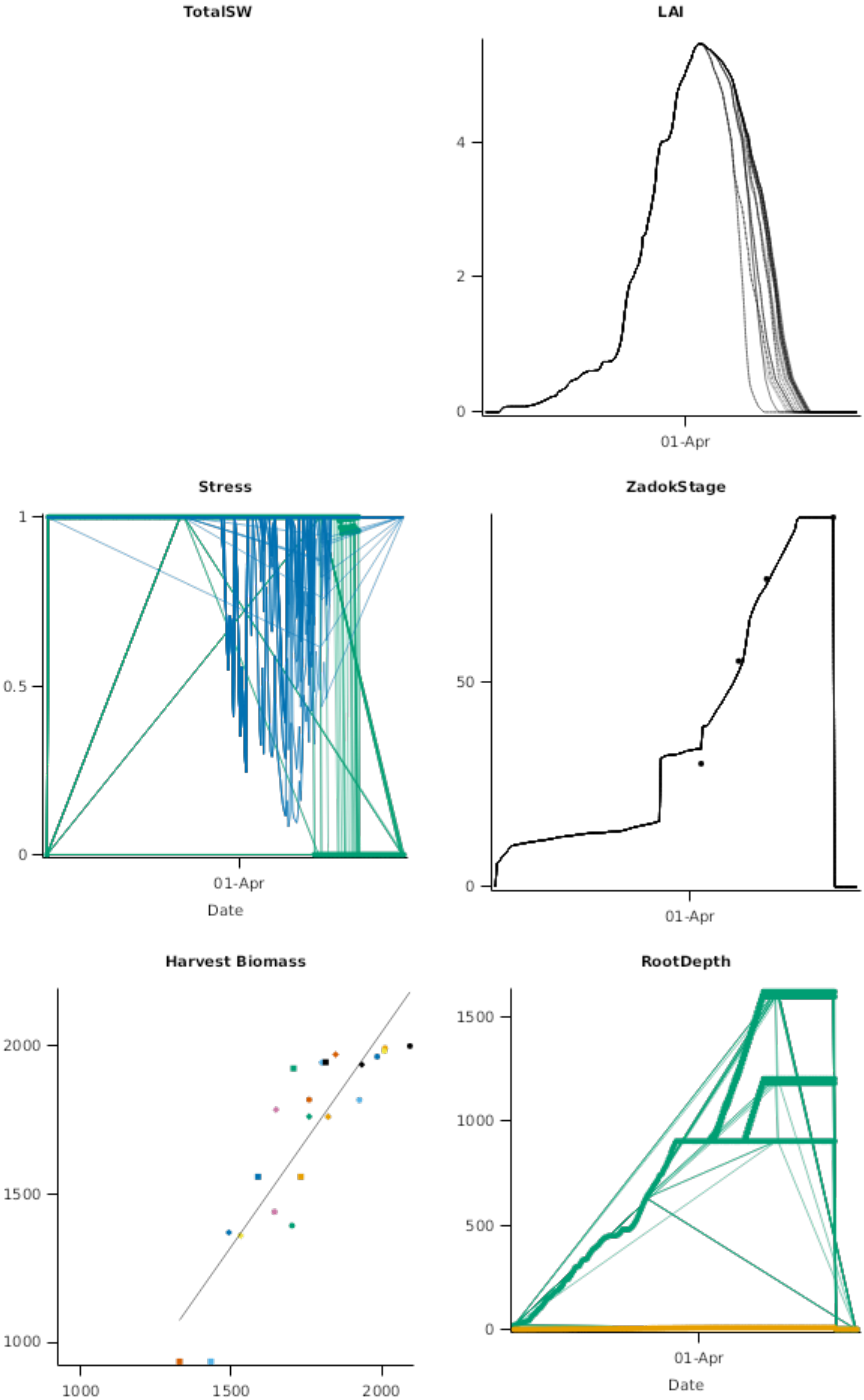
The dataset of Ali Fuat Tari, 2016 includes 4 irrigation deficit treatments applied at each of 3 plant growth stages. The experiment was conducted at Konya in the Central Anatolia region of Turkey. Yields ranged from 2.88 t/ha to 6.82 t/ha. These treatments were reproduced over two growing seasons, resulting in 44 individual wheat crops including differing levels of water stress at different stages of development. Soil data have been estimated from that provided within the original publication.

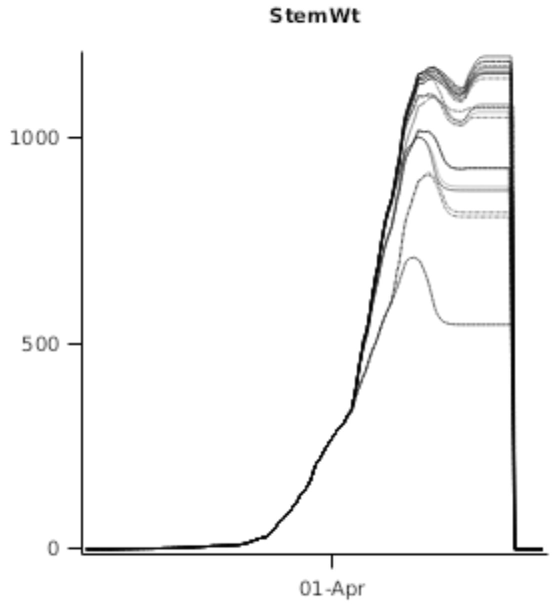
2.5.1 List of experiments

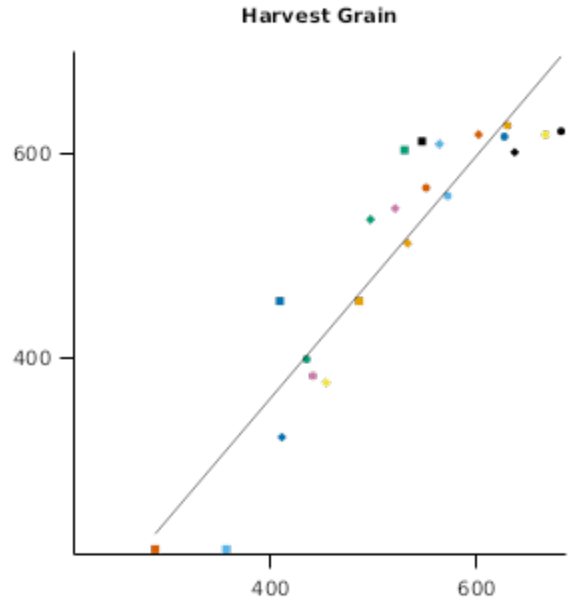
Experiment Name	Design (Number of Treatments)
Konya09	Water (22)
Konya11	Water (22)

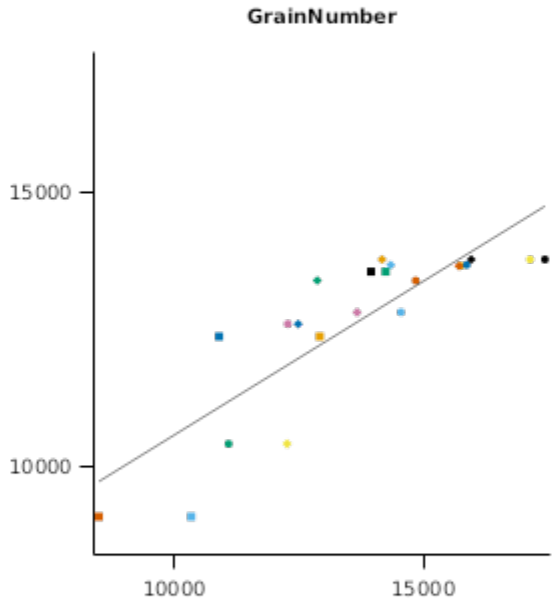

Harvest Yield
600
400
200
200
400
600
Harvest Biomass
2000
1500
1000
1000
1500
2000
GrainNumber
15000
10000
10000
15000
GrainN
15
10
5
5
10
15

2.5.2 Konya09

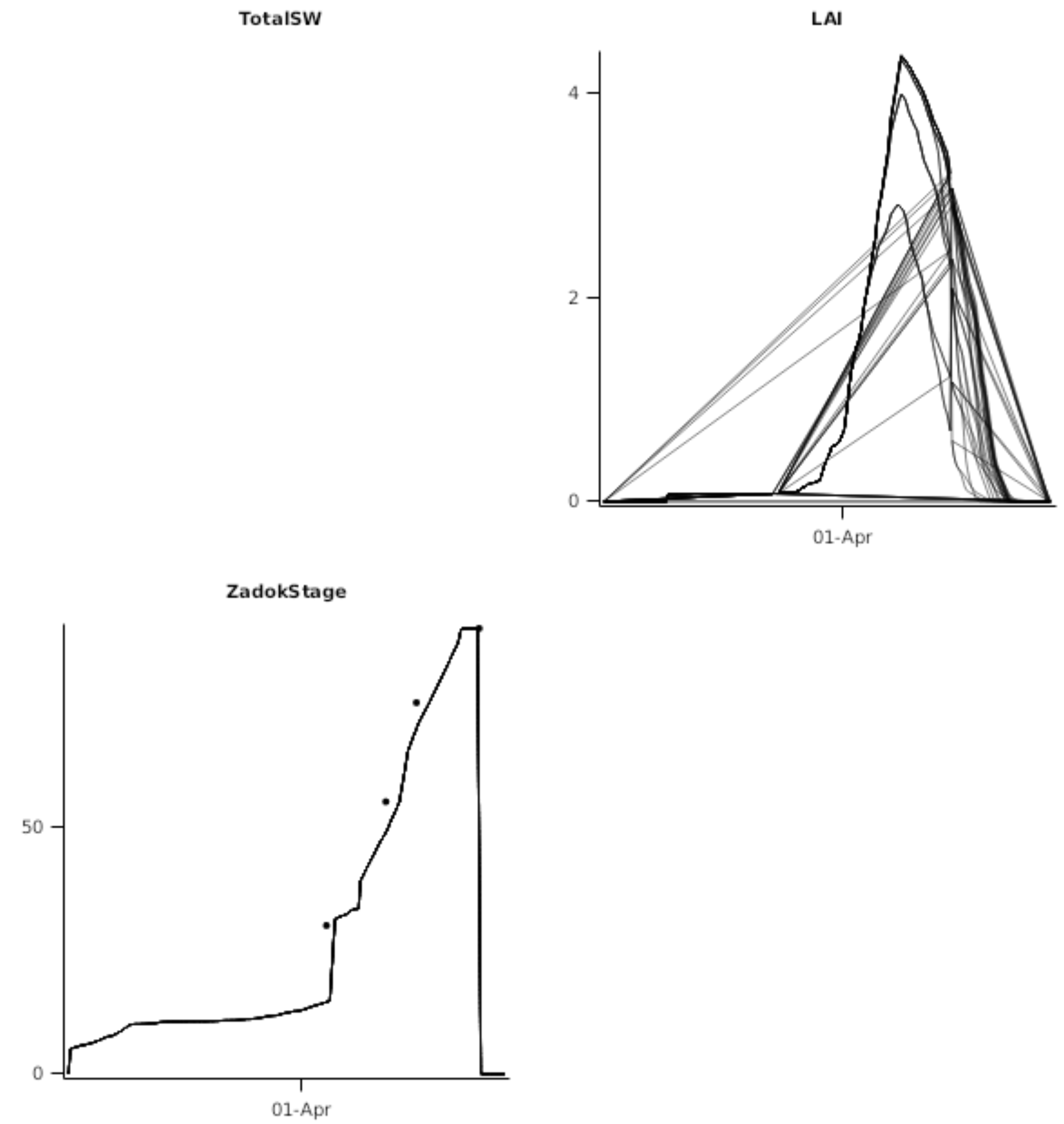

TotalSW
LAI
0
2
4
01-Apr
Stress
1
0.5
0
01-Apr
Date
ZadokStage
50
0
01-Apr
Harvest Biomass
2000
1500
1000
1000
1500
2000
RootDepth
1500
1000
500
0
01-Apr
Date


StemWt
1000
500
0
01-Apr


Harvest Grain
600
400
400
600


GrainNumber
15000
10000
10000
15000

2.5.3 Konya11

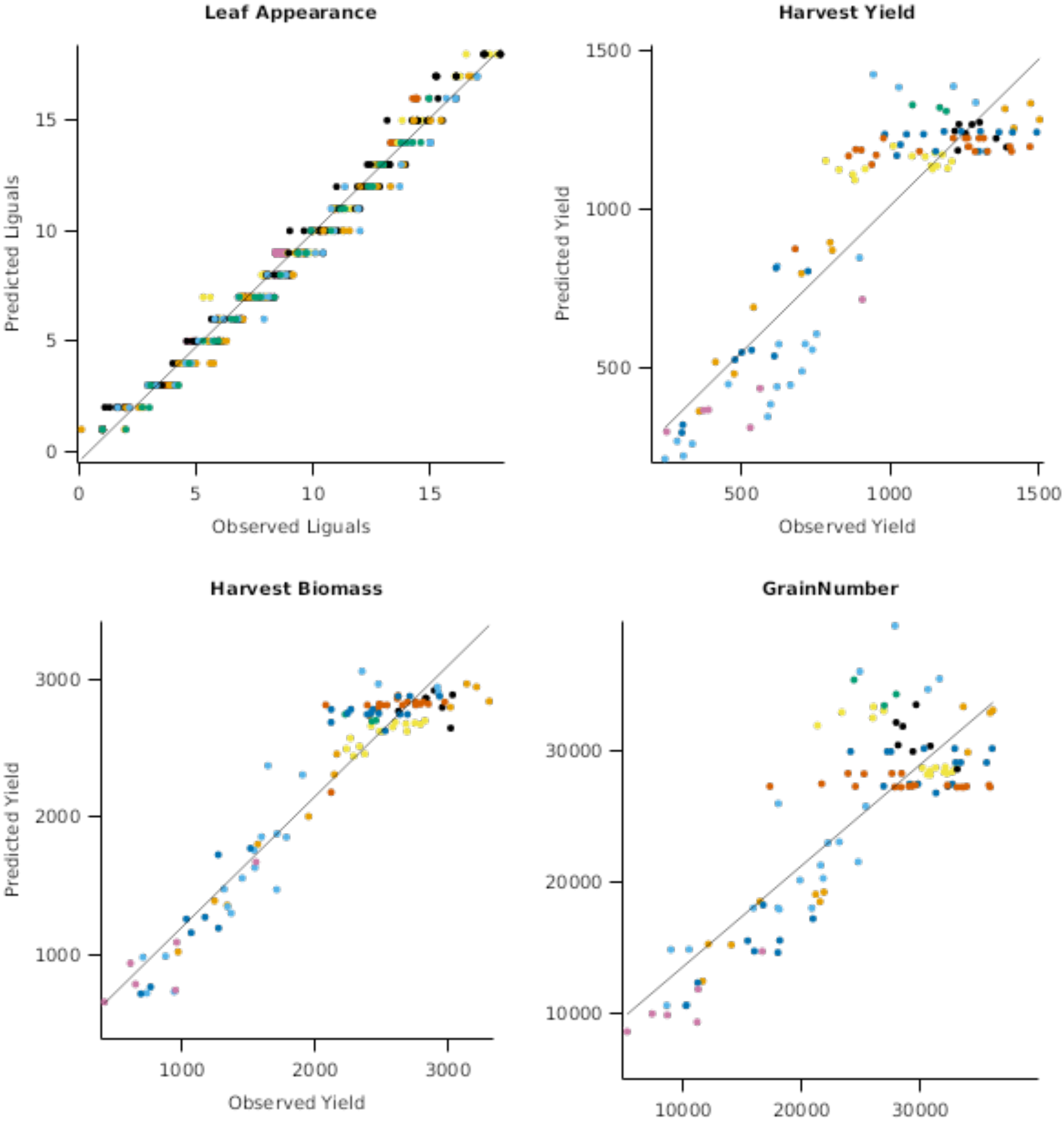


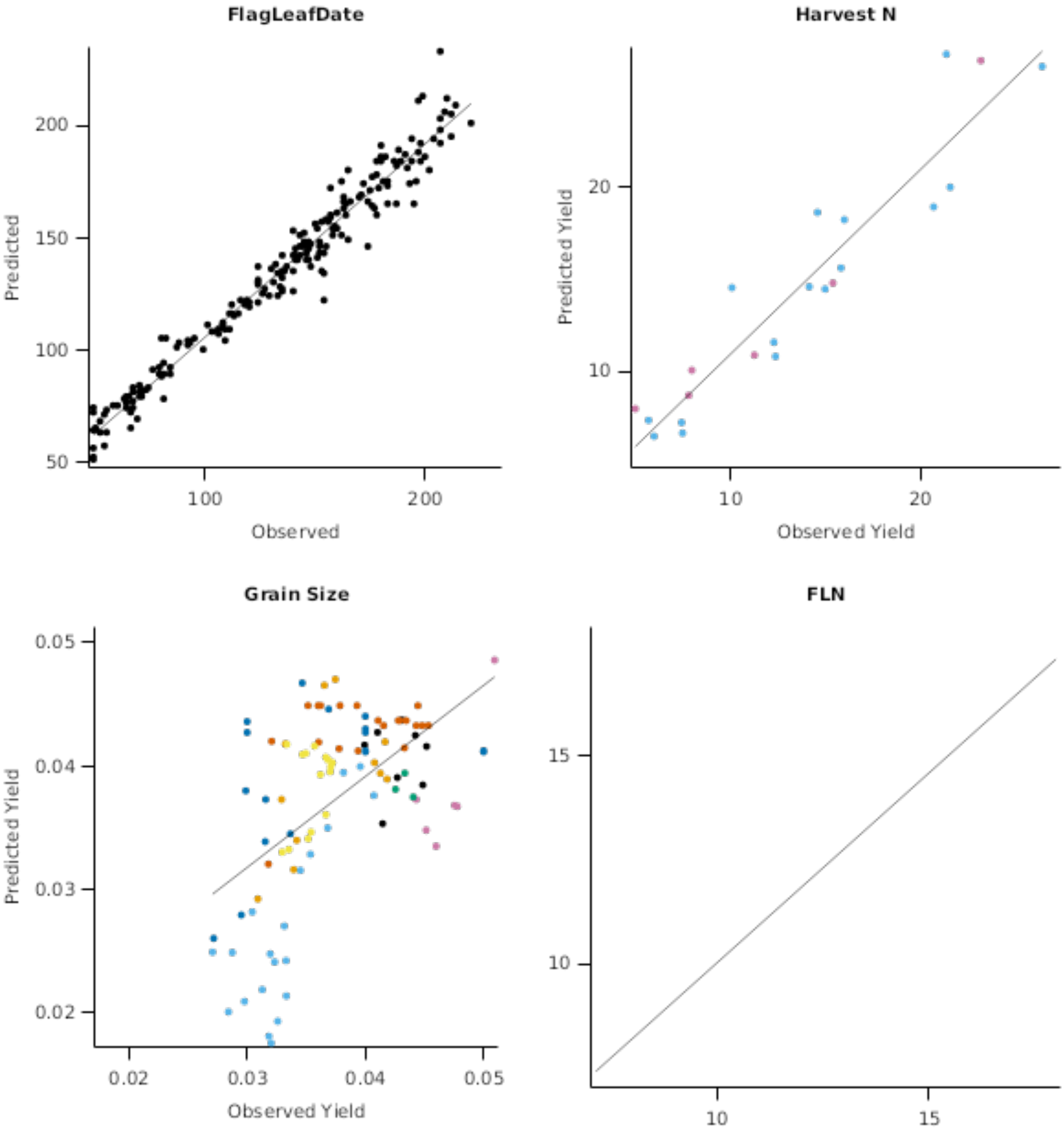
2.6 New Zealand

2.6.1 List of experiments

Experiment Name	Design (Number of Treatments)
PalmerstonNorth1989	Sow x Cv (18)
Lincoln9192	Irrig (7)
Lincoln1992	Sow x Irr x Nit (16)
Lincoln1994	Sow x Cv (10)
Lincoln2010	Sow x Irr (8)
Lincoln2014	Irrig (6)
Lincoln2015	Nit x Irr (6)
Leeston2013	Sow x Popn (15)
Leeston2014	Sow x Popn (8)
Wakanui2015	Sow x Cm (4)

Experiment Name	Design (Number of Treatments)
Wakanui2016	Sow x Cm (4)
Wakanui2017	Sow x Cm (3)
Lincoln2021	SD x CV (16)
Lincoln2023	SD x CV (18)





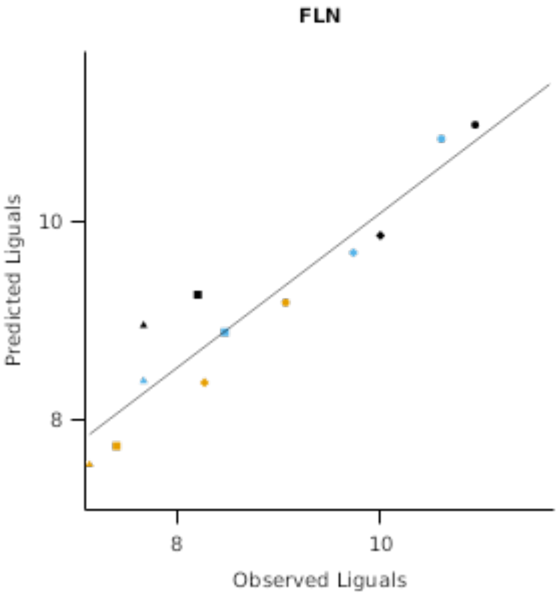
2.6.2 PalmerstonNorth1989

The design, management and yield results of this trial have been described in full by Craigie R.A., 2015. In brief, this trial was conducted to assess the impact of earlier sowing on potential yields of 'Wakanui' wheat grown at Wakanui (the cultivar was named after the area) in Mid Canterbury, New Zealand. it was a 4 x 4 factorial with 4 replicates of the following treatments:

1. Sowing date (20 February, 10 March, 28 March, 23 April)
2. Sowing density (50,100,150 and 200 plants/m^2

In addition to yield, measurements of leaf appearance and senescence and canopy cover (measured with NDVI) were measured at 10 - 14 day intervals and biomass measurements were taken at growth stages 32 and 65.

Considerable canopy decay was observed during the winter for the early sown treatments and we have not introduced mechanisms into the model to capture this yet so there is a genral over prediction of canopy size and biomass in these first sowing dates.

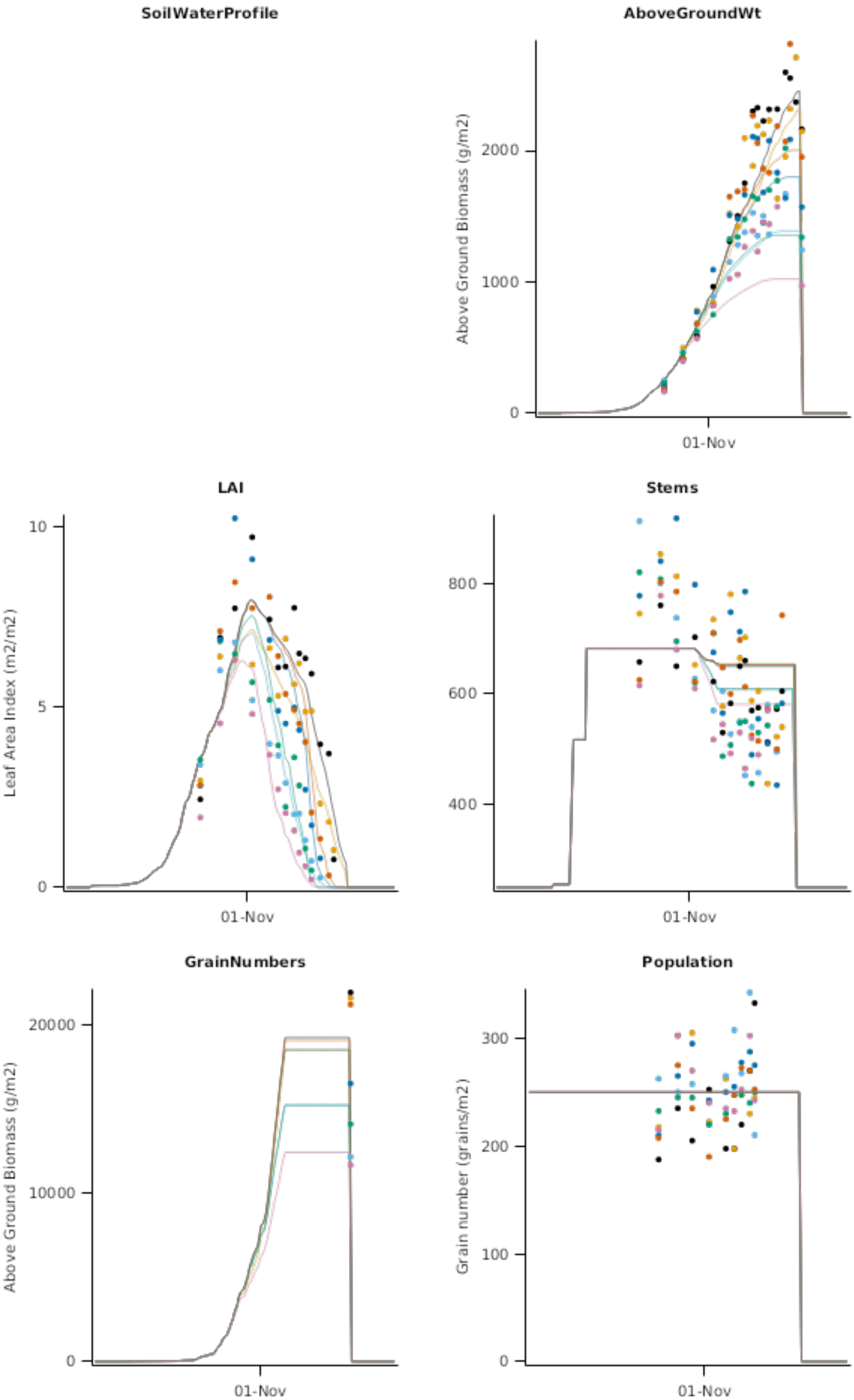


2.6.3 Lincoln9192

This is a water response trial run in the rain out shelter at Plant and Food Research in Lincoln, New Zealand. It is described in full by Jamieson et al., 1995 but briefly. A winter crop of 'Batten' wheat was sown at 300 plants/m^2 on the 8th of June 1991 and range of irrigation amount and timing treatments were applied. Six of these treatments have been included in this validation:

1. Full irrigation where measured ET was replaced weekly
2. Short Early Drought where irrigation was withheld from sowing until late October then full irrigation was applied
3. Long Early Drought where irrigation was withheld from sowing until mid December then full irrigation was applied
4. Long Late Drought where full irrigation was applied from sowing until mid September then withheld for the rest of the season
5. Moderate Late Drought where full irrigation was applied from sowing until mid October then withheld for the rest of the season
6. Short Late Drought where full irrigation was applied from sowing until Early November then withheld for the rest of the season
7. Nil where no water was applied and the crop grew on soil stored water only.

Irrigation was applied at weekly intervals through and assemply of low rate drip emitters on each plot. Soil water content was measured weekly with a neutron probe and biomass was measured at 10 - 14 day intervals. Samples throughtout the crop were from two 0.1m^2 quatrants and the final harvest sample was from a 1 m^2 quadrant. Each treatment was replicated twice and there was considerable soil variation from plot to plot so each treatment was initianilised with unique soil parameters which best described the soil they were growing on.



2.6.4 Lincoln1992

This trial has never been formally written up. It was conducted at Plant and Foods A Block, Lincoln, New Zealand with 'Batten' Wheat grown on a Templeton silt loam (160mm AWC/m). It was a 2 x 2 x 4 factorial with the following treatments:

1. Sowing Date (5 May 1992 and 5 Aug 1992)
2. Irrigation (Nil and 120 mm)
3. Nitrogen (0, Low, Medium and High)

The N applied to the Low, Medium and High N treatments was 100, 150 and 250 kg/ha, respectively, for the May sowing and 50, 100 and 150, respectively, for the August sowing.

Could not find informaiton confirming sowing rate so assumed typical values of 300 plants per m/2 for the spring sowing 100 plants per m/2 for May sowing. Emergence was recorded as the 28th of May for the first planting. The model was predicting this early so delayed sowing date to get emergence date correct..

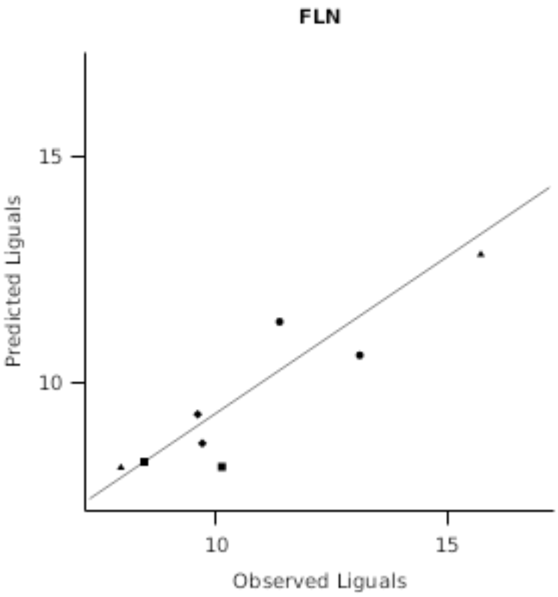
2.6.5 Lincoln1994

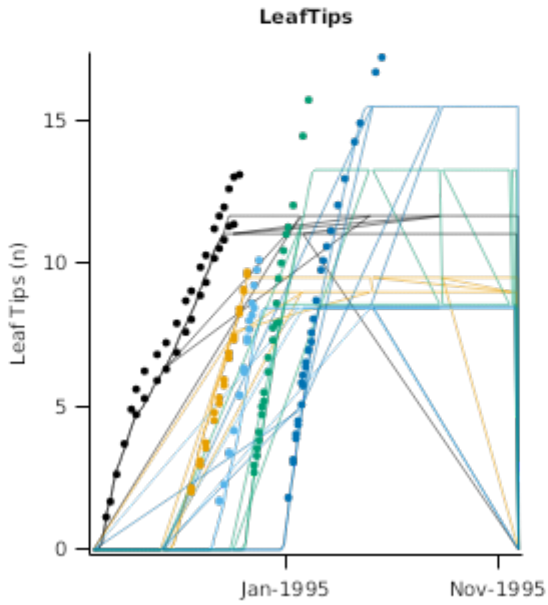
The design, management and yield results of this trial have been described in full by Craigie R.A., 2015. In brief, this trial was conducted to assess the impact of earlier sowing on potential yields of 'Wakanui' wheat grown at Wakanui (the cultivar was named after the area) in Mid Canterbury, New Zealand. it was a 4 x 4 factorial with 4 replicates of the following treatments:

1. Sowing date (20 February, 10 March, 28 March, 23 April)
2. Sowing density (50,100,150 and 200 plants/m^2

In addition to yield, measurements of leaf appearance and senescence and canopy cover (measured with NDVI) were measured at 10 - 14 day intervals and biomass measurements were taken at growth stages 32 and 65.

Considerable canopy decay was observed during the winter for the early sown treatments and we have not introduced mechanisms into the model to capture this yet so there is a genral over prediction of canopy size and biomass in these first sowing dates.





2.6.6 Lincoln2010

- Could not find informaiton confirming sowing rate. Protocole said aim for 300 plants per m/2 which is usual for a spring sowing but very high for an Autumn sowing. Assumed 100 plants per m/2 for May sowing and 300 for August.
- Emergence was recorded as the 28th of May for the first planting. The model was predicting this early so delayed sowing date to get emergence date correct..

This is a water response trial run in the rain out shelter at Plant and Food Research in Lincoln, New Zealand. It is described in full by E. Chakwizira et al., 2014 but briefly. An Autumn crop of 'Wakanui' wheat was sown at 165 plants/m^2 on the 28th of March 2013 and 6 irrigation timing treatments were applied:

1. Full irrigation where measured ET was replaced weekly .
2. Nill irrigation.
3. Very Early Drought where irrigation was withheld from sowing until the beginning of stem extension.
4. Early Drought where irrigation was withheld between Flag leaf and the beginning of grain fill.
5. Middle Drought where irrigation was withheld between Flag leaf and 1 week into grain fill.
6. Late Drought where irrigation was withheld from heading until harvest.

Irrigation was applied at weekly intervals through and assemply of low rate drip emitters on each plot. Soil water content was measured weekly with a neutron probe and biomass was measured on 5 occasions throughout the crop. Samples throughtout the crop were from a 0.43m^2 quatrant and the final harvest sample was from a 1 m^2 quadrant. Each treatment was replicated four times and there was considerable soil variation from plot to plot so each treatment was initianilised with unique soil parameters which best described the soil they were growing on.

2.6.7 Lincoln2014

This is a water response trial run in the rain out shelter at Plant and Food Research in Lincoln, New Zealand. It is described in full by E. Chakwizira et al., 2014 but briefly. An Autumn crop of 'Wakanui' wheat was sown at 165 plants/m^2 on the 28th of March 2013 and 6 irrigation timing treatments were applied:

1. Full irrigation where measured ET was replaced weekly .
2. Nill irrigation.
3. Very Early Drought where irrigation was withheld from sowing until the beginning of stem extension.
4. Early Drought where irrigation was withheld between Flag leaf and the beginning of grain fill.
5. Middle Drought where irrigation was withheld between Flag leaf and 1 week into grain fill.
6. Late Drought where irrigation was withheld from heading until harvest.

Irrigation was applied at weekly intervals through and assemply of low rate drip emitters on each plot. Soil water content was measured weekly with a neutron probe and biomass was measured on 5 occasions throughout the crop. Samples throughtout the crop were from a 0.43m^2 quatrant and the final harvest sample was from a 1 m^2 quadrant. Each treatment was replicated four times and there was considerable soil variation from plot to plot so each treatment was initianilised with unique soil parameters which best described the soil they were growing on.

2.6.8 Lincoln2015

2.6.8.1 Lincoln2012 (Rain-Shelter Trail)

Testing of APSIM Maize under New Zealand conditions was undertaken using the data of Teixeira et al., 2014. This dataset includes the impact of three N (0 to 250 kg/ha N) and two water regimes (dryland and fully irrigated) using a rain-shelter structure. Observations include biomass growth and nitrogen content of individual organs, soil water contents, leaf area index, phenology and yield components. Total biomass ranged from 8000 kg/ha for dryland nil N crops to up to 28000kg/ha for fully irrigated and N fertilised crops. Dryland crops recovered 25 percent less N from applied fertilizer than irrigated crops.

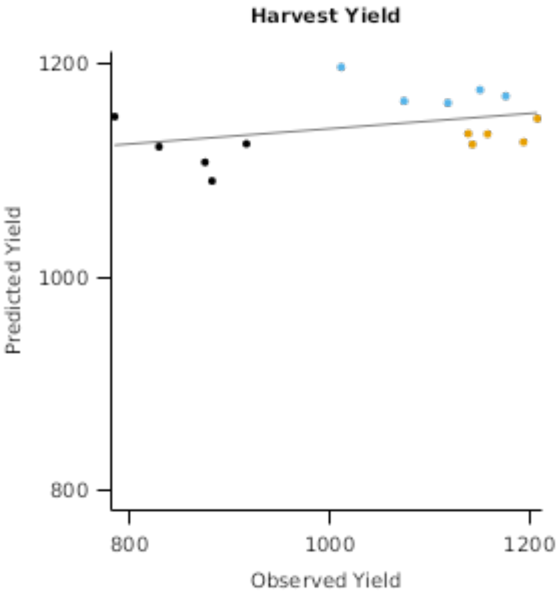
2.6.9 Leeston2013

The design, management and yield results of this trial have been described in full by Craigie R.A., 2015. In brief, this trial was conducted to assess the impact of earlier sowing on potential yields of 'Wakanui' wheat grown at Wakanui (the cultivar was named after the area) in Mid Canterbury, New Zealand. it was a 4 x 4 factorial with 4 replicates of the following treatments:

1. Sowing date (20 February, 10 March, 28 March, 23 April)
2. Sowing density (50,100,150 and 200 plants/m^2

In addition to yield, measurements of leaf appearance and senescence and canopy cover (measured with NDVI) were measured at 10 - 14 day intervals and biomass measurements were taken at growth stages 32 and 65.

Considerable canopy decay was observed during the winter for the early sown treatments and we have not introduced mechanisms into the model to capture this yet so there is a genral over prediction of canopy size and biomass in these first sowing dates.



2.6.10 Leeston2014

The design, management and yield results of this trial have been described in full by Craigie R.A., 2015. In brief, this trial was conducted to assess the impact of earlier sowing on potential yields of 'Wakanui' wheat grown at Wakanui (the cultivar was named after the area) in Mid Canterbury, New Zealand. it was a 4 x 4 factorial with 4 replicates of the following treatments:

1. Sowing date (20 February, 10 March, 28 March, 23 April)
2. Sowing density (50,100,150 and 200 plants/m^2

In addition to yield, measurements of leaf appearance and senescence and canopy cover (measured with NDVI) were measured at 10 - 14 day intervals and biomass measurements were taken at growth stages 32 and 65.

Considerable canopy decay was observed during the winter for the early sown treatments and we have not introduced mechanisms into the model to capture this yet so there is a genral over prediction of canopy size and biomass in these first sowing dates.

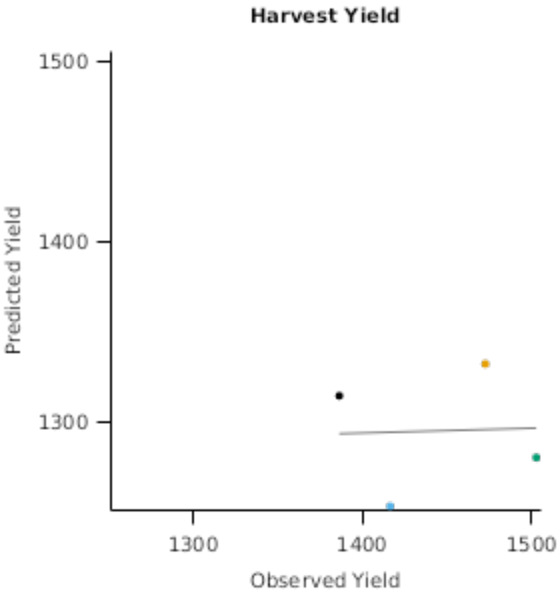
2.6.11 Wakanui2015

The design, management and yield results of this trial have been described in full by Craigie R.A., 2015. In brief, this trial was conducted to assess the impact of earlier sowing on potential yields of 'Wakanui' wheat grown at Wakanui (the cultivar was named after the area) in Mid Canterbury, New Zealand. it was a 4 x 4 factorial with 4 replicates of the following treatments:

1. Sowing date (20 February, 10 March, 28 March, 23 April)
2. Sowing density (50,100,150 and 200 plants/m^2

In addition to yield, measurements of leaf appearance and senescence and canopy cover (measured with NDVI) were measured at 10 - 14 day intervals and biomass measurements were taken at growth stages 32 and 65.

Considerable canopy decay was observed during the winter for the early sown treatments and we have not introduced mechanisms into the model to capture this yet so there is a genral over prediction of canopy size and biomass in these first sowing dates.



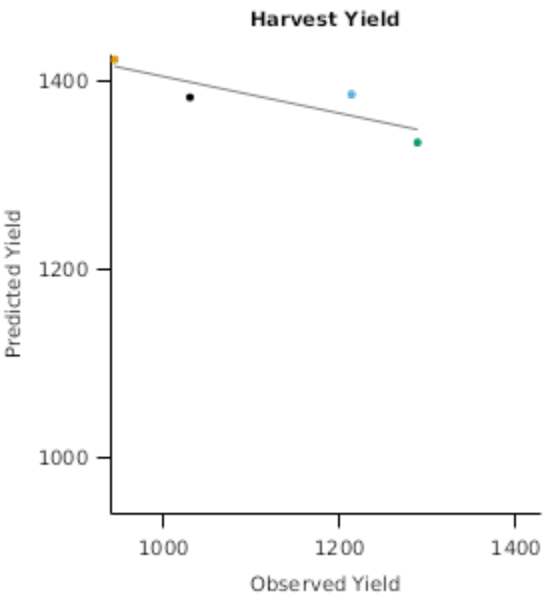
2.6.12 Wakanui2016

The design, management and yield results of this trial have been described in full by Craigie R.A., 2015. In brief, this trial was conducted to assess the impact of earlier sowing on potential yields of 'Wakanui' wheat grown at Wakanui (the cultivar was named after the area) in Mid Canterbury, New Zealand. it was a 4 x 4 factorial with 4 replicates of the following treatments:

1. Sowing date (20 February, 10 March, 28 March, 23 April)
2. Sowing density (50,100,150 and 200 plants/m^2

In addition to yield, measurements of leaf appearance and senescence and canopy cover (measured with NDVI) were measured at 10 - 14 day intervals and biomass measurements were taken at growth stages 32 and 65.

Considerable canopy decay was observed during the winter for the early sown treatments and we have not introduced mechanisms into the model to capture this yet so there is a genral over prediction of canopy size and biomass in these first sowing dates.



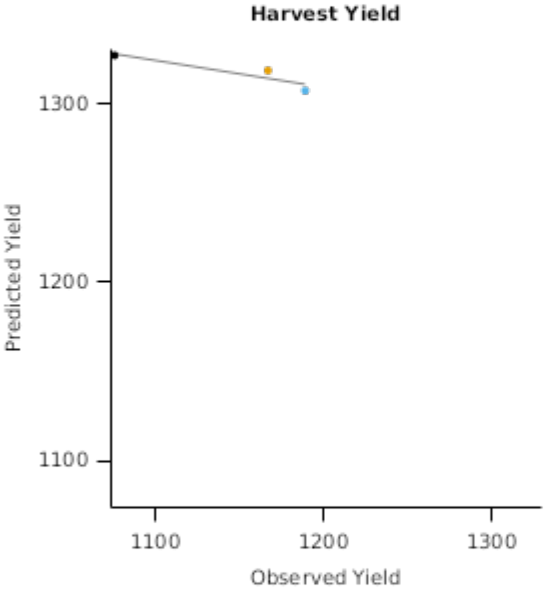
2.6.13 Wakanui2017

The design, management and yield results of this trial have been described in full by Craigie R.A., 2015. In brief, this trial was conducted to assess the impact of earlier sowing on potential yields of 'Wakanui' wheat grown at Wakanui (the cultivar was named after the area) in Mid Canterbury, New Zealand. it was a 4 x 4 factorial with 4 replicates of the following treatments:

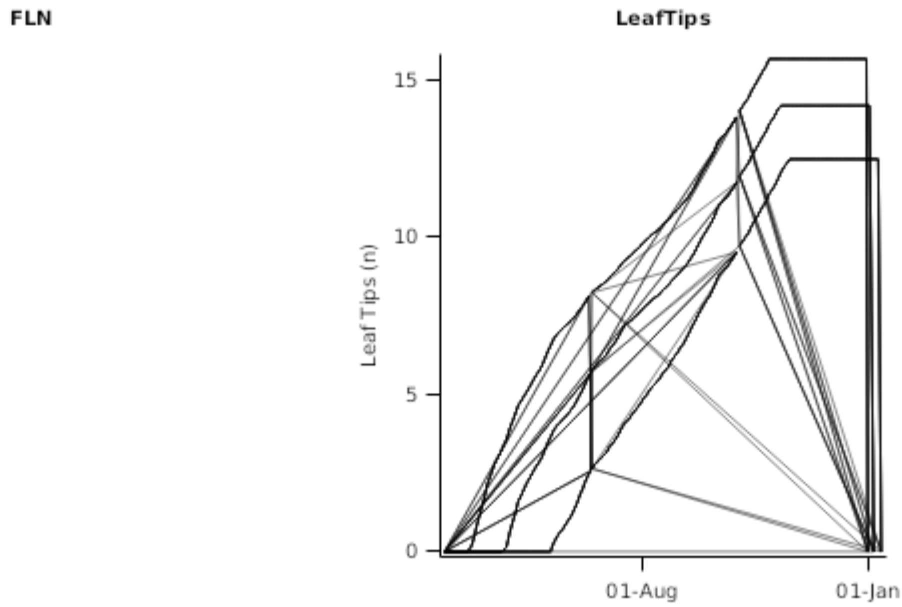
1. Sowing date (20 February, 10 March, 28 March, 23 April)
2. Sowing density (50,100,150 and 200 plants/m^2

In addition to yield, measurements of leaf appearance and senescence and canopy cover (measured with NDVI) were measured at 10 - 14 day intervals and biomass measurements were taken at growth stages 32 and 65.

Considerable canopy decay was observed during the winter for the early sown treatments and we have not introduced mechanisms into the model to capture this yet so there is a genral over prediction of canopy size and biomass in these first sowing dates.



2.6.14 Lincoln2023



2.6.15 CPTPhenology

A range of soon to be released cultivars have their phenology assesed each year at Plant and Food Research in Lincoln, New Zealand. Each cultivar is planted on 4 sowing dates representing Autumn, Winter, Early Spring and Late Spring sowings. (approx April, June, Aug, Nov). Each cultivar is observed for 3 years but a number of standards are included each year or for more than 3 years bacause of the value of the data they provided.

2.6.15.1 List of experiments

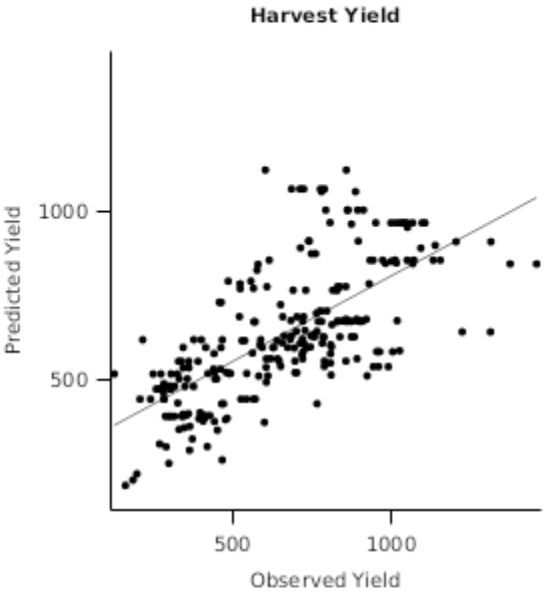
Experiment Name	Design (Number of Treatments)
CPTCultOtane	Sow (40)

Experiment Name	Design (Number of Treatments)
CPTCultAmarok	Sow (26)
CPTCultClaire	Sow (43)
CPTCultWakanui	Sow (6)
CPTCultBattenSpring	Sow (13)
CPTCultBattenWinter	Sow (12)
CPTCultYitpi	Sow x Cv (13)
CPTCultSunco	Sow (13)
CPTCultMcCubbin	Sow (13)
CPTCultMacKellar	Sow (13)
CPTCultJanz	Sow x Cv (13)
CPTCultLang	Sow (13)
CPTCultH45	Sow (13)

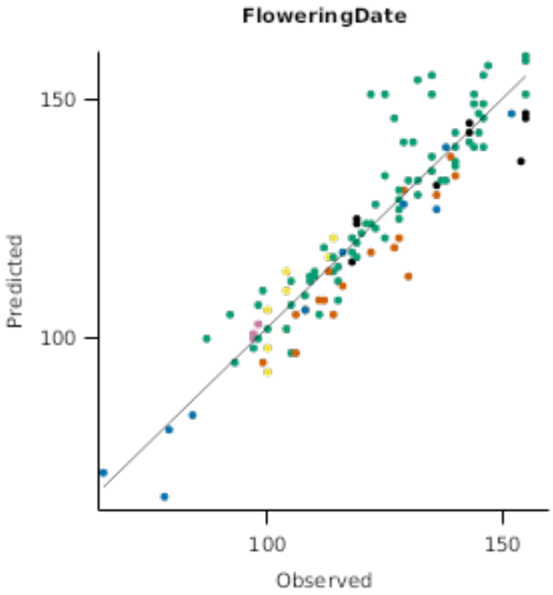
2.7 Southern Australia

2.7.1 List of experiments

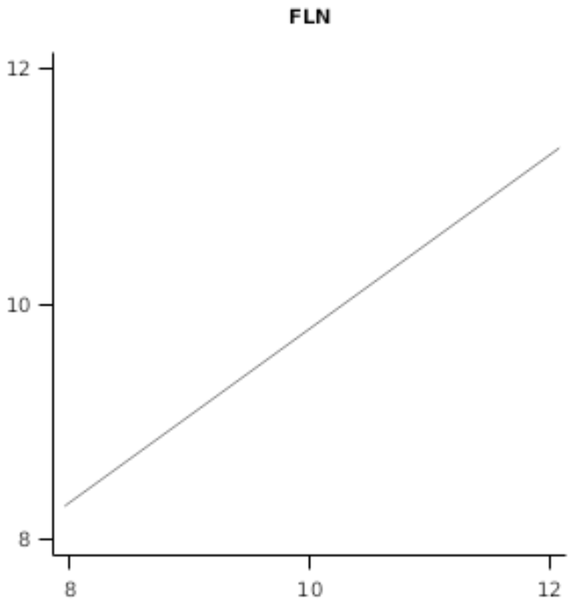
Experiment Name	Design (Number of Treatments)
Mouse	Removal x Date (20)
Walpeup2011	Cv x TOS (12)
Walpeup2012	Cv x TOS (8)
Minnipa2012	Cv x TOS (9)
Temora2012	Cv x TOS (9)
Birchip2011	TOS x Cv (16)
Tarlee2011	TOS x Cv (16)
Tamworth1992	Cv x TOS (75)



Harvest Yield
Predicted Yield
Observed Yield
500
1000
500
1000

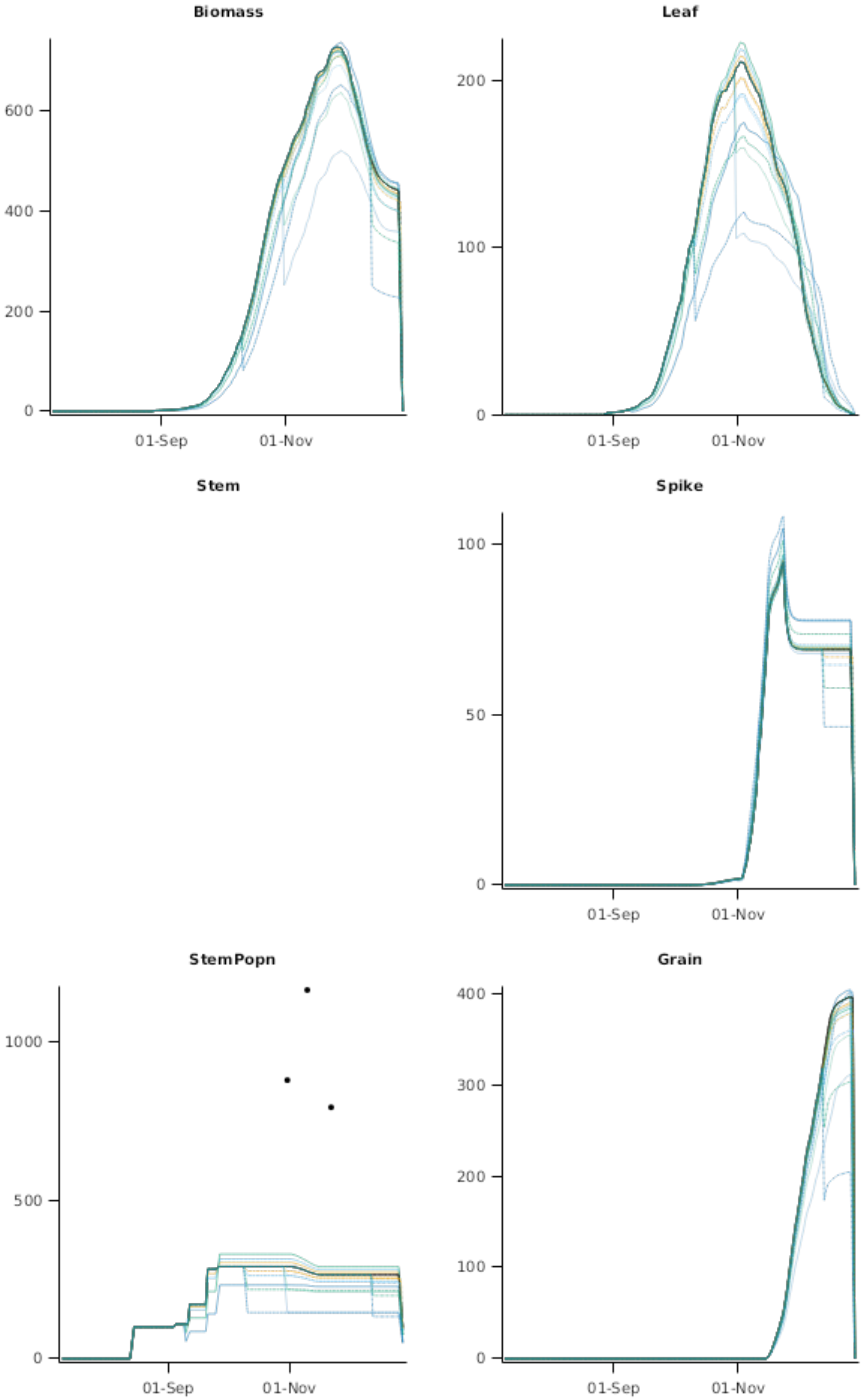


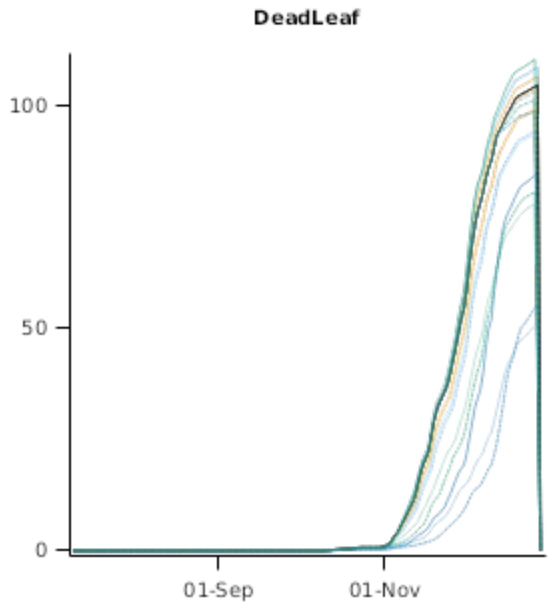
FloweringDate
Predicted
Observed
100
150
100
150



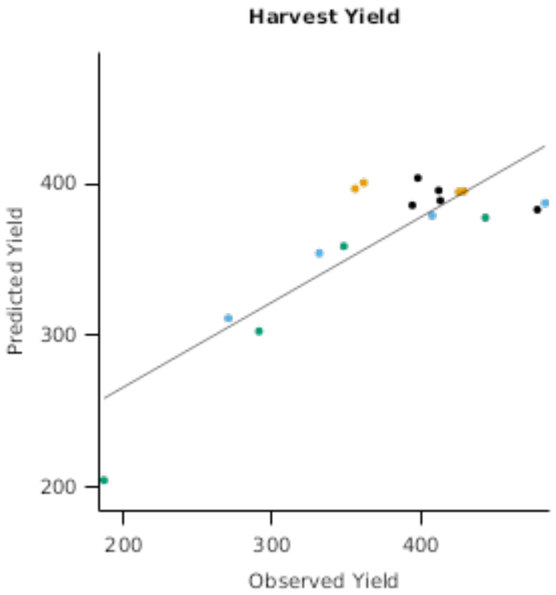
FLN
8
10
12
8
10
12

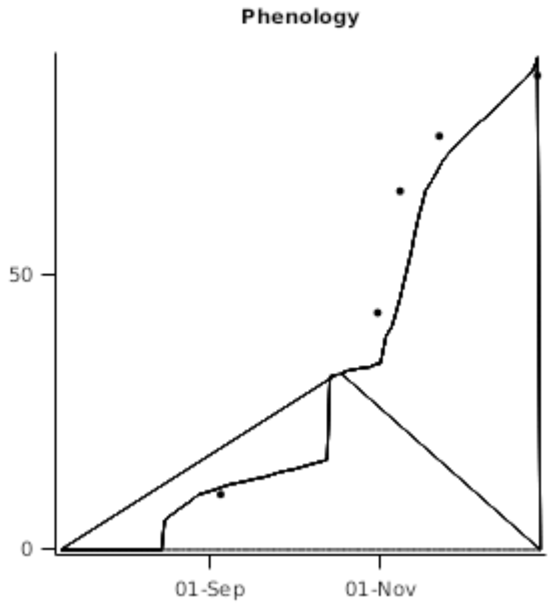
2.7.2 Mouse


Biomass
0
200
400
600
01-Sep
01-Nov
Leaf
0
100
200
01-Sep
01-Nov
Stem
Spike
0
50
100
01-Sep
01-Nov
StemPopn
0
500
1000
01-Sep
01-Nov
Grain
0
100
200
300
400
01-Sep
01-Nov



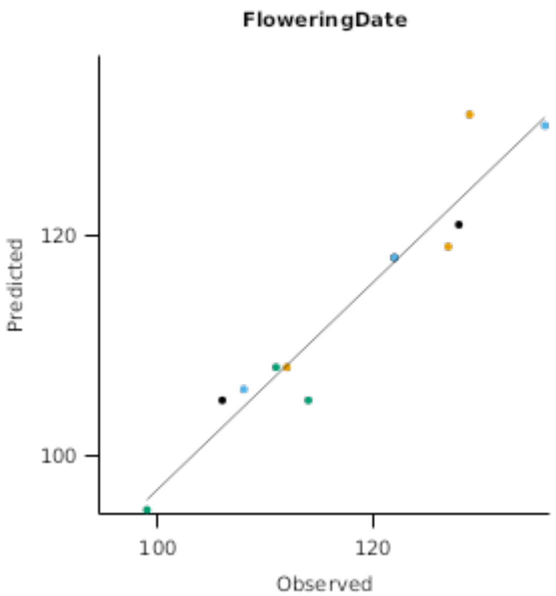
SurfaceOM





2.7.3 Walpeup2011

INSERT TEXT HERE



2.7.4 Walpeup2012

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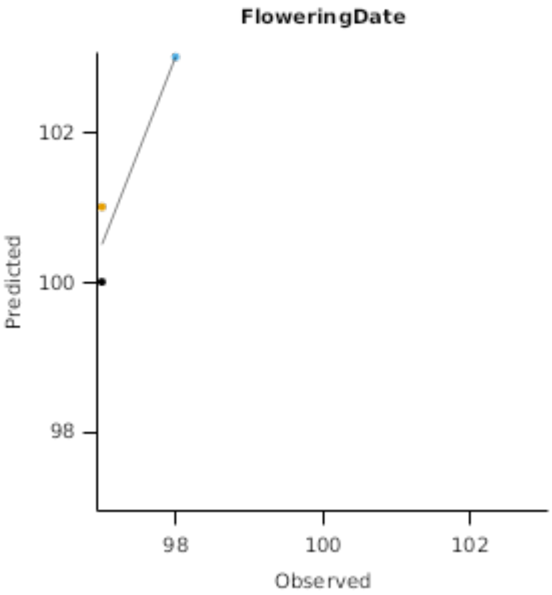

2.7.5 Minnipa2012

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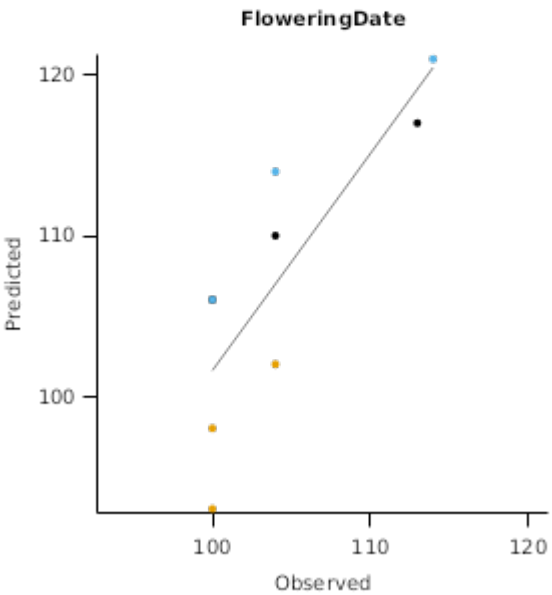

2.7.6 Temora2012

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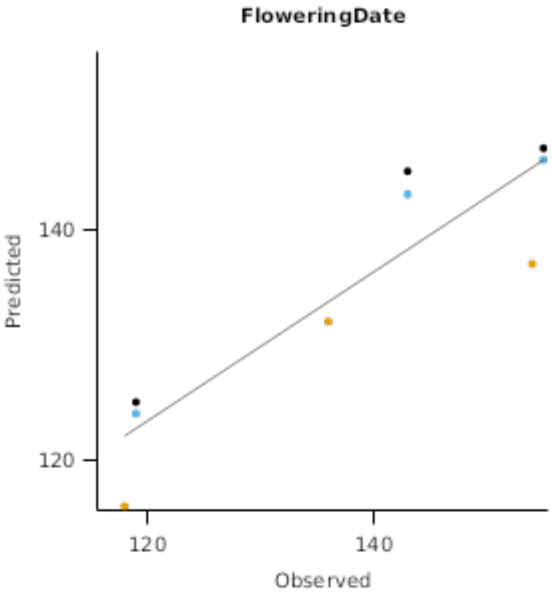
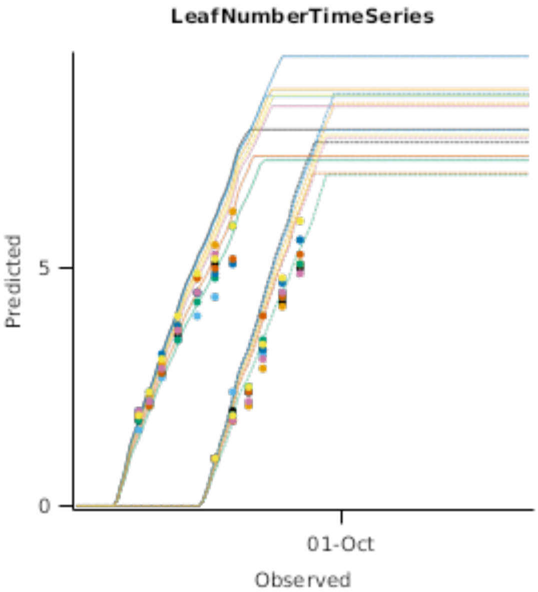
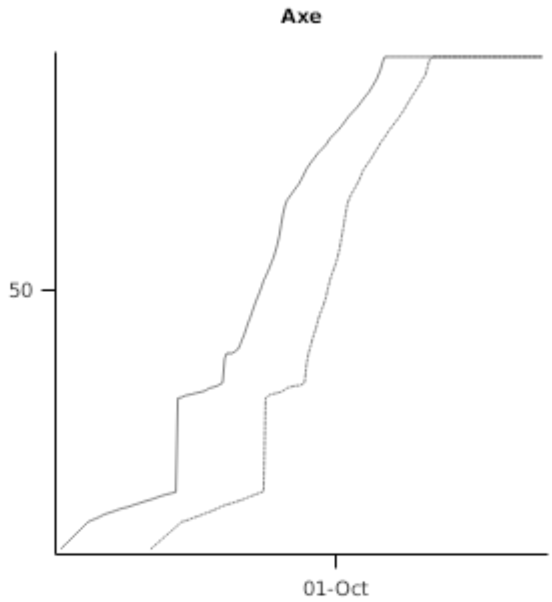
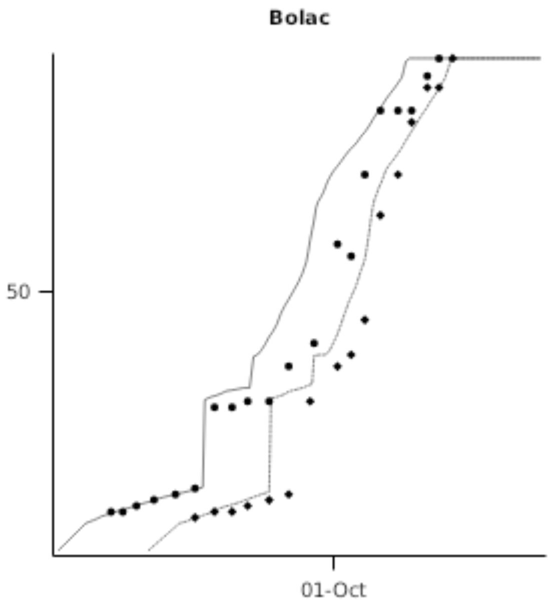
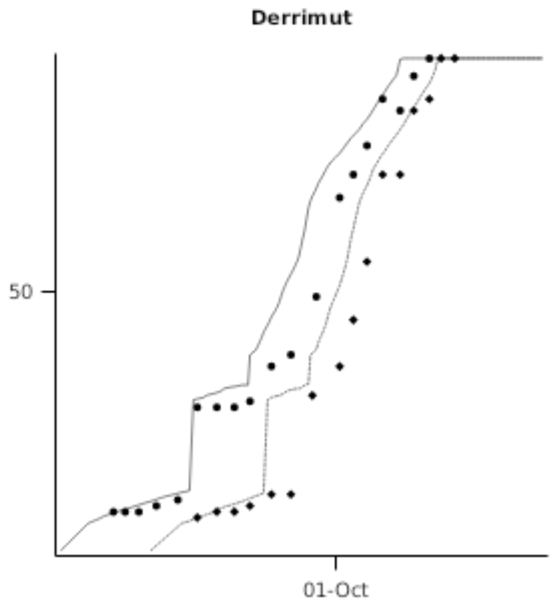


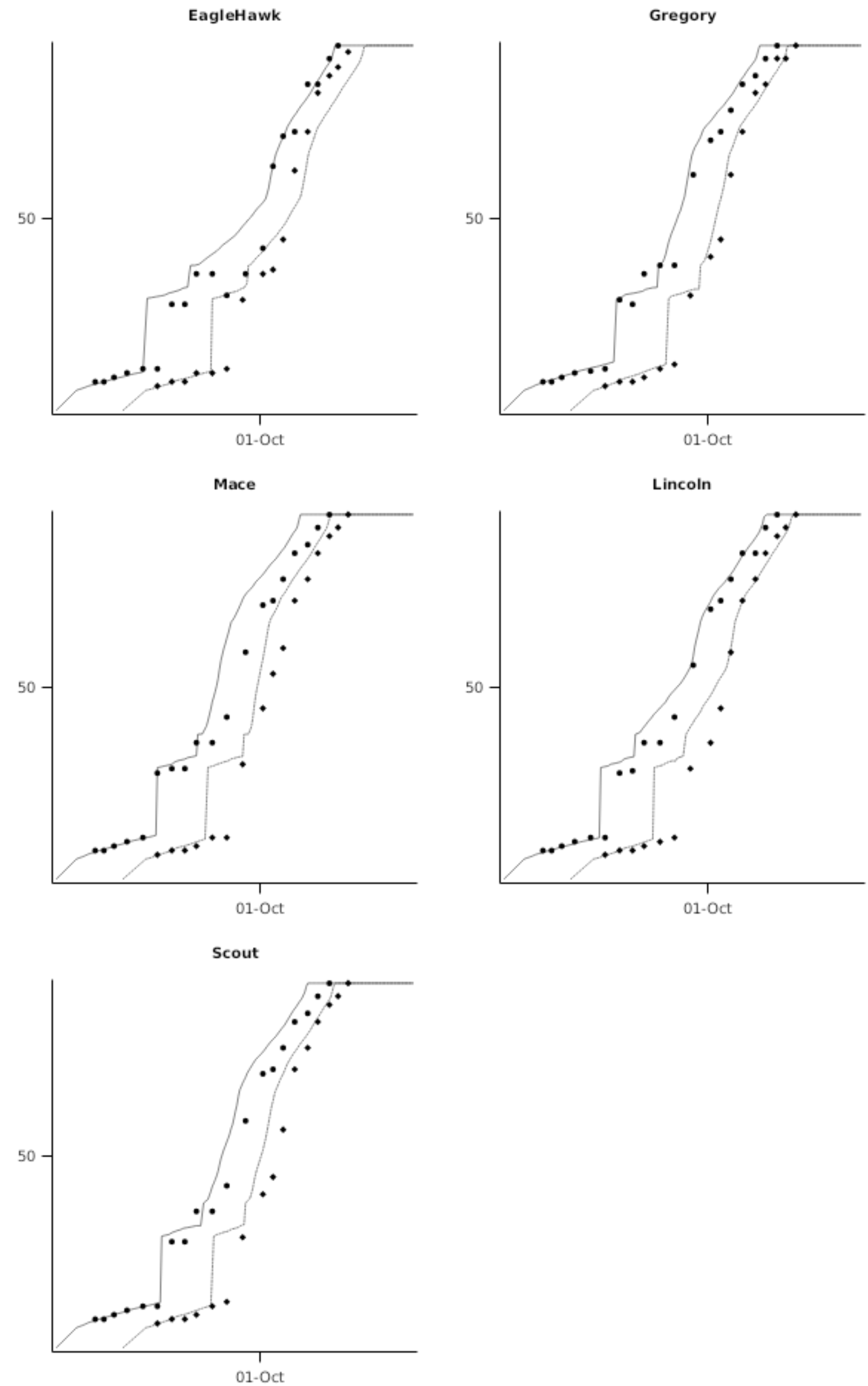
2.7.7 Birchip2011



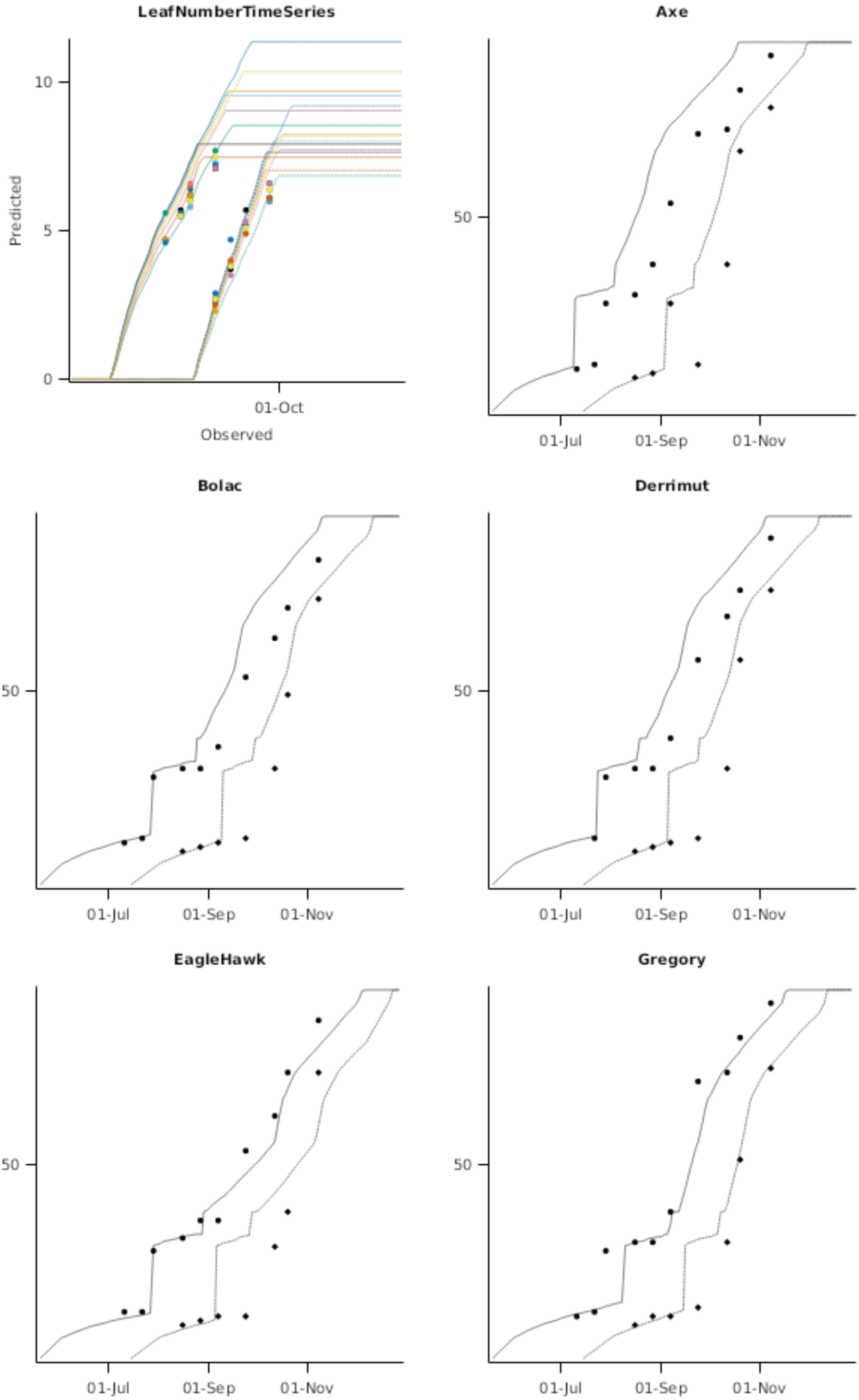




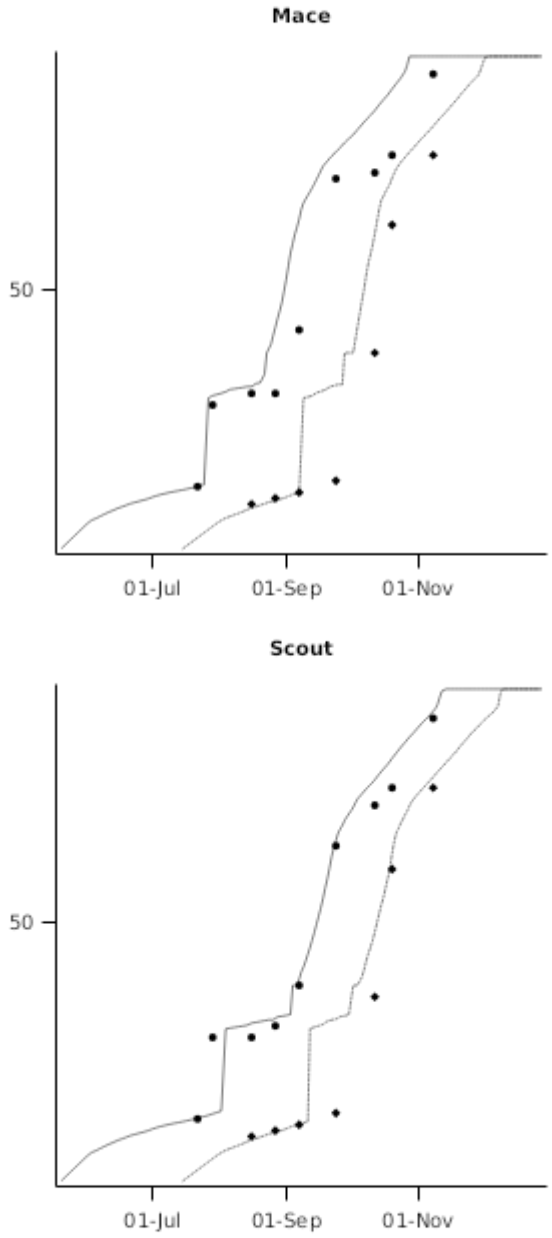




2.7.8 Tarlee2011

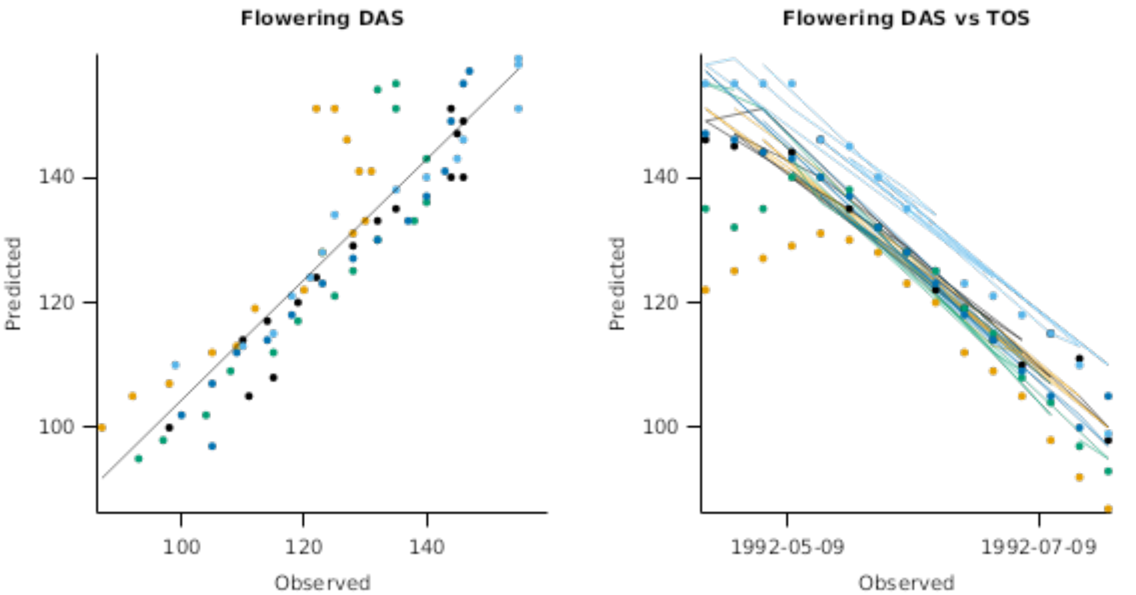


LeafNumberTimeSeries
Predicted
Observed
0
5
10
01-Oct
Axe
50
01-Jul
01-Sep
01-Nov
Bolac
50
01-Jul
01-Sep
01-Nov
Derrimut
50
01-Jul
01-Sep
01-Nov
EagleHawk
50
01-Jul
01-Sep
01-Nov
Gregory
50
01-Jul
01-Sep
01-Nov



2.7.9 Tamworth1992

This dataset includes observed flowering date for five cultivars (Batavia, Hartog, Sunbri, Sunco, Suneca) for a range planting dates at Tamworth.



2.7.10 van Herwaarden et al 1998

2.7.10.1 List of experiments

Experiment Name	Design (Number of Treatments)
Wagga1991	N (6)
Ginninderra1991	N x Cv (7)

2.7.11 Wagga1314

The dataset of K.T. Zeleke et al., 2016 includes plantings of two wheat varieties (Gregory, Livingston) under two water regimes (dry and irrigated) for 2013 and 2014 at the Wagga Wagga Agricultural Research Institute. Yields ranged from 1.63 t/ha to 6.01 t/ha.

2.7.11.1 List of experiments

Experiment Name	Design (Number of Treatments)
Wagga2013	Cv x Water (4)
Wagga2014	Cv x Water (4)

2.7.12 YarrabahCreek

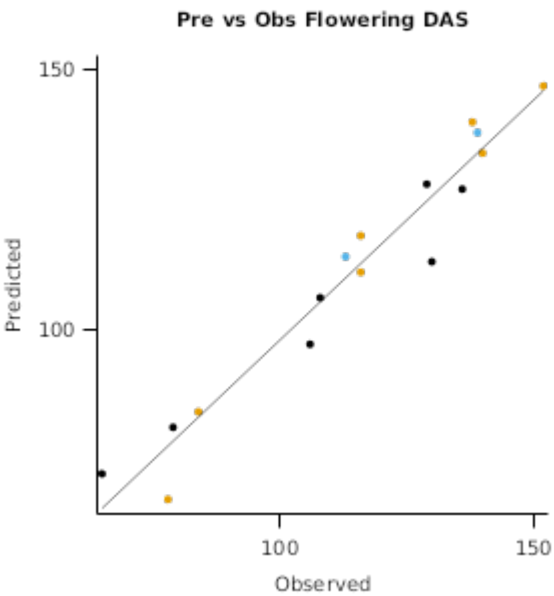
This trial was conducted on a Vertosol soil on the Liverpool Plains, central-eastern Australia in 2001. Hybrid Mercury was sown on 19th of June and biomass, leaf area, phenology, soil water (Neutron Moisture Meter) and water use (Bowen Ratio method) were monitored. More information can be found in Young et al., 2008.

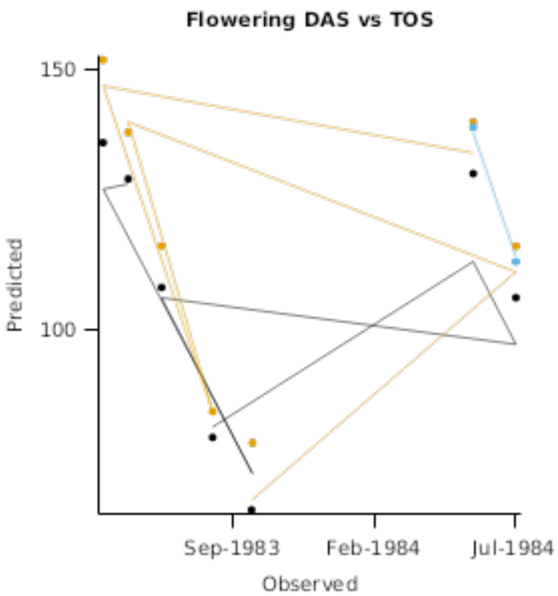
2.7.13 Griffith

This dataset from Stapper et al., 0 includes observed phenological data for range of cultivars, three of which have been used here (Yecora, Egret, Hartog). Planting dates from 1983 and 1984 provide a range of climatic conditions.

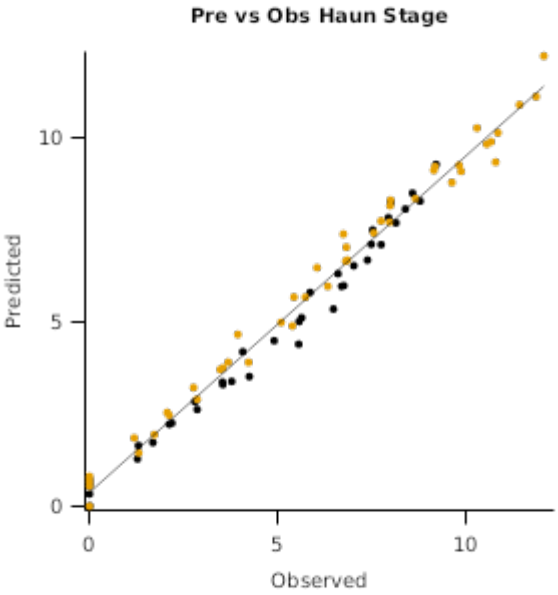
2.7.13.1 List of experiments

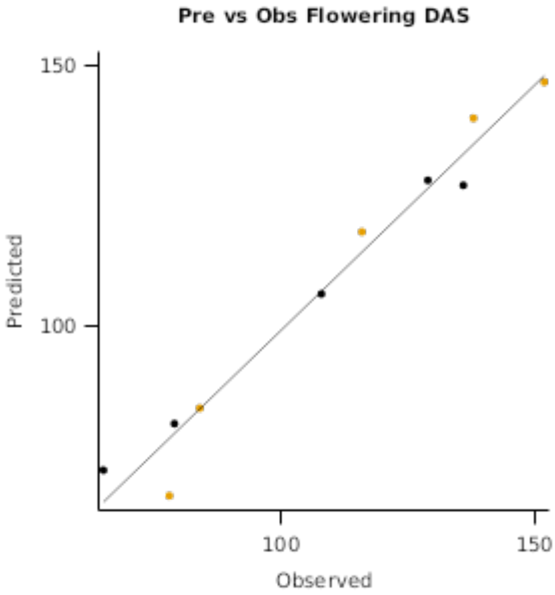
Experiment Name	Design (Number of Treatments)
Griffith1983	Cv x TOS (10)
Griffith1984	Cv x TOS (6)

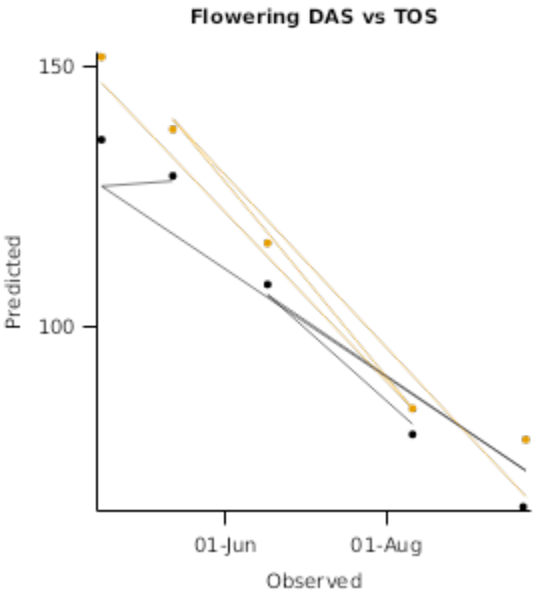


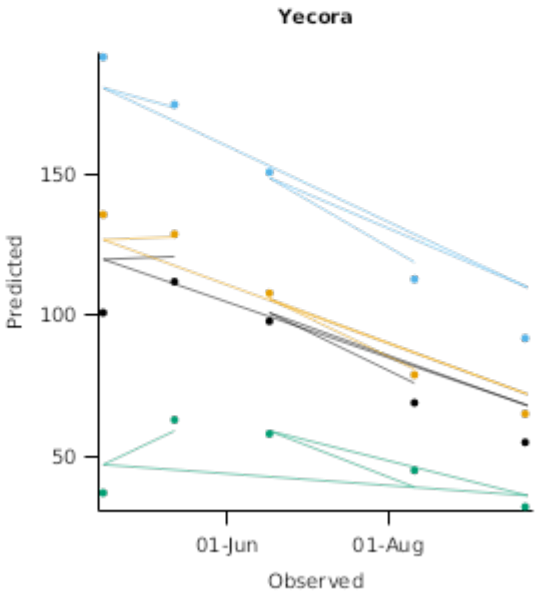


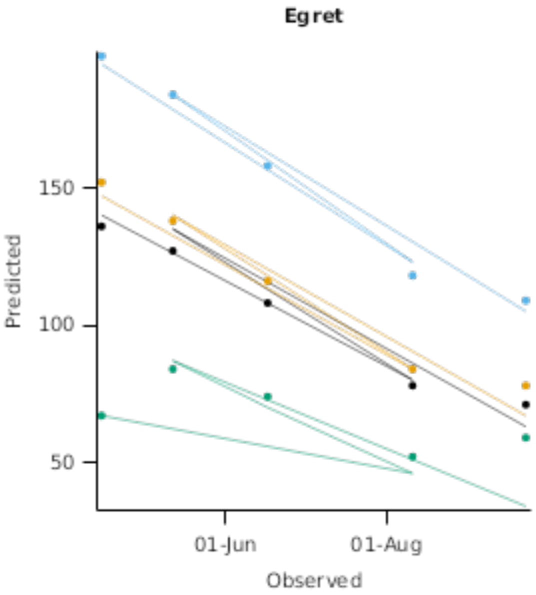
2.7.13.2 Griffith1983

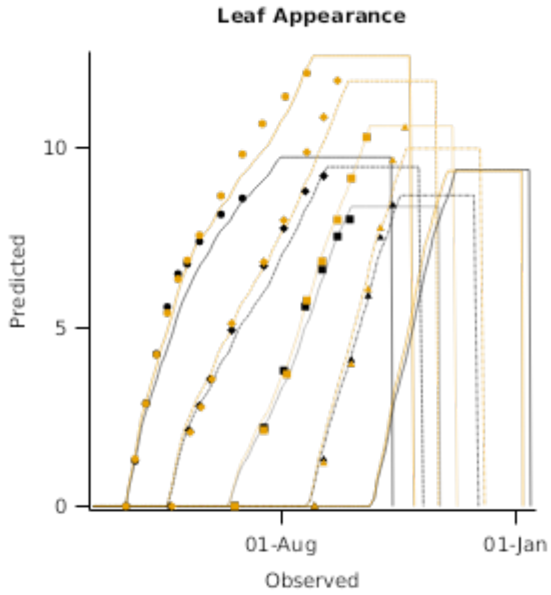

Pre vs Obs Haun Stage
Predicted
Observed
0
5
10

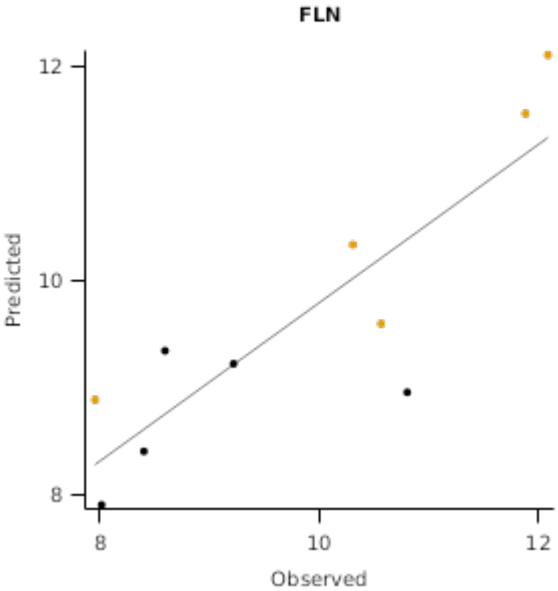

Pre vs Obs Flowering DAS
Predicted
Observed
100
150


Flowering DAS vs TOS
Predicted
Observed
100
150
01-Jun
01-Aug

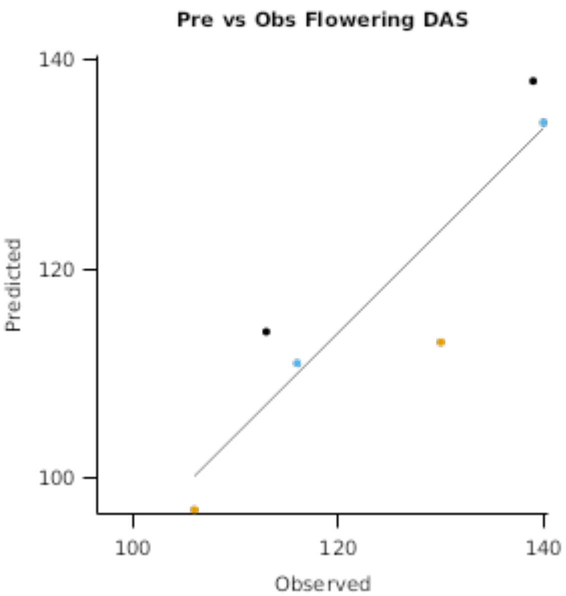

Yecora
Predicted
Observed
50
100
150
01-Jun
01-Aug

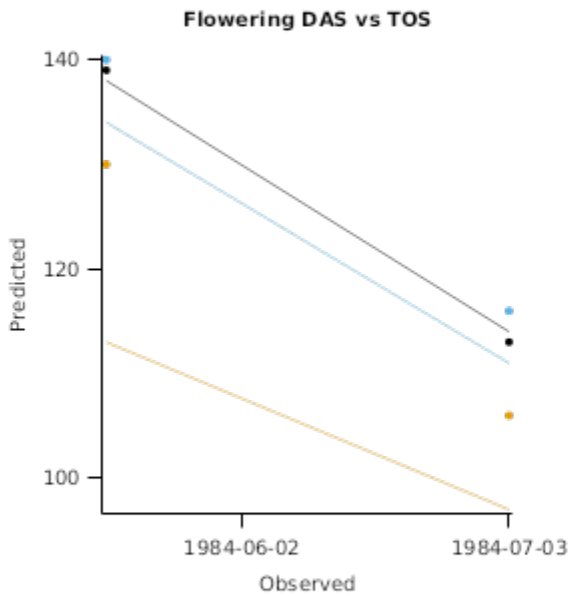






2.7.13.3 Griffith1984





2.7.14 FAR

2.7.14.1 Albany

2.7.14.1.1 List of experiments

Experiment Name	Design (Number of Treatments)
FAR WAA W20-01a	Mgmt x Cv (9)
FAR WAA W20-01b	Mgmt x Cv (9)

2.7.14.1.2 FAR WAA W20-01a

2.7.14.1.2.1 Field Applied Research (FAR) Australia trial FAR WAA W20-01a at Albany in 2020.

This trial has been selected because it used 2 cultivars with parameters already in APSIM, and had up to 2 Greenseeker (NDVI) and 3 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **Compare winter and spring wheat germplasm managed under different levels of management sown on 1 May on soil that was clayed.**

Trial write-up

2.7.14.1.3 FAR WAA W20-01b

2.7.14.1.3.1 Field Applied Research (FAR) Australia trial FAR WAA W20-01b at Albany in 2020.

This trial has been selected because it used 3 cultivars with parameters already in APSIM, and had up to 2 Greenseeker (NDVI) and 3 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **Compare winter and spring wheat germplasm managed under different levels of management sown on 1 May on soil that was un-clayed.**

Trial write-up

2.7.14.2 Esperance

2.7.14.2.1 List of experiments

Experiment Name	Design (Number of Treatments)
FAR WAE W21-05	Cv (4)
FAR WAE W22-02	Mgmt x Cv (9)

2.7.14.2.2 FAR WAE W21-05

2.7.14.2.2.1 Field Applied Research (FAR) Australia trial FAR WAE W21-05 at Esperance in 2021.

This trial has been selected because it used 4 cultivars with parameters already in APSIM, and had up to 6 Greenseeker (NDVI) and 1 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **Performance of wheat (winter and spring germplasm) sown in the early sowing window (sown 16th April) under a single high management approach (as described in Trial 3).**

Trial write-up

2.7.14.2.3 FAR WAE W22-02

2.7.14.2.3.1 Field Applied Research (FAR) Australia trial FAR WAE W22-02 at Esperance in 2022.

This trial has been selected because it used 3 cultivars with parameters already in APSIM, and had up to 6 Greenseeker (NDVI) and 4 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **Compare early sown winter and spring wheat germplasm under different levels of management (sown 16 April).**

Trial write-up

2.7.14.3 Gnarwarre

2.7.14.3.1 List of experiments

Experiment Name	Design (Number of Treatments)
FAR DMC W20-03	Mgmt x Cv (15)
FAR DMC W20-05	Grazed x Cv (4)
FAR VIC W22-03-2	Fungicide x Nutrition x Cv (4)

2.7.14.3.2 FAR DMC W20-03

2.7.14.3.2.1 Field Applied Research (FAR) Australia trial FAR DMC W20-03 at Gnarwarre in 2020.

This trial has been selected because it used 5 cultivars with parameters already in APSIM, and had up to 8 Greenseeker (NDVI) and 2 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **Performance of winter and spring wheat germplasm managed under three different levels of management (ANZAC 25 April sown).**

Trial write-up

2.7.14.3.3 FAR DMC W20-05

2.7.14.3.3.1 Field Applied Research (FAR) Australia trial FAR DMC W20-05 at Gnarwarre in 2020.

This trial has been selected because it used 1 cultivars with parameters already in APSIM, and had up to 7 Greenseeker (NDVI) and 1 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **Canopy Management A winter and spring wheat (RGT Accroc and Trojan) were hard grazed and light grazed at start of stem elongation at GS30**

Trial write-up

2.7.14.3.4 FAR VIC W22-03-2

2.7.14.3.4.1 Field Applied Research (FAR) Australia trial FAR VIC W22-03-2 at Gnarwarre in 2022.

This trial has been selected because it used 1 cultivars with parameters already in APSIM, and had up to 6 Greenseeker (NDVI) and 2 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **Genotype x Management - Time of Sowing 2**

Trial write-up

2.7.14.4 Hagley

2.7.14.4.1 List of experiments

Experiment Name	Design (Number of Treatments)
FAR HYC W17-01-1	Mgmt x Cv (6)
FAR HYC W17-01-2	Mgmt x Cv (6)
FAR HYC W17-02-1	Cv (2)
FAR HYC W17-02-2	Cv (5)
FAR TAS W16-01-1	Mgmt x Cv (6)
FAR TAS W16-01-2	Mgmt x Cv (6)
FAR TAS W16-06	PGR x Seeds x Cv (36)
FAR TAS W16-08	Nutrition x Cv (13)
FAR HYC W18-02-2	Seeds x Cv (3)
FAR HYC W18-02-2a	PGR x Cv (2)
FAR HYC W18-08-1	Nutrition x Cv (5)
FAR HYC W19-03-1	Grazed x Seeds x Cv (9)
FAR HYC W19-06-1	PGR x Cv (5)
FAR TAS W21-03-1	Mgmt x Cv (6)

2.7.14.4.2 FAR HYC W17-01-1

2.7.14.4.2.1 Field Applied Research (FAR) Australia trial FAR HYC W17-01-1 at Hagley in 2017.

This trial has been selected because it used 2 cultivars with parameters already in APSIM, and had up to 11 Greenseeker (NDVI) and 3 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **Germplasm management interaction - Time of Sowing 1**

Some trial details may be found here

2.7.14.4.3 FAR HYC W17-01-2

2.7.14.4.3.1 Field Applied Research (FAR) Australia trial FAR HYC W17-01-2 at Hagley in 2017.

This trial has been selected because it used 3 cultivars with parameters already in APSIM, and had up to 10 Greenseeker (NDVI) and 2 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **Germplasm management interaction - Time of Sowing 2**

Some trial details may be found here

2.7.14.4.4 FAR HYC W17-02-1

2.7.14.4.4.1 Field Applied Research (FAR) Australia trial FAR HYC W17-02-1 at Hagley in 2017.

This trial has been selected because it used 2 cultivars with parameters already in APSIM, and had up to 12 Greenseeker (NDVI) and 1 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **European and new lines wheat cultivar trial Time of Sowing 1**

Some trial details may be found here

2.7.14.4.5 FAR HYC W17-02-2

2.7.14.4.5.1 Field Applied Research (FAR) Australia trial FAR HYC W17-02-2 at Hagley in 2017.

This trial has been selected because it used 5 cultivars with parameters already in APSIM, and had up to 10 Greenseeker (NDVI) and 1 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **European and new lines wheat cultivar trial Time of Sowing 2**

Some trial details may be found here

2.7.14.4.6 FAR TAS W16-01-1

2.7.14.4.6.1 Field Applied Research (FAR) Australia trial FAR TAS W16-01-1 at Hagley in 2016.

This trial has been selected because it used 3 cultivars with parameters already in APSIM, and had up to 12 Greenseeker (NDVI) and 4 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **Elite Wheat Germplasm x Management Interaction Time of Sowing 1 (6 April)**

Some trial details may be found here

2.7.14.4.7 FAR TAS W16-01-2

2.7.14.4.7.1 Field Applied Research (FAR) Australia trial FAR TAS W16-01-2 at Hagley in 2016.

This trial has been selected because it used 3 cultivars with parameters already in APSIM, and had up to 14 Greenseeker (NDVI) and 2 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **Elite Wheat Germplasm x Management Interaction Time of Sowing 2 (27 April)**

Some trial details may be found here

2.7.14.4.8 FAR TAS W16-06

2.7.14.4.8.1 Field Applied Research (FAR) Australia trial FAR TAS W16-06 at Hagley in 2016.

This trial has been selected because it used 1 cultivars with parameters already in APSIM, and had up to 10 Greenseeker (NDVI) and 2 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **Wheat Plant Growth Regulator agronomy**

Some trial details may be found here

2.7.14.4.9 FAR TAS W16-08

2.7.14.4.9.1 Field Applied Research (FAR) Australia trial FAR TAS W16-08 at Hagley in 2016.

This trial has been selected because it used 1 cultivars with parameters already in APSIM, and had up to 12 Greenseeker (NDVI) and 3 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **Wheat Nitrogen agronomy**

Some trial details may be found here

2.7.14.4.10 FAR HYC W18-02-2

2.7.14.4.10.1 Field Applied Research (FAR) Australia trial FAR HYC W18-02-2 at Hagley in 2018.

This trial has been selected because it used 1 cultivars with parameters already in APSIM, and had up to 7 Greenseeker (NDVI) and 2 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **Wheat Germplasm**

Some trial details may be found here

2.7.14.4.11 FAR HYC W18-02-2a

2.7.14.4.11.1 Field Applied Research (FAR) Australia trial FAR HYC W18-02-2a at Hagley in 2018.

This trial has been selected because it used 1 cultivars with parameters already in APSIM, and had up to 7 Greenseeker (NDVI) and 3 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **Wheat Germplasm and Plant Growth Regulator Trial evaluating the top wheat cultivars plus and minus PGR input.**

Some trial details may be found here

2.7.14.4.12 FAR HYC W18-08-1

2.7.14.4.12.1 Field Applied Research (FAR) Australia trial FAR HYC W18-08-1 at Hagley in 2018.

This trial has been selected because it used 1 cultivars with parameters already in APSIM, and had up to 8 Greenseeker (NDVI) and 3 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **Nitrogen management in wheat optimising nitrogen applications for hyper yielding wheat crops (40 plots taken to yield sown 5 April).**

Some trial details may be found here

2.7.14.4.13 FAR HYC W19-03-1

2.7.14.4.13.1 Field Applied Research (FAR) Australia trial FAR HYC W19-03-1 at Hagley in 2019.

This trial has been selected because it used 1 cultivars with parameters already in APSIM, and had up to 3 Greenseeker (NDVI) and 3 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **Grazing management in early sown DS Bennett**

Some trial details may be found here

2.7.14.4.14 FAR HYC W19-06-1

2.7.14.4.14.1 Field Applied Research (FAR) Australia trial FAR HYC W19-06-1 at Hagley in 2019.

This trial has been selected because it used 1 cultivars with parameters already in APSIM, and had up to 7 Greenseeker (NDVI) and 2 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **Wheat Plant Growth Regulator agronomy trial**

Some trial details may be found here

2.7.14.4.15 FAR TAS W21-03-1

2.7.14.4.15.1 Field Applied Research (FAR) Australia trial FAR TAS W21-03-1 at Hagley in 2021.

This trial has been selected because it used 2 cultivars with parameters already in APSIM, and had up to 5 Greenseeker (NDVI) and 1 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **Performance of winter and spring wheat germplasm managed under three different levels of management (ANZAC 25 April sown).**

Trial write-up

2.7.14.5 Millicent

2.7.14.5.1 List of experiments

Experiment Name	Design (Number of Treatments)
FAR SAC W18-01	Mgmt x Cv (12)
FAR SAC W18-02	Fungicide x Cv (14)
FAR SAC W19-01	Mgmt x Cv (12)
FAR SAC W19-02	Fungicide x Cv (12)
FAR SAC W20-03-2	Mgmt x Cv (12)
FAR SAC W20-05-1	Grazed x Cv (4)
FAR SAC W22-03-2	Fungicide x N x Cv (4)

2.7.14.5.2 FAR SAC W18-01

2.7.14.5.2.1 Field Applied Research (FAR) Australia trial FAR SAC W18-01 at Millicent in 2018.

This trial has been selected because it used 4 cultivars with parameters already in APSIM, and had up to 9 Greenseeker (NDVI) and 0 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **Genotype x management**

Some trial details may be found here

2.7.14.5.3 FAR SAC W18-02

2.7.14.5.3.1 Field Applied Research (FAR) Australia trial FAR SAC W18-02 at Millicent in 2018.

This trial has been selected because it used 7 cultivars with parameters already in APSIM, and had up to 10 Greenseeker (NDVI) and 0 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **Response to fungicide**

Some trial details may be found here

2.7.14.5.4 FAR SAC W19-01

2.7.14.5.4.1 Field Applied Research (FAR) Australia trial FAR SAC W19-01 at Millicent in 2019.

This trial has been selected because it used 4 cultivars with parameters already in APSIM, and had up to 9 Greenseeker (NDVI) and 3 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **Germplasm management interaction**

Trial write-up

2.7.14.5.5 FAR SAC W19-02

2.7.14.5.5.1 Field Applied Research (FAR) Australia trial FAR SAC W19-02 at Millicent in 2019.

This trial has been selected because it used 4 cultivars with parameters already in APSIM, and had up to 7 Greenseeker (NDVI) and 1 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **Germplasm response to fungicide management**

Trial write-up

2.7.14.5.6 FAR SAC W20-03-2

2.7.14.5.6.1 Field Applied Research (FAR) Australia trial FAR SAC W20-03-2 at Millicent in 2020.

This trial has been selected because it used 4 cultivars with parameters already in APSIM, and had up to 6 Greenseeker (NDVI) and 1 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **Performance of winter and spring wheat germplasm managed under three different levels of management (mid-May sown).**

Trial write-up

2.7.14.5.7 FAR SAC W20-05-1

2.7.14.5.7.1 Field Applied Research (FAR) Australia trial FAR SAC W20-05-1 at Millicent in 2020.

This trial has been selected because it used 1 cultivars with parameters already in APSIM, and had up to 8 Greenseeker (NDVI) and 1 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **Canopy Management - assess the value of pre and post GS30 defoliation in winter and spring germplasm grown in HRZ regions of different season lengths using 17th April sowing date.**

Trial write-up

2.7.14.5.8 FAR SAC W22-03-2

2.7.14.5.8.1 Field Applied Research (FAR) Australia trial FAR SAC W22-03-2 at Millicent in 2022.

This trial has been selected because it used 1 cultivars with parameters already in APSIM, and had up to 7 Greenseeker (NDVI) and 2 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **Genotype x Management - Time of Sowing 2**

Trial write-up

2.7.14.6 Wallendbeen

2.7.14.6.1 List of experiments

Experiment Name	Design (Number of Treatments)
FAR RRC W21-03	Mgmt x Cv (9)
FAR RRC W22-03	Canopy x Fungicide x Cv (8)

2.7.14.6.2 FAR RRC W21-03

2.7.14.6.2.1 Field Applied Research (FAR) Australia trial FAR RRC W21-03 at Wallendbeen in 2021.

This trial has been selected because it used 3 cultivars with parameters already in APSIM, and had up to 6 Greenseeker (NDVI) and 3 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **Performance of winter and spring wheat germplasm managed under three different levels of management (20th April sown).**

Trial write-up

2.7.14.6.3 FAR RRC W22-03

2.7.14.6.3.1 Field Applied Research (FAR) Australia trial FAR RRC W22-03 at Wallendbeen in 2022.

This trial has been selected because it used 1 cultivars with parameters already in APSIM, and had up to 3 Greenseeker (NDVI) and 3 biomass measurements.

Treatments with suboptimal fungicide applications (if made) have been excluded.

Trial description: **Genotype x Management 3 cultivars tested under 2 fungicide programs (single spray and High input) and 4 Canopy management strategies (Standard 150kg N/ha**

Trial write-up

2.8 Europe

2.8.1 Belgium

This trial was conducted at Lonzee near Gembuloux in Belgium and is described in detail by Dufranne et al., 2011 and Moureaux et al., 2008. The trial was run to measure carbon flux from wheat crops using eddy covariance but sufficient crop information was collected to make it suitable as a model validataion dataset also. Crops of wheat (cultivars 'Dekan', 'Rosario', 'Ararat' for the three respective sowing dates) were sown on 14/10/2004, 13/10/2004 and 13/11/2004. Standard management practices for winter wheat in this area were followed. Dates for the timing of key phenological events were used to determine the developmental coefficients for each of the cultivars.

2.9 NorthAmerica

2.9.1 Arizona

These FACE trials were conducted to investigate the effects of atmospheric CO2 concentrations and water stress on wheat growth and development [Hanksar_1996_FACE]. It was conducted at Maricopa, Arazona using Free Air Carbon Enrichment to create elevated CO2 treatments:

1. Normal CO2 (370 ppm) (that is no longer normal)
2. High CO2 (550 ppm)

Irrigation treatmetnts were also applied with:

1. High Irrigation (~600 mm)
2. Low irrigation (~265 mm)

Crop development, Biomass production and soil moisture were monitored throughout the crops duration.

2.9.1.1 List of experiments

Experiment Name	Design (Number of Treatments)
ArizonaFACE92	CO_2 x Irr (4)
ArizonaFACE93	CO_2 x Irr (4)

2.9.1.2 ArizonaFACE92

This trial was conducted to investigate the effects of atmospheric CO_2 concentrations and water stress on wheat growth and development [Hanksar_1996_FACE]. It was conducted at Maricopa, Arazona using Free Air Carbon Enrichment to create elevated CO_2 treatments:

1. Normal CO_2 (370 ppm) (that is no longer normal)
2. High CO_2 (550 ppm)

Irrigation treatmetnts were also applied with:

1. High Irrigation (~600 mm)
2. Low irrigation (~265 mm)

Crop development, Biomass production and soil moisture were monitored throughout the crops duration.

2.10 Africa

This trial was run in the Jamma district of the Amhara region of the Ethiopia country of the Africa contenentand is described in full by Getu, 2012. 'HAR 1685' Wheat was sown in 20 cm row spacing. Different N fertiliser treatments were applied:

1. 0NUSG = 0kg N/ha
2. 23NUSG = 23 kg N/ha as Urea Super Granules (a slow release urea product)
3. 46NUSG = 46 kg N/ha as Urea Super Granules
4. 69NUSG = 69 kg N/ha as Urea Super Granules
5. 46NUC = 46 kg N/ha as Uncoated Urea

2.10.1 List of experiments

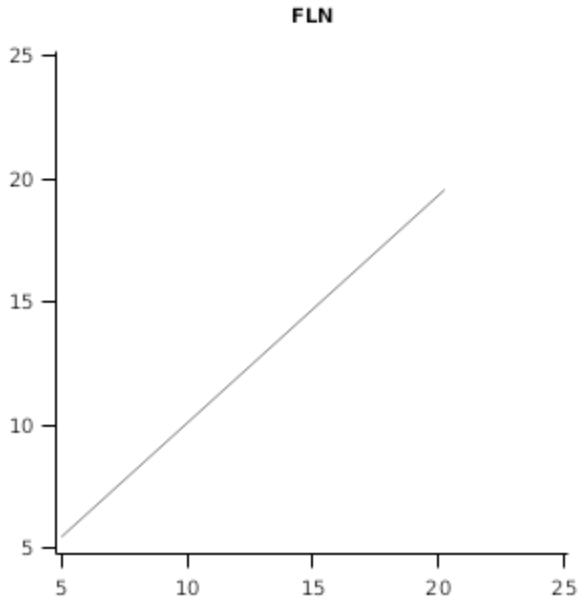
Experiment Name	Design (Number of Treatments)
Jamma	NRate (5)

2.10.2 Jamma

2.11 ControlledEnvironment

2.11.1 List of experiments

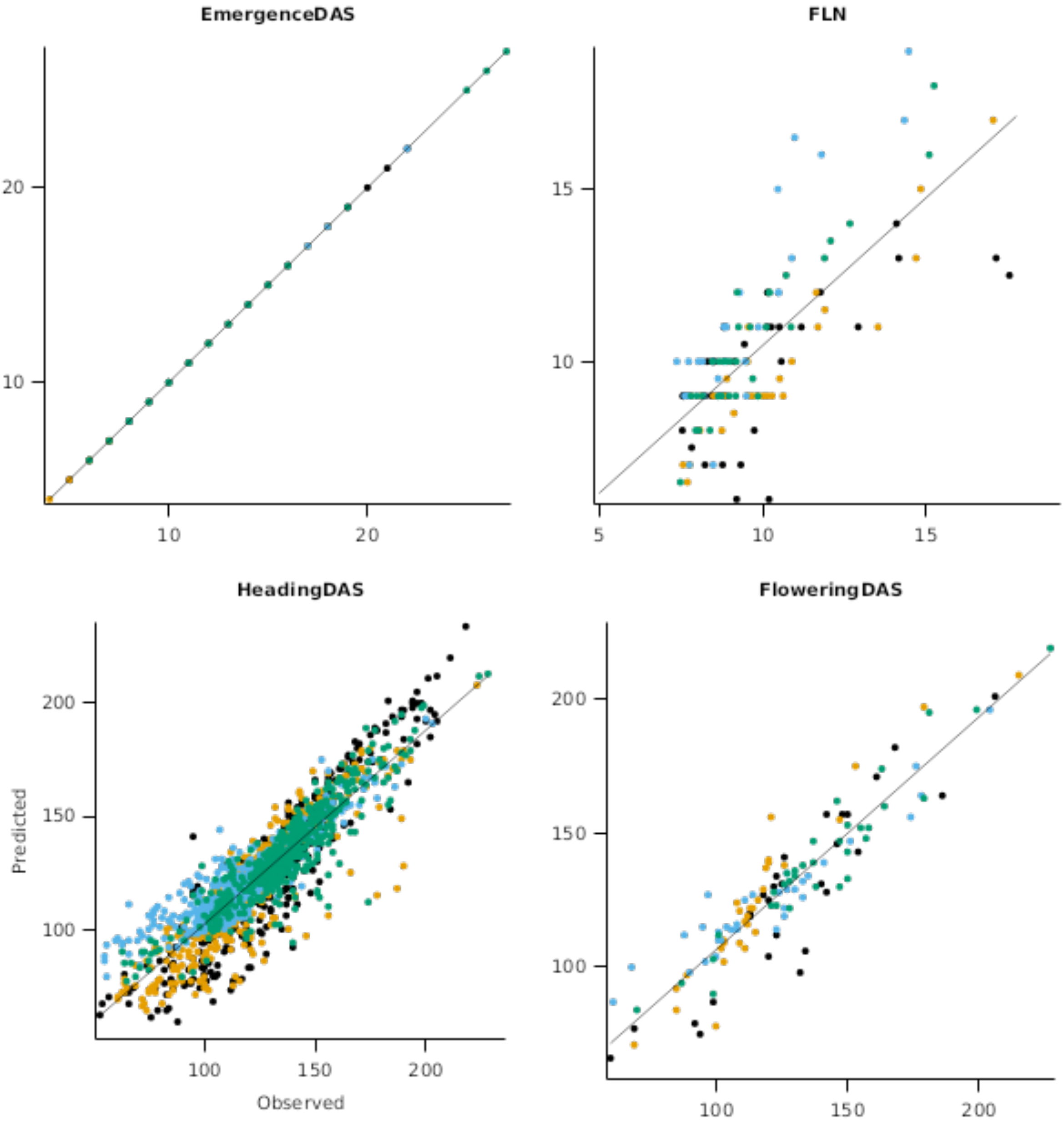
Experiment Name	Design (Number of Treatments)
LaTrobeCE	Treat x CV x Durat (276)
PalmerstonNorthCE	Treat x Cv x Durat (208)
LincolnCE	Treat x Cv x Durat (24)



2.12 NPIField2019

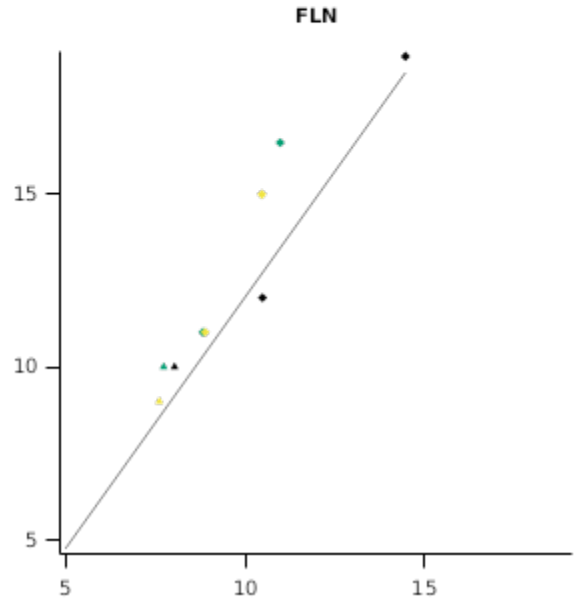
2.12.1 List of experiments

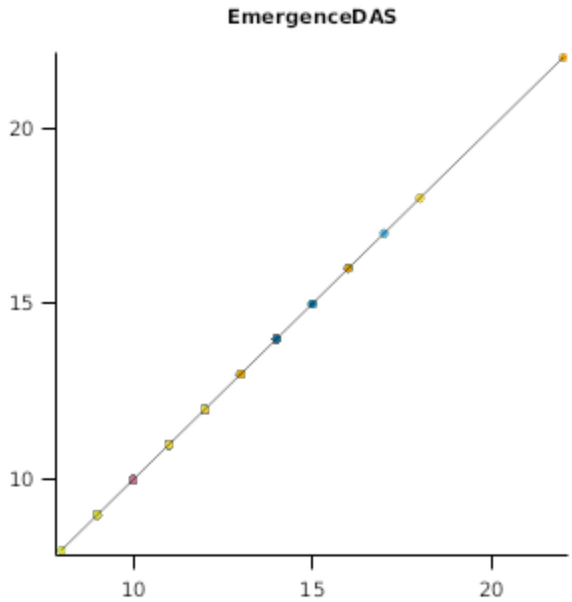
Experiment Name	Design (Number of Treatments)
WaggaWagga	TOS x Cv (512)
Callington	TOS x Cv (512)
Dale	TOS x Cv (512)
YanYean	TOS x Cv (512)


EmergenceDAS
FLN
HeadingDAS
FloweringDAS
Predicted
Observed

2.12.2 Dale

HaunStage





2.13 NPIValidation

2.13.1 List of experiments

Experiment Name	Design (Number of Treatments)
SGEHEAT_13GEHEAT-1	Cultivar (6)
SGEHEAT_13GEHEAT-2	Cultivar (6)
14SSOW-1	Cultivar (34)
14SSOW-2	Cultivar (35)
14SSOW-4	Cultivar (34)
14SSOW-5	Cultivar (31)
12JuneeJames-1-100	Cultivar (2)
12JuneeJames-1-50	Cultivar (1)
12JuneeJames-2-100	Cultivar (2)
12JuneeJames-2-50	Cultivar (1)

Experiment Name	Design (Number of Treatments)
12JuneeJames-3-100	Cultivar (3)
12JuneeJames-4-100	Cultivar (2)
BCVT_Ardingly_1992-06-19	Cultivar (1)
BCVT_Badgingarra_2005-05-26	Cultivar (1)
BCVT_Badgingarra_2005-05-28	Cultivar (1)
BCVT_Badjaling_2003-05-30	Cultivar (1)
BCVT_Chapman_1992-06-23	Cultivar (1)
BCVT_Chapman_1992-06-24	Cultivar (1)
BCVT_Chapman_1994-06-10	Cultivar (1)
BCVT_Gairdner_River_2004-06-09	Cultivar (1)
BCVT_Georgina_1992-06-26	Cultivar (1)
BCVT_Konnongorring_1997-06-13	Cultivar (1)
BCVT_Konnongorring_1997-06-27	Cultivar (1)
BCVT_Kumarl_1999-05-22	Cultivar (1)
BCVT_Kunjin_2005-05-26	Cultivar (1)
BCVT_Meckering_2003-06-04	Cultivar (1)
BCVT_Merredin_1995-05-30	Cultivar (1)
BCVT_Merredin_1996-06-25	Cultivar (1)
BCVT_Merredin_1996-07-02	Cultivar (1)
BCVT_Merredin_1998-06-19	Cultivar (1)
BCVT_Merredin_2000-06-19	Cultivar (1)
BCVT_Merredin_2002-06-10	Cultivar (1)
BCVT_Merredin_2003-06-06	Cultivar (2)
BCVT_Mt_Madden_1994-06-13	Cultivar (1)
BCVT_Mukinbudin_2000-06-13	Cultivar (1)
BCVT_Mullewa_1993-06-04	Cultivar (1)
BCVT_Mullewa_2004-05-28	Cultivar (1)
BCVT_Munglinup_1994-06-08	Cultivar (1)
BCVT_Scaddan_1999-05-25	Cultivar (1)
BCVT_Speddingup_2001-05-30	Cultivar (1)
BCVT_Tammin_1999-06-09	Cultivar (1)
BCVT_Wannamal_1992-06-25	Cultivar (1)
BCVT_Wongan_Hills_1998-06-09	Cultivar (1)
BCVT_Wongan_Hills_2001-06-11	Cultivar (1)

Experiment Name	Design (Number of Treatments)
BCVT_Wongan_Hills_2002-06-09	Cultivar (1)
BTOS_2008GE1	Cultivar (6)
BTOS_2008GE2	Cultivar (7)
BTOS_2008GE3	Cultivar (8)
BTOS_2008GE4	Cultivar (11)
BTOS_2008KA1	Cultivar (2)
BTOS_2008KA2	Cultivar (1)
BTOS_2008KA3	Cultivar (5)
BTOS_2008KA4	Cultivar (12)
BTOS_2008NM2	Cultivar (1)
BTOS_2008NM3	Cultivar (12)
BTOS_2008NM4	Cultivar (12)
BTOS_2009GE1	Cultivar (5)
BTOS_2009GE2	Cultivar (2)
BTOS_2009GE3	Cultivar (10)
BTOS_2009GE4	Cultivar (12)
BTOS_2009KA3	Cultivar (3)
BYIE_08HIR	Cultivar (4)
BYIE_08KA	Cultivar (7)
BYIE_08NB	Cultivar (13)
BYIE_08RS	Cultivar (13)
BYIE_08WH	Cultivar (13)
BYIE_09ER	Cultivar (12)
BYIE_09GN	Cultivar (13)
BYIE_09HIR	Cultivar (1)
BYIE_09KA	Cultivar (7)
BYIE_09MDL	Cultivar (14)
BYIE_09RS	Cultivar (5)
BYIE_09WH	Cultivar (14)
PTOS_10Kairi-1	Cultivar (8)
PTOS_10Kairi-2	Cultivar (8)
PTOS_10Kairi-3	Cultivar (7)
PTOS_10Kairi-4	Cultivar (7)
PTOS_10Kairi-5	Cultivar (9)

Experiment Name	Design (Number of Treatments)
PTOS_10Mackay-1	Cultivar (8)
PTOS_10Mackay-2	Cultivar (8)
PTOS_10Mackay-3	Cultivar (7)
PTOS_10Mackay-4	Cultivar (7)
PTOS_10Mackay-5	Cultivar (9)
HAGT_09Roseworthy-1	Cultivar (2)
HAGT_09Roseworthy-2	Cultivar (2)
HAGT_09Roseworthy-3	Cultivar (2)
HAGT_09Roseworthy-4	Cultivar (3)
HAGT_09Roseworthy-5	Cultivar (3)
17CuryoMESW-TOS1	Cultivar (5)
17CuryoMESW-TOS2	Cultivar (5)
17CuryoMESW-TOS3	Cultivar (5)
17CuryoMESW-TOS4	Cultivar (5)
17HartMESW-TOS1	Cultivar (5)
17HartMESW-TOS2	Cultivar (5)
17HartMESW-TOS3	Cultivar (5)
17HartMESW-TOS4	Cultivar (5)
17LoxtonMESW-TOS1	Cultivar (5)
17LoxtonMESW-TOS2	Cultivar (5)
17LoxtonMESW-TOS3	Cultivar (5)
17LoxtonMESW-TOS4	Cultivar (5)
17MilduraMESW-TOS1	Cultivar (5)
17MilduraMESW-TOS2	Cultivar (5)
17MilduraMESW-TOS3	Cultivar (5)
17MilduraMESW-TOS4	Cultivar (5)
17MinnipaMESW-TOS1	Cultivar (4)
17MinnipaMESW-TOS2	Cultivar (4)
17MinnipaMESW-TOS3	Cultivar (4)
17MinnipaMESW-TOS4	Cultivar (4)
18HartMESW-TOS1	Cultivar (5)
18HartMESW-TOS2	Cultivar (5)
18HartMESW-TOS3	Cultivar (5)
18HartMESW-TOS4	Cultivar (5)

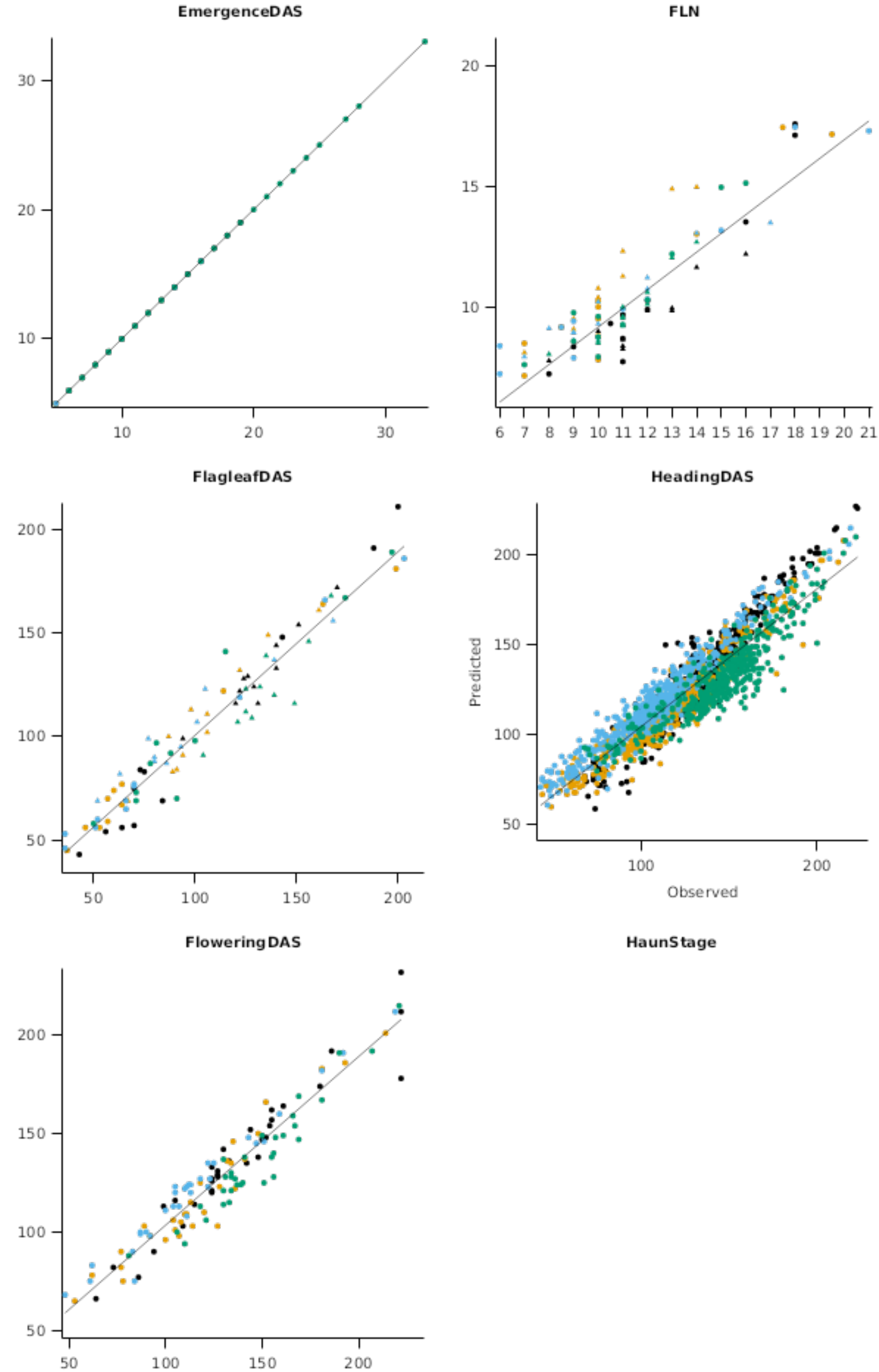
Experiment Name	Design (Number of Treatments)
18LoxtonMESW-TOS1	Cultivar (5)
18LoxtonMESW-TOS2	Cultivar (5)
18LoxtonMESW-TOS3	Cultivar (5)
18LoxtonMESW-TOS4	Cultivar (5)
18MilduraMESW-TOS1	Cultivar (5)
18MilduraMESW-TOS2	Cultivar (5)
18MilduraMESW-TOS3	Cultivar (5)
18MilduraMESW-TOS4	Cultivar (5)
Inverleigh2013-TOS1	Cultivar (1)
Inverleigh2013-TOS2	Cultivar (1)
Temora2015-TOS1	Cultivar (7)
Temora2015-TOS2	Cultivar (7)
Temora2015-TOS3	Cultivar (7)
Temora2015-TOS4	Cultivar (7)
Brookstead2015-TOS1	Cultivar (3)
Brookstead2015-TOS2	Cultivar (3)
Brookstead2015-TOS3	Cultivar (3)
Emerald2015-TOS1	Cultivar (3)
Emerald2015-TOS2	Cultivar (3)
Emerald2015-TOS3	Cultivar (3)
Minnipa2015-TOS1	Cultivar (4)
Minnipa2015-TOS2	Cultivar (4)
Minnipa2015-TOS3	Cultivar (4)
Temora2016-TOS4	Cultivar (2)
Hart2015-TOS1	Cultivar (2)
Hart2015-TOS2	Cultivar (2)
Hart2015-TOS3	Cultivar (2)
Inverleigh2013-TOS3	Cultivar (1)
Inverleigh2013-TOS4	Cultivar (1)

2.14 NPIField2020

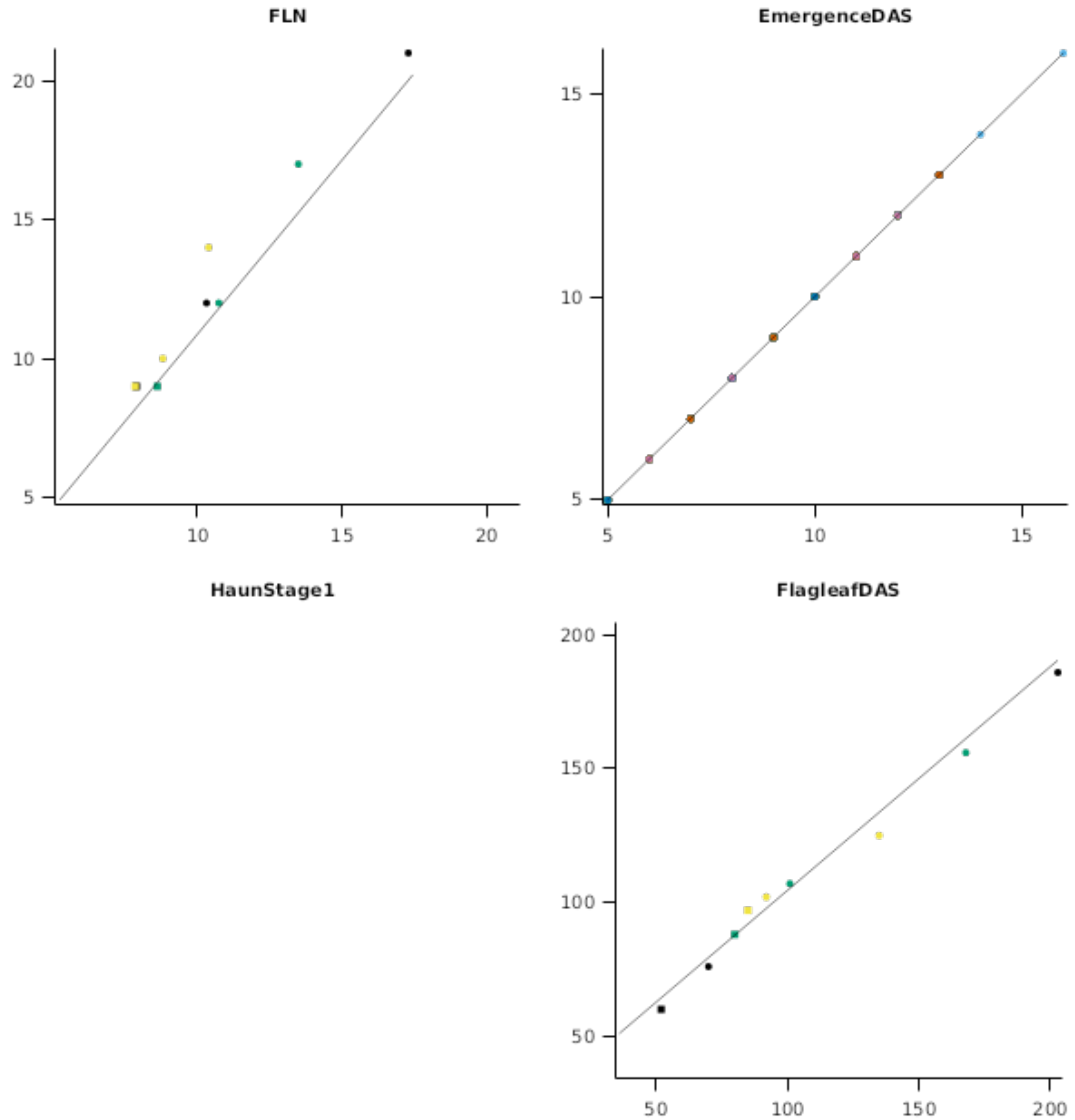
2.14.1 List of experiments

Experiment Name	Design (Number of Treatments)
WaggaWagga2020	TOS x Cv (504)
Urrbrae2020	TOS x Cv (504)

Experiment Name	Design (Number of Treatments)
Dale2020	TOS x Cv (504)
YanYean2020	TOS x Cv (441)



2.14.2 Dale2020



3 Sensibility

3.1 CO2AndTranspirationEfficiency

3.1.1 List of experiments

Experiment Name	Design (Number of Treatments)
CO2TE	CO2 (2)

3.1.2 CO2TE

This test examines the impact of a doubling of CO2 from historical (350ppm) on Transpiration Efficiency. Reyenga et al., 1999 suggest an increase of approximately 37% in Transpiration Efficiency over this range in CO2 concentration. In this test, a series of wheat crops are simulated for Dalby, Queensland, Australia. Nitrogen limitation is removed. The slope of plots of biomass production vs crop water use is used to quantify a gross seasonal TE. The change in slope should approximate the response suggested by Reyenga et al., 1999.

3.2 CO2AndTemperatureInteractions

3.2.1 List of experiments

Experiment Name	Design (Number of Treatments)
CO2XTemperature	CO2 x MaxT (16)

3.2.2 CO2XTemperature

This test examines the impact and interactions between increasing temperature and increasing CO2. Constant weather conditions are applied with daily maximum temperature increasing between treatments (20C to 35C). CO2 is constant and but doubles between treatments (350ppm to 700ppm).

3.3 ProteinAccumulation

3.3.1 List of experiments

Experiment Name	Design (Number of Treatments)
ProteinAccumulation	NRate (2)
NResponse	NRate (8)
WaterResponse	Irrigation (5)
PotentialGrainSize	Value (3)

3.3.2 ProteinAccumulation

This sensibility test investigates the time course of protein and mass accumulation in grains in response to water stress levels.

3.3.3 NResponse

This sensibility test investigates the time course of protein and mass accumulation in grains in response to water stress levels.

3.3.4 WaterResponse

This sensibility test investigates the time course of protein and mass accumulation in grains in response to water stress levels.

3.3.5 PotentialGrainSize

This sensibility test investigates the time course of protein and mass accumulation in grains in response to water stress levels.

3.4 TerminalWaterStress

3.4.1 List of experiments

Experiment Name	Design (Number of Treatments)
TerminalWaterStress	Irrigation (2)

3.4.2 TerminalWaterStress

This sensibility test investigates the time course of protein and mass accumulation in grains in response to water stress levels.

3.5 DetailedDynamics

3.5.1 List of experiments

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

3.5.2 DetailedDynamics

This sensibility test investigates the time course of dry matter and nitrogen content in plant organs within a growing season.

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