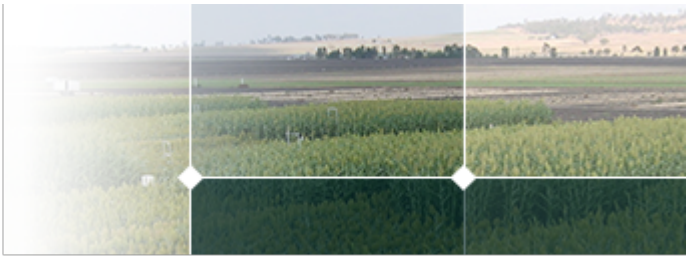


1 The APSIM Wheat Model

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

The APSIM wheat 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 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

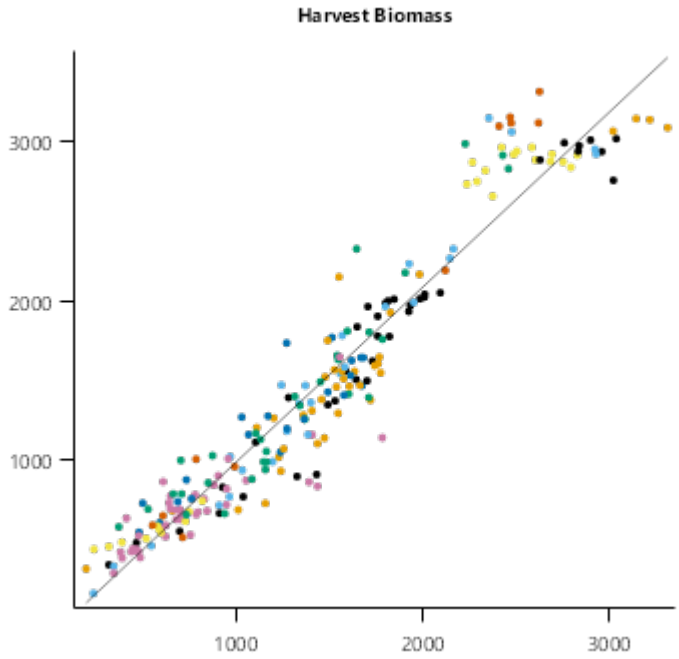
This work builds upon earlier APSIM Wheat models such as NWheat (S Asseng et al., 2002, BA Keating, 2001), NWheatS (S Asseng et al., 1998), Cropmod-Wheat (Wang et al., 2002), and the earlier versions developed in Plant (APSIM Wheat 7.5") and then within the Plant Modelling Framework (Brown et al., 2014).

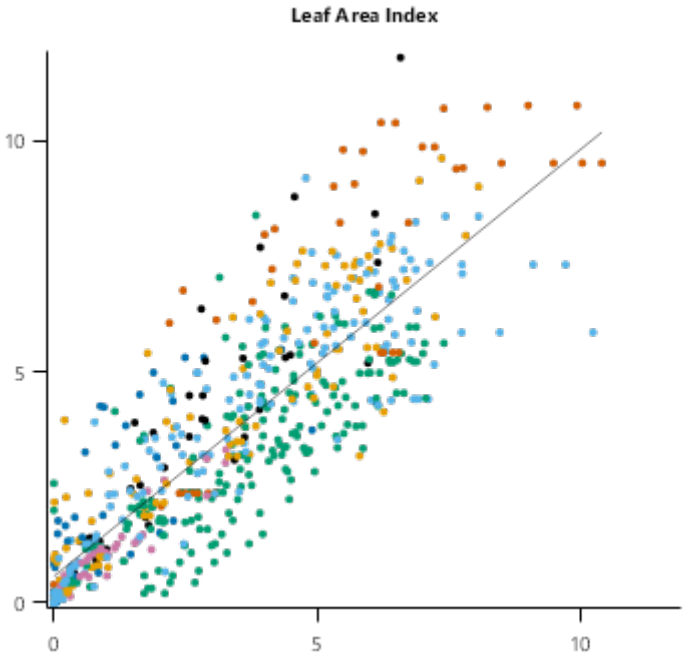
2 Validation

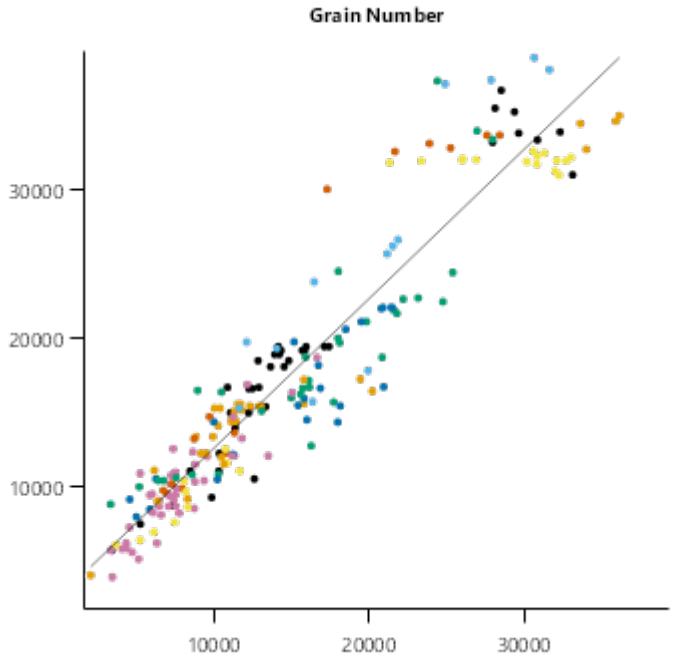
A test dataset has been developed to test the APSIM Wheat model for a range of environmental (soil and climate) conditions, management options (sowing dates, populations, nitrogen rates, row spacing, irrigation), genetic backgrounds (different regions, cultivar types) and for special considerations such 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.

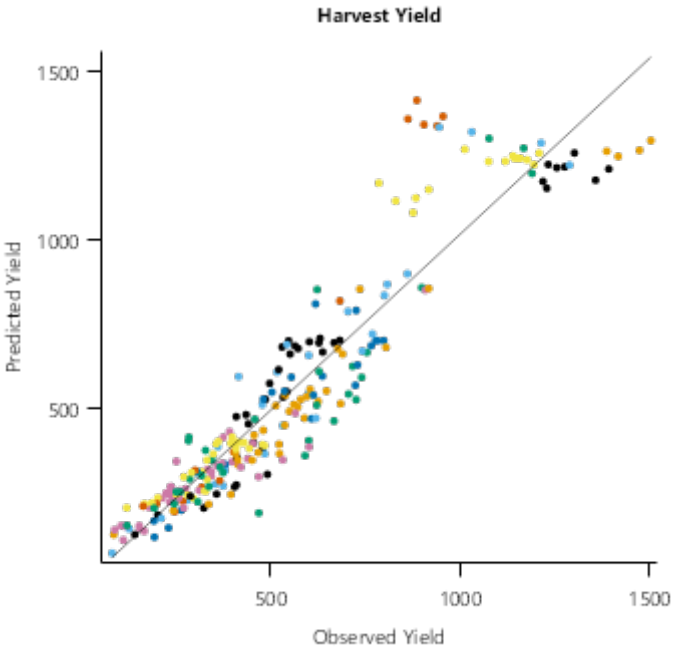
2.1 Combined Results

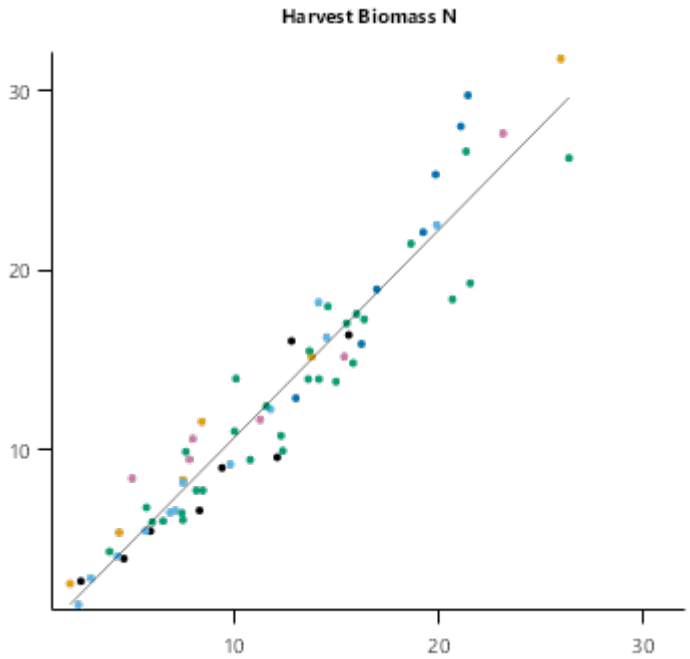
Simulation results for the combined datasets from the various countries are shown in the following graphs. The model is able to adequately capture the influence of growing conditions (soil, climate) and management (population, Nitrogen, irrigation, sowing date).

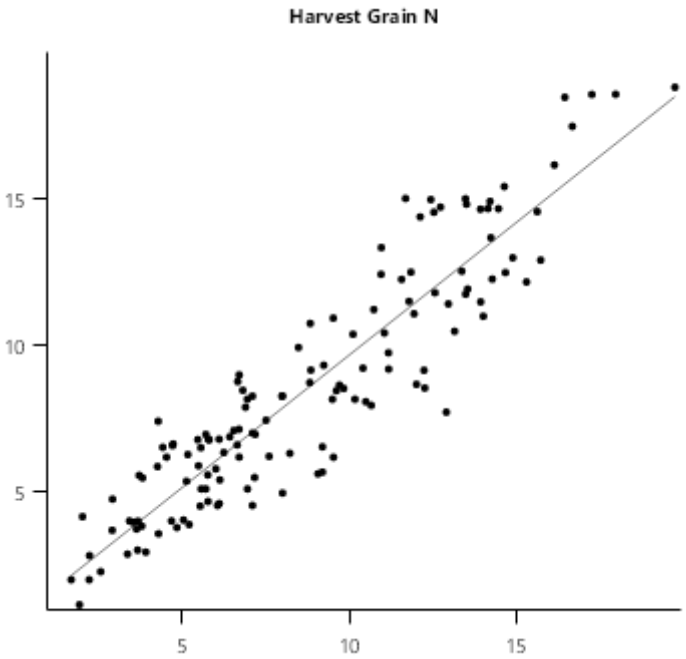

Harvest Biomass
3000
2000
1000
1000
2000
3000

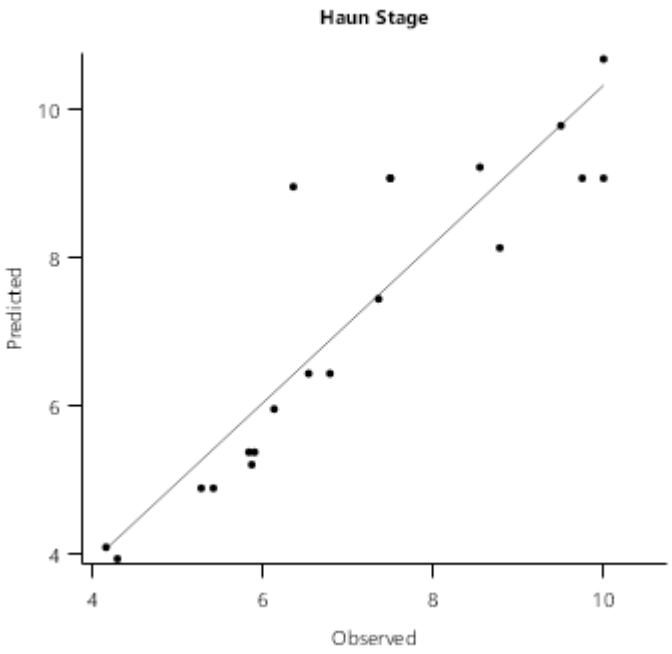

Leaf Area Index
10
5
0
0
5
10

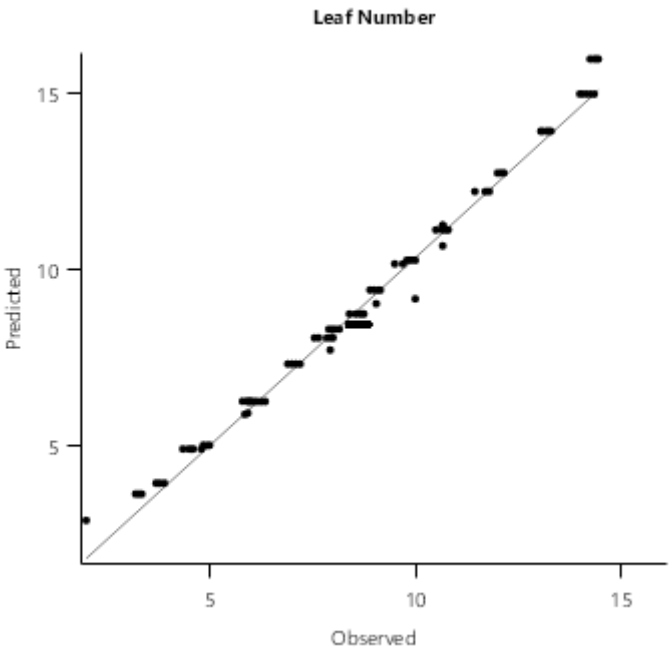

Grain Number
30000
20000
10000
10000
20000
30000

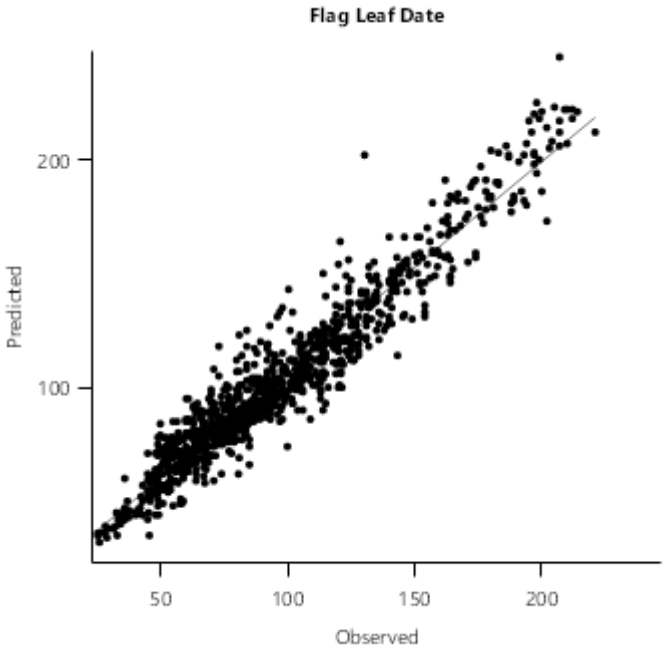

Harvest Yield
1500
1000
500
Predicted Yield
500
1000
1500
Observed Yield

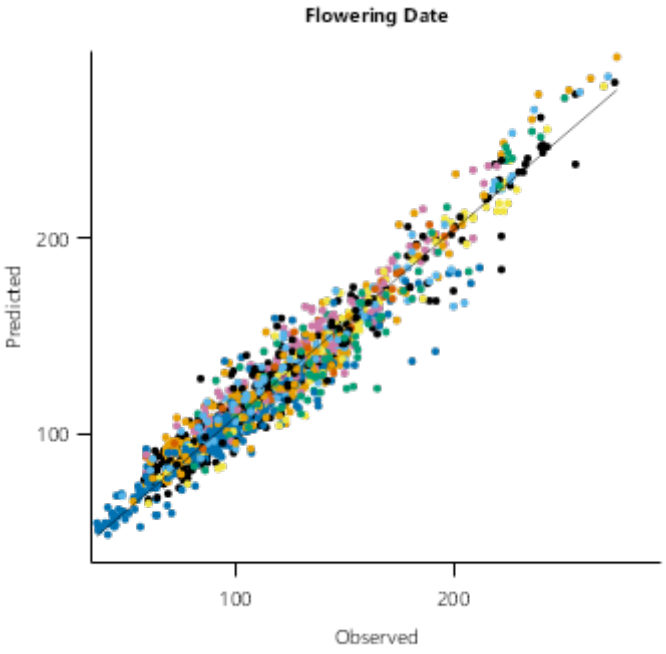

Harvest Biomass N
30
20
10
10
20
30

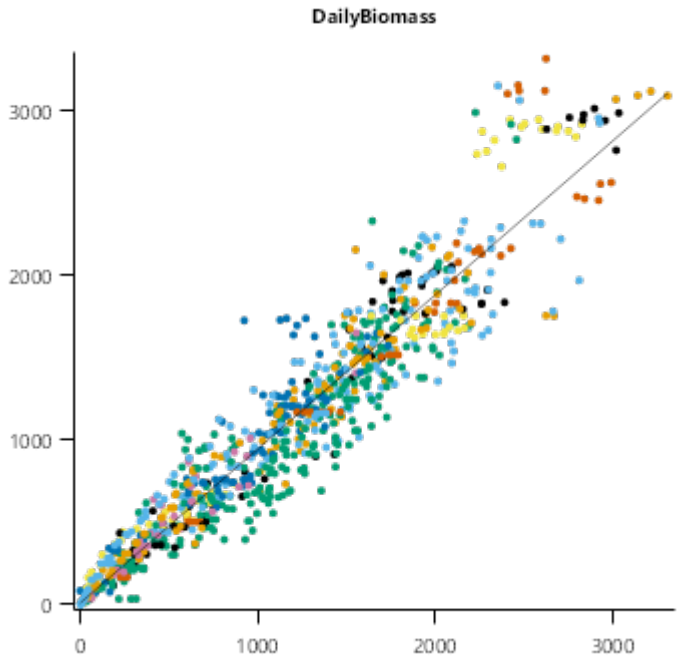

Harvest Grain N
15
10
5
5
10
15

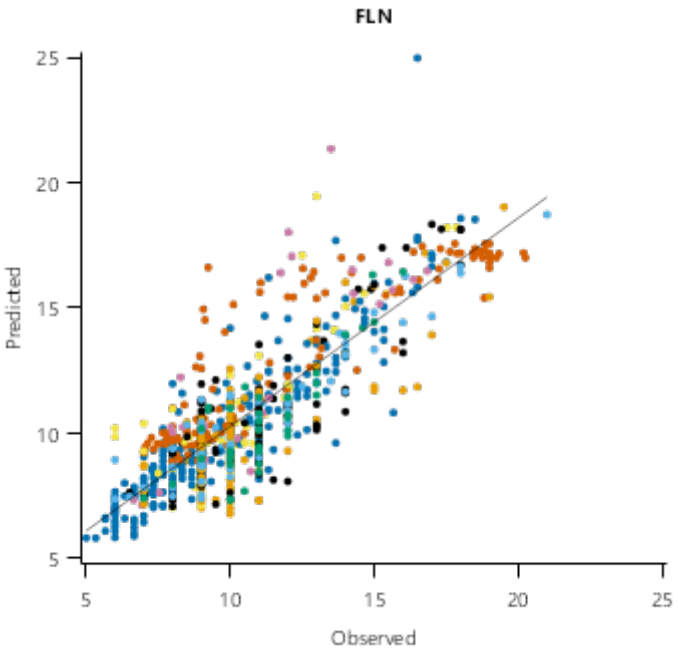

Haun Stage
Predicted
Observed
4
6
8
10


Leaf Number
Predicted
Observed
5
10
15


Flag Leaf Date
Predicted
Observed
100
200
50
100
150
200


Flowering Date
Predicted
Observed
100
200


DailyBiomass
0
1000
2000
3000


FLN
Predicted
Observed
5
10
15
20
25

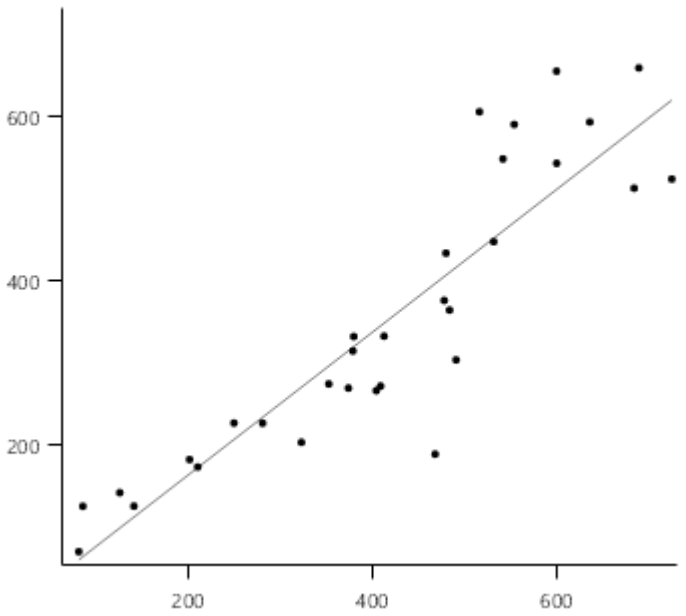
2.2 SE Queensland

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.

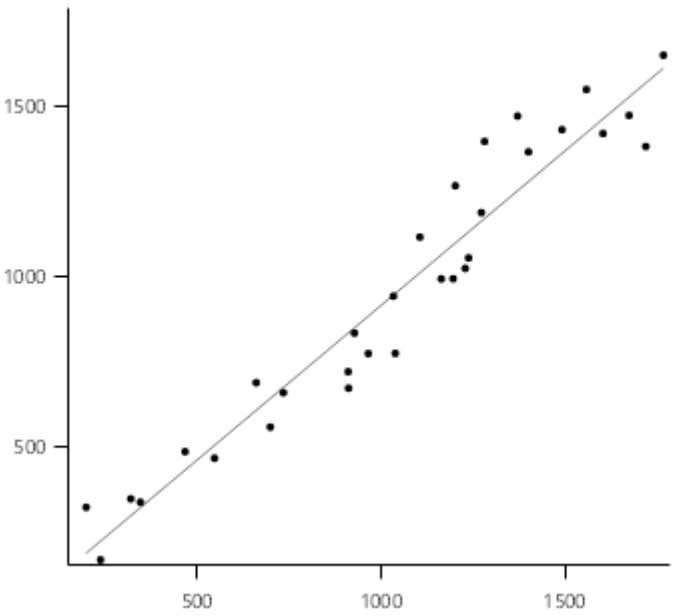
List of experiments.

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)
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)

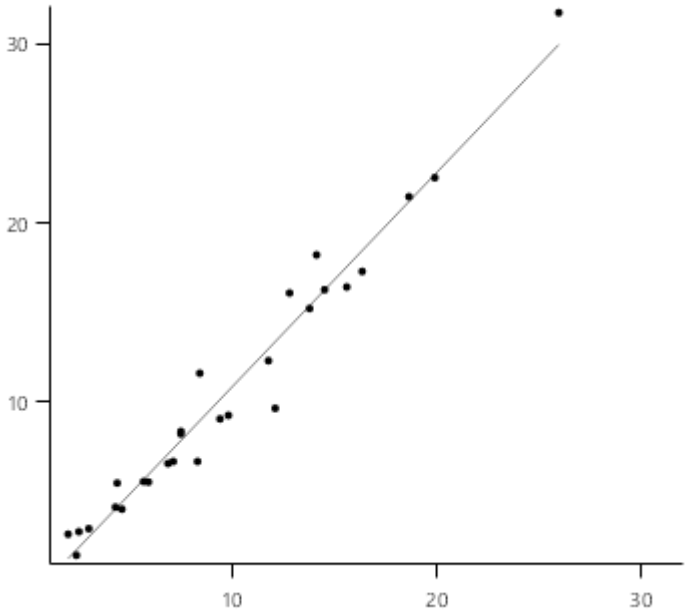
Harvest Yield



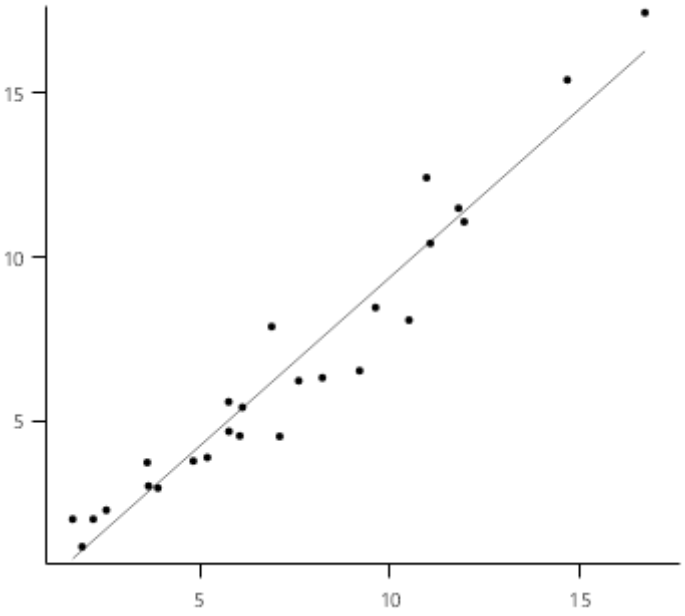
Harvest Biomass



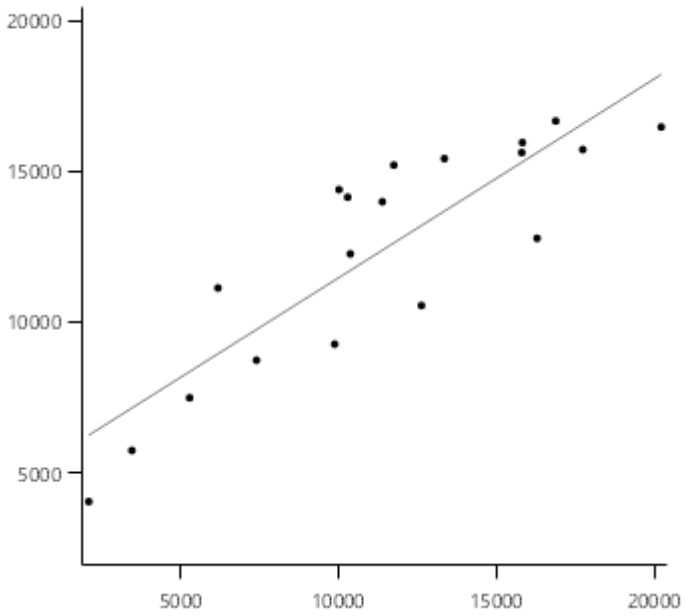
Harvest Biomass N



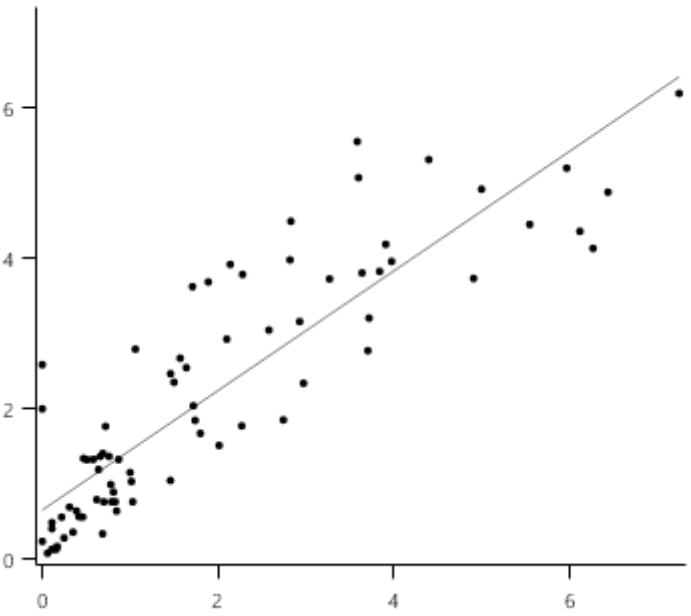
Harvest Grain N

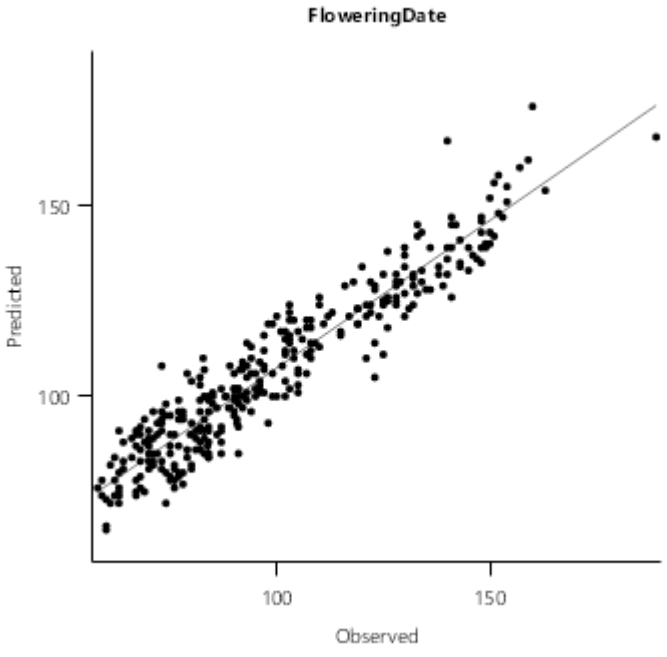


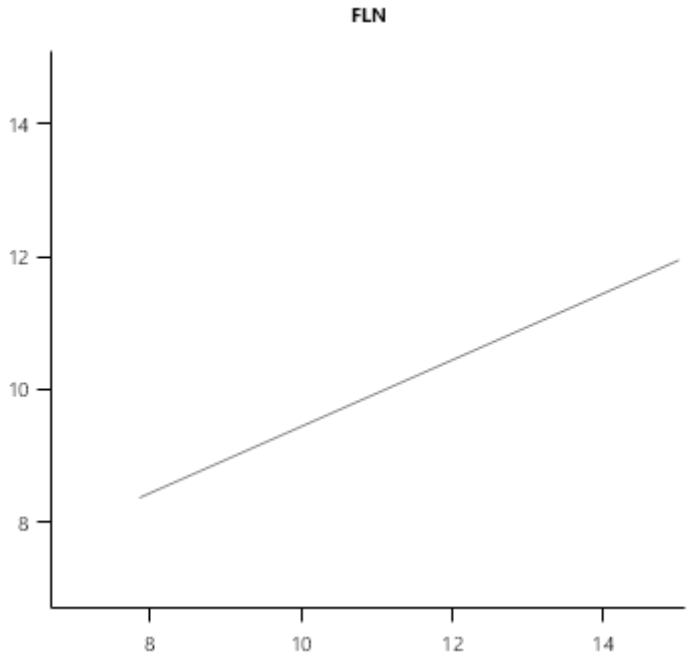
GrainNumber



Leaf Area Index





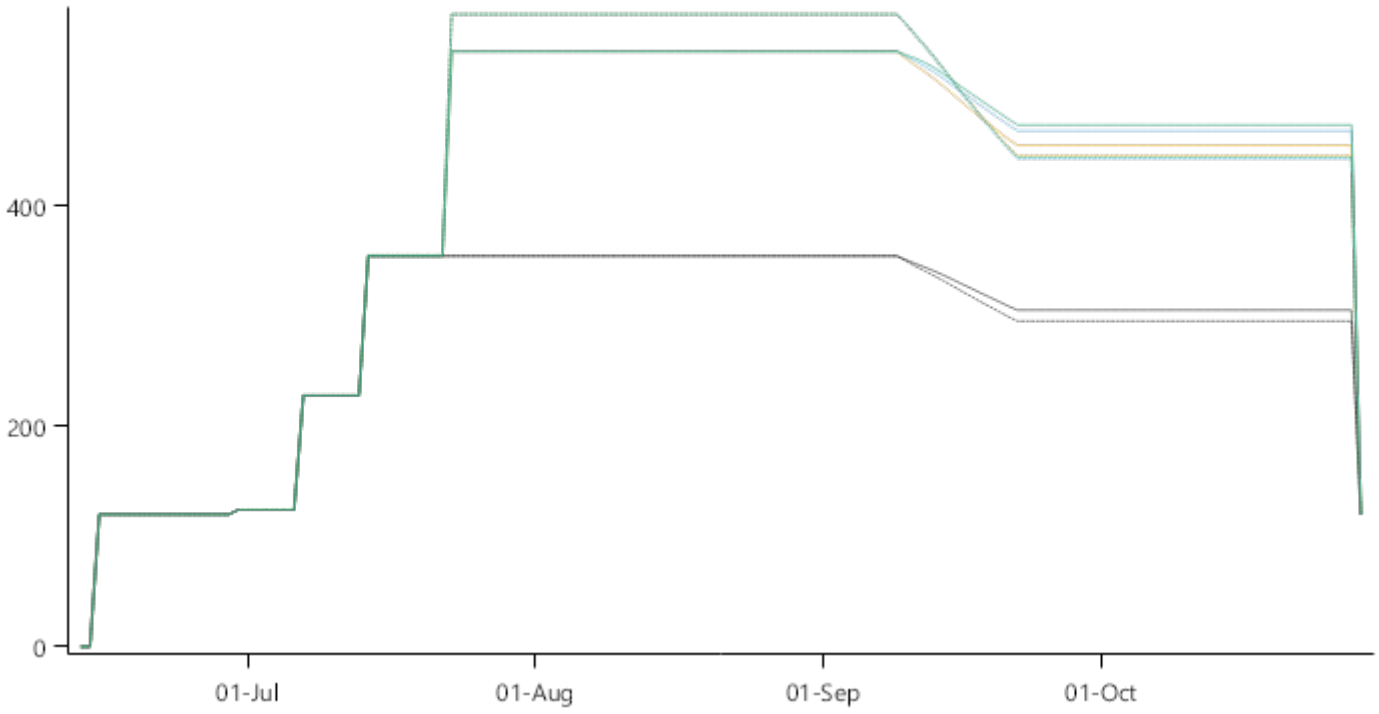


2.2.1 APS26

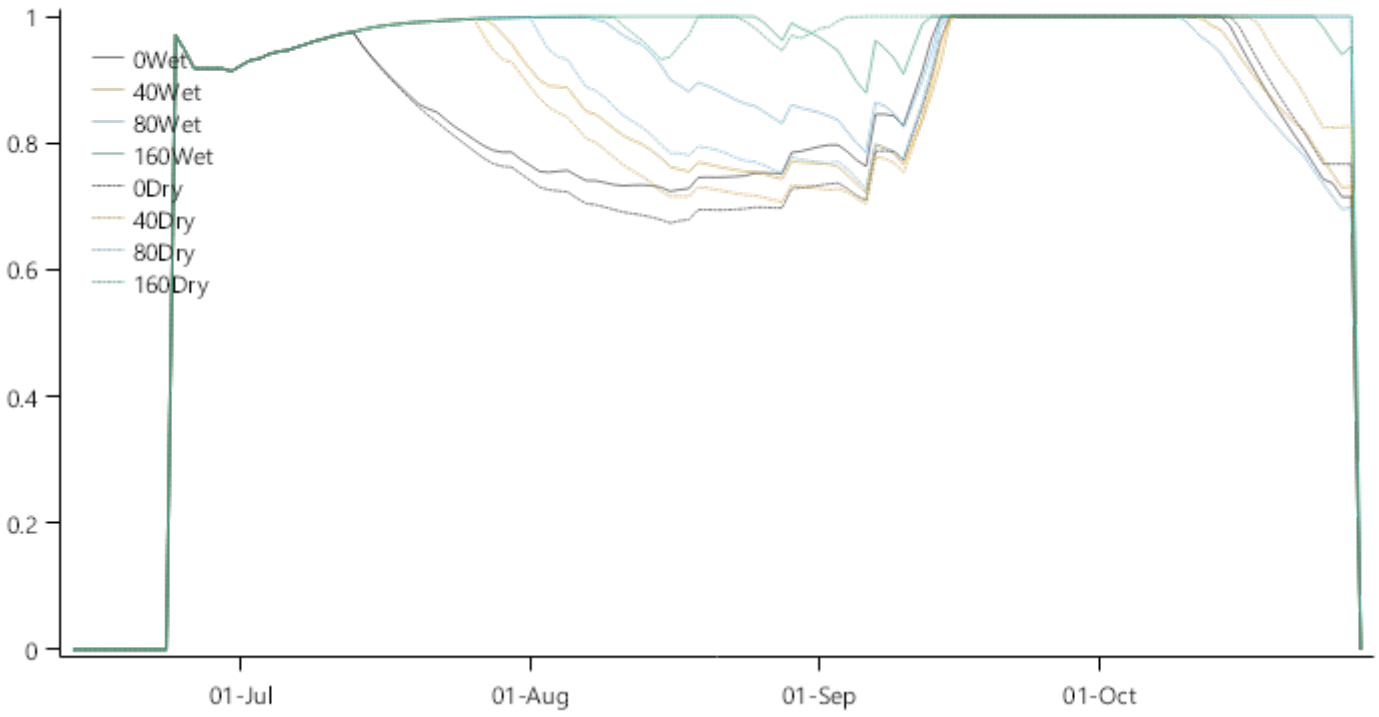
This trial was conducted at Gatton in 1995 using the local variety, Hartog. It consisted of 4 Nitrogen rates (0,40,80,160) with two irrigation rates (minimal amount for establishment, fully irrigated). Yields ranged from 1.4 t/ha to 5.4 t/ha.

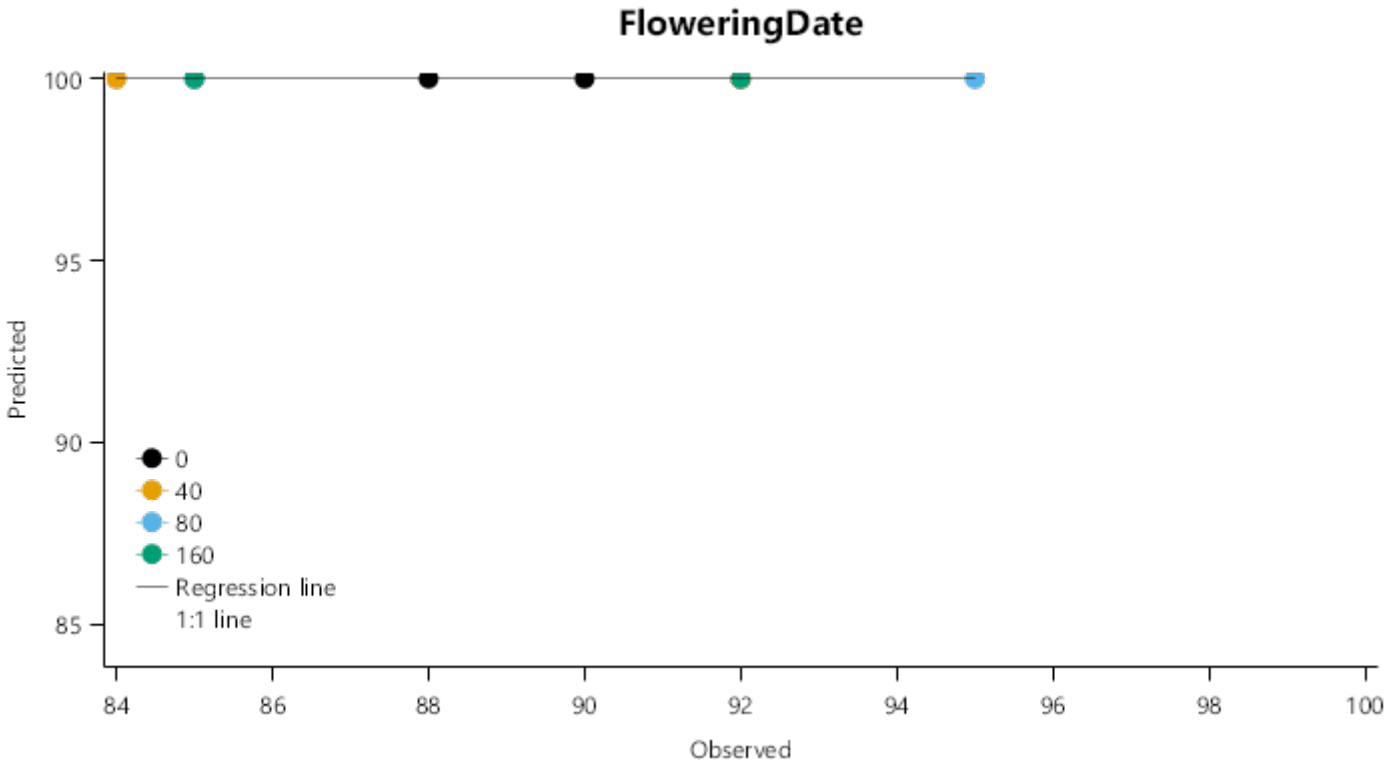
FW photo

StemNumber



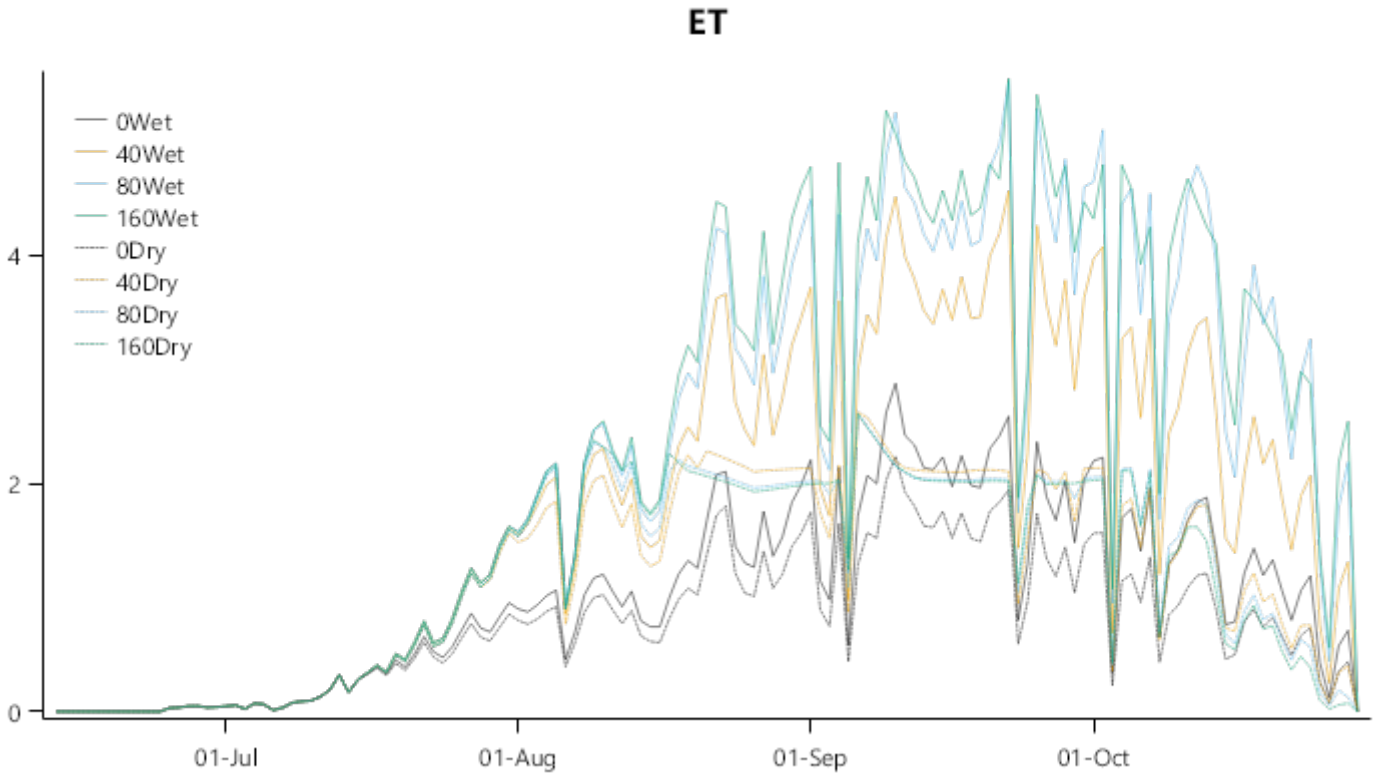
Leaf Fn



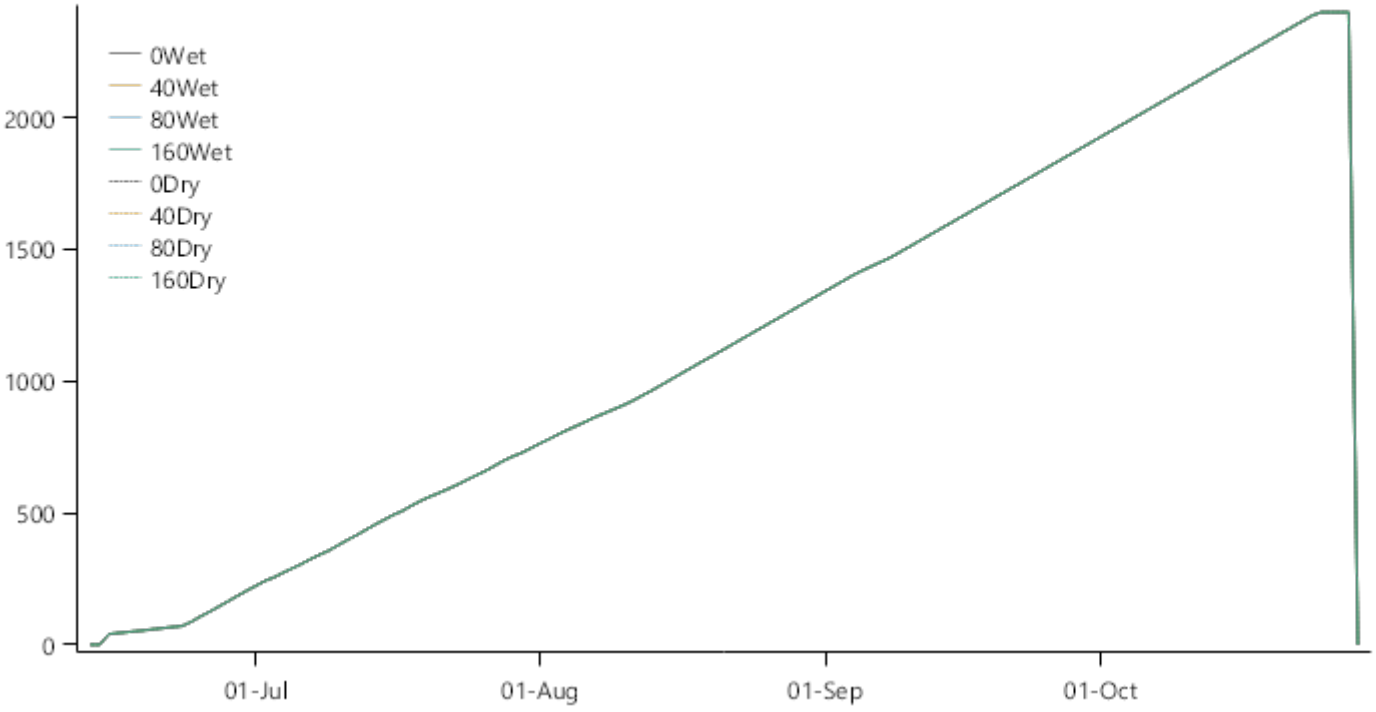


WaterPotential

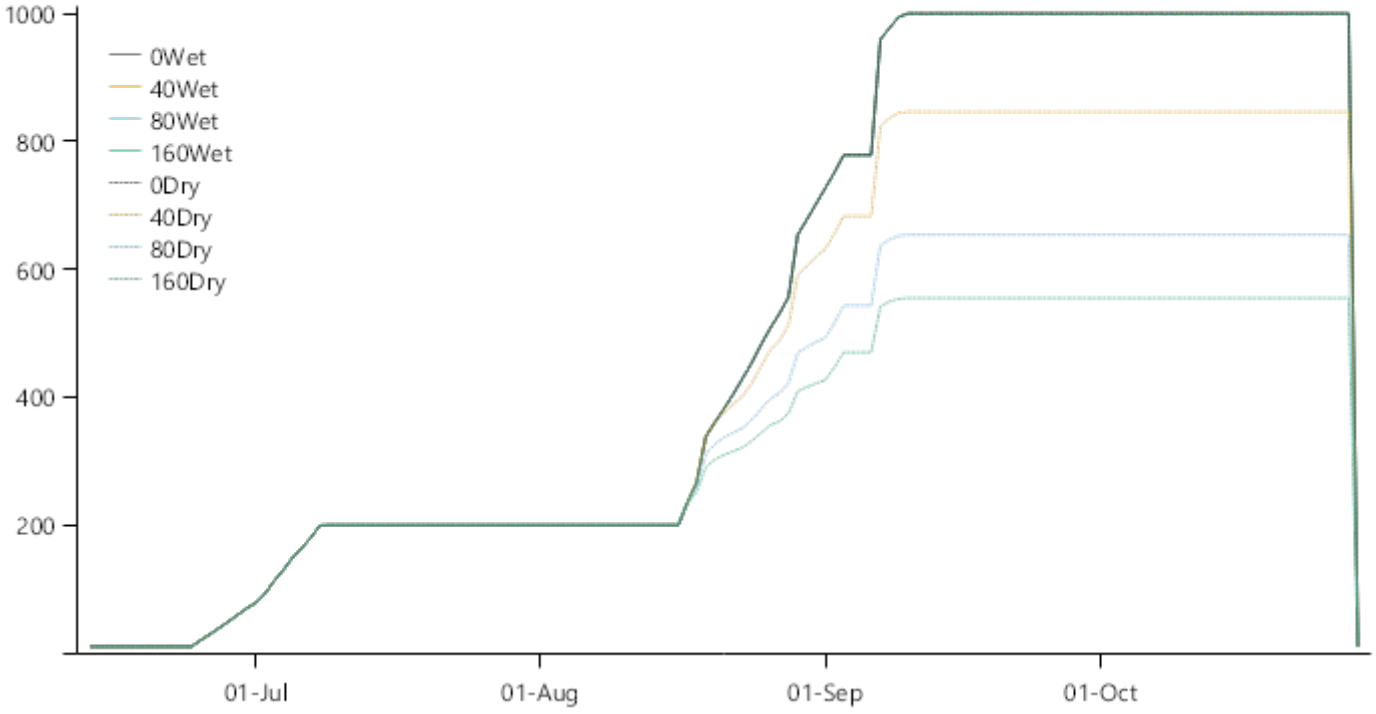
C Supply and Demand



RootDepth



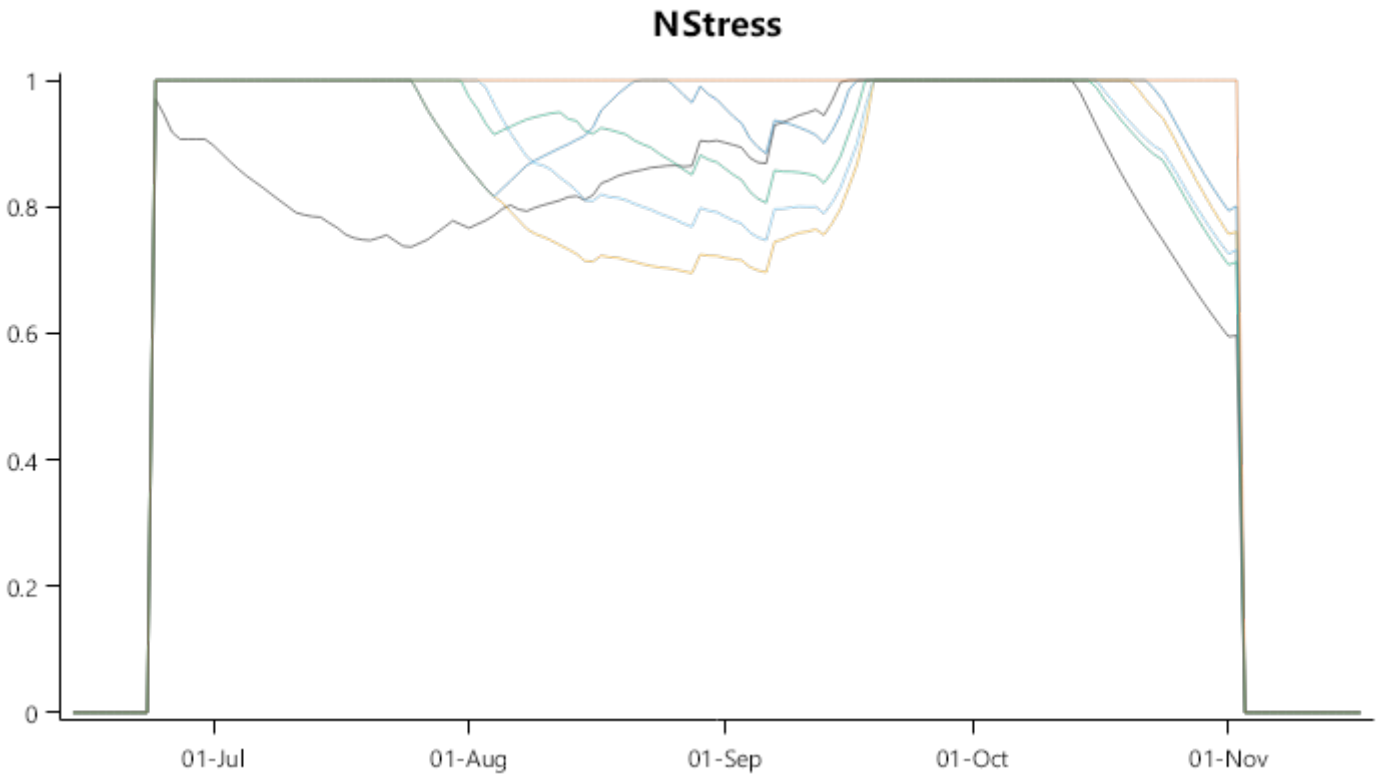
Height



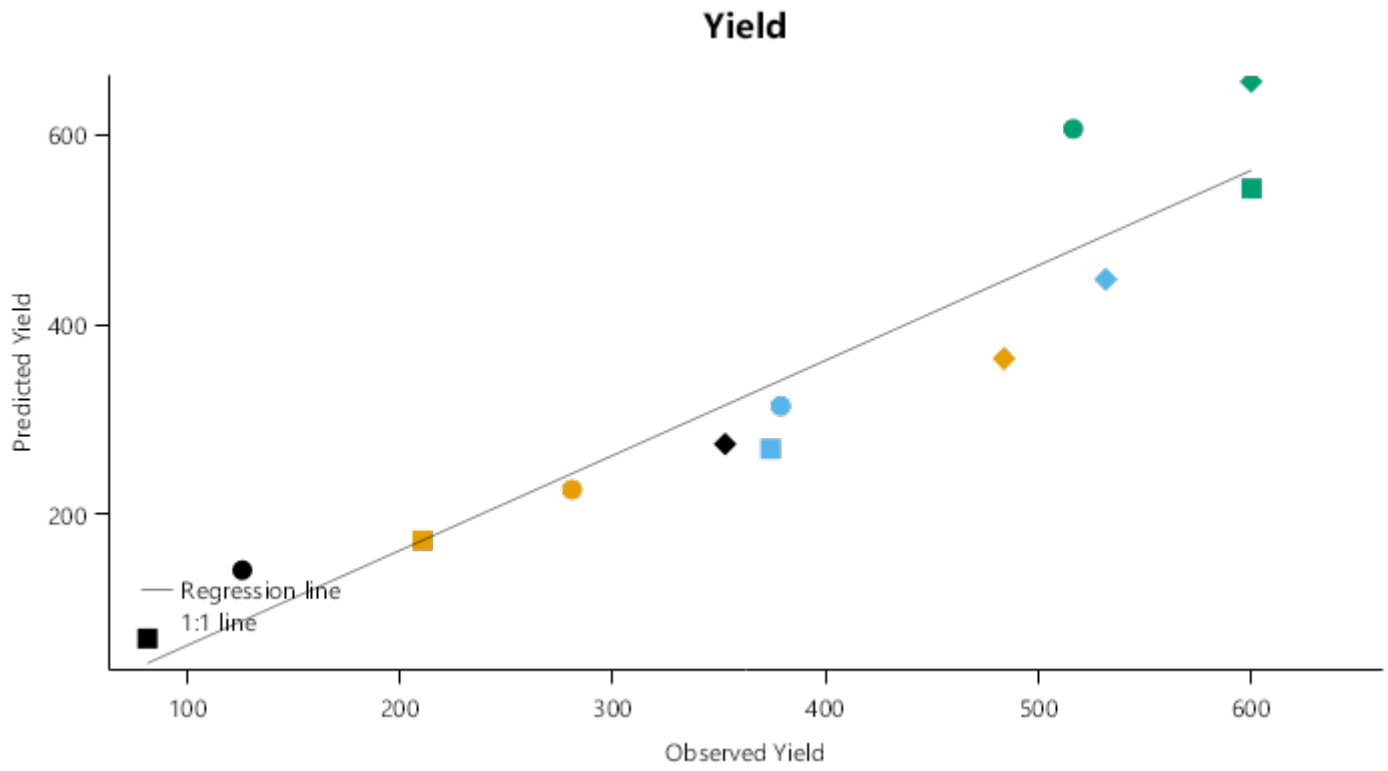
RootLengthDensity

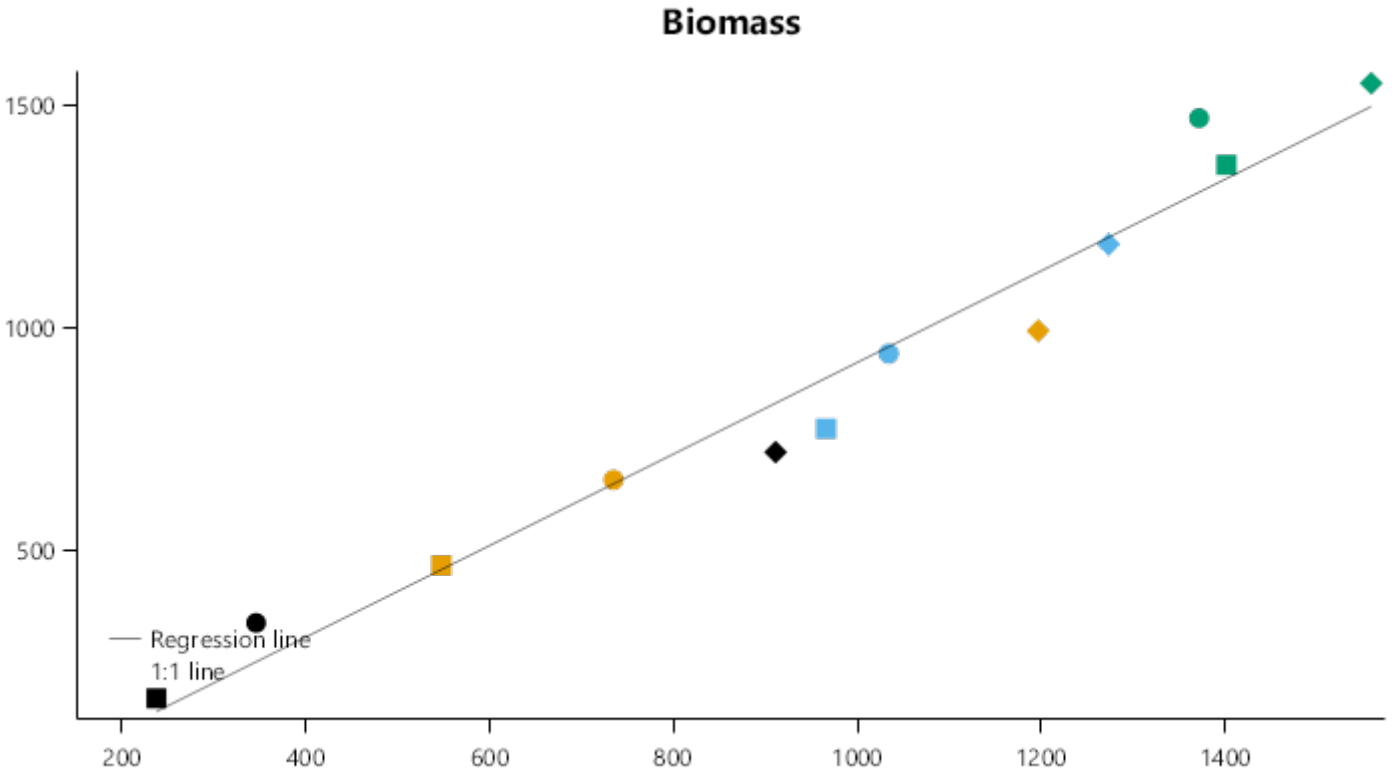
2.2.2 APS6

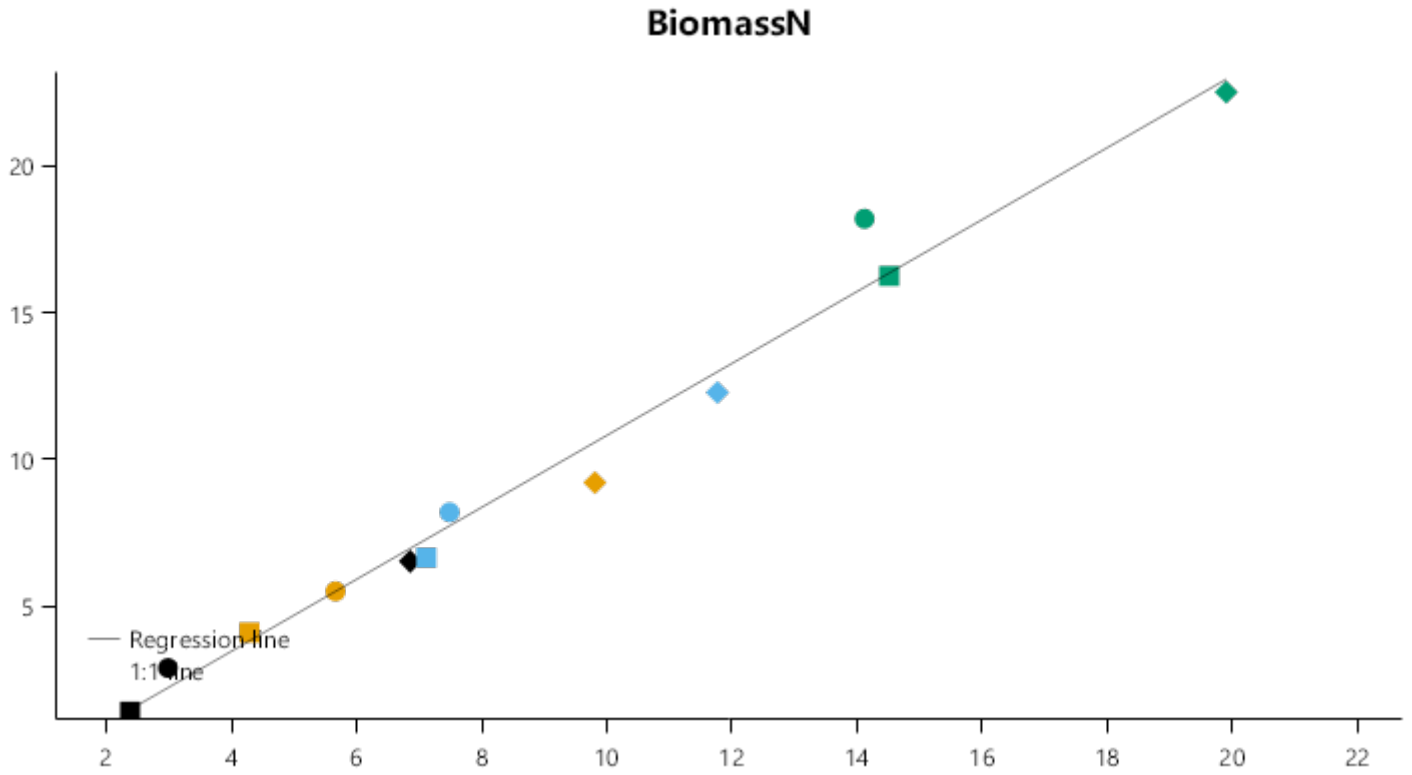
NOTE: High N treatment logdged. Final grain sizes were less than expected.



2.2.3 APS14

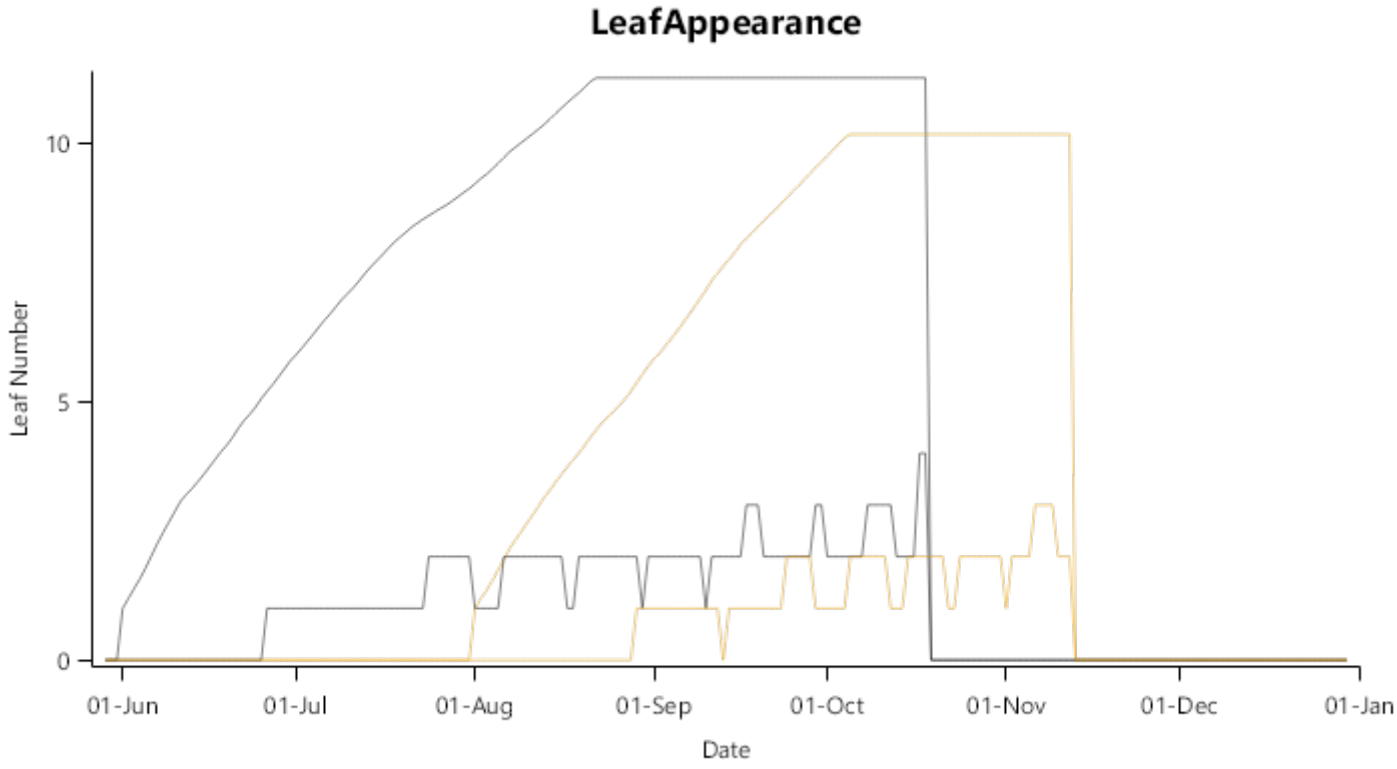

Yield
Predicted Yield
600
400
200
100
200
300
400
500
600
Observed Yield
Regression line
1:1 line

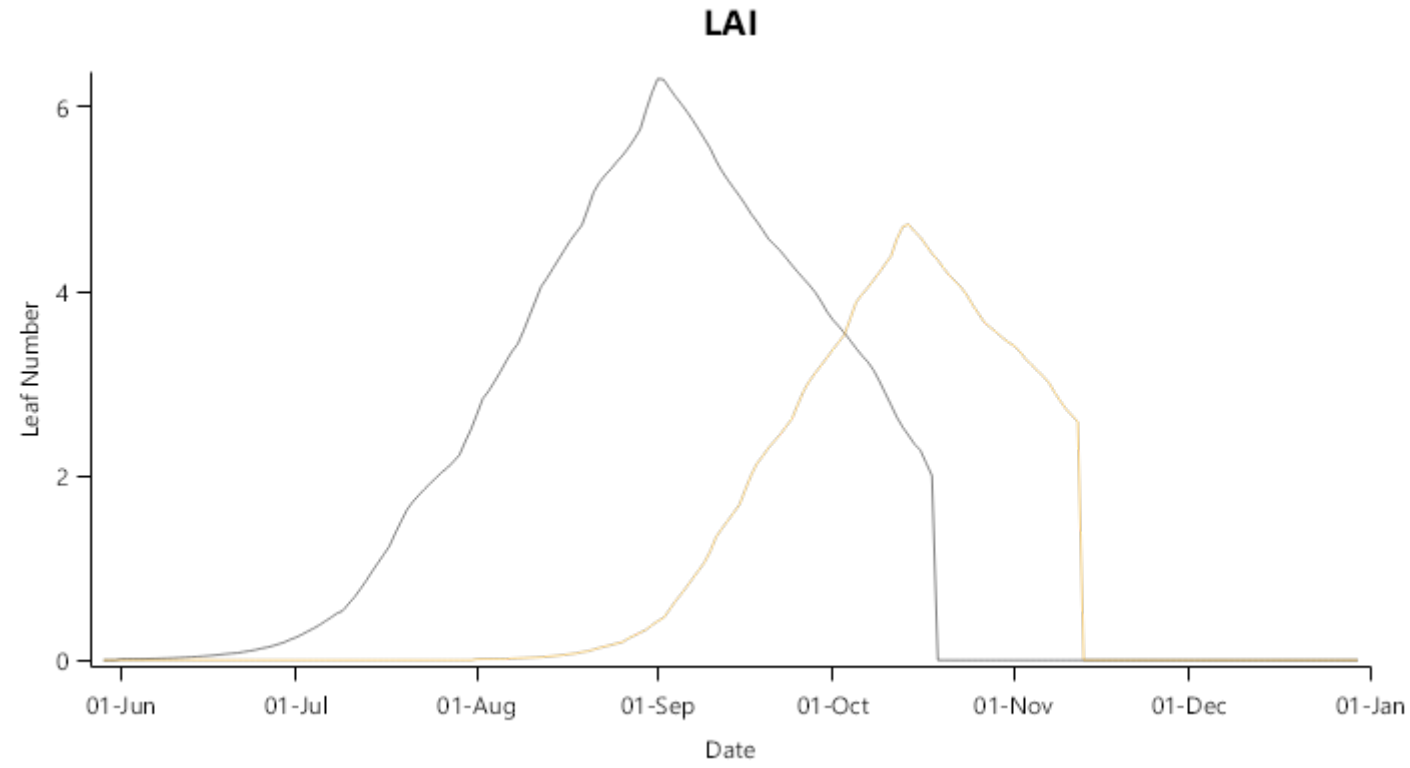

Biomass
1500
1000
500
200
400
600
800
1000
1200
1400
Regression line
1:1 line

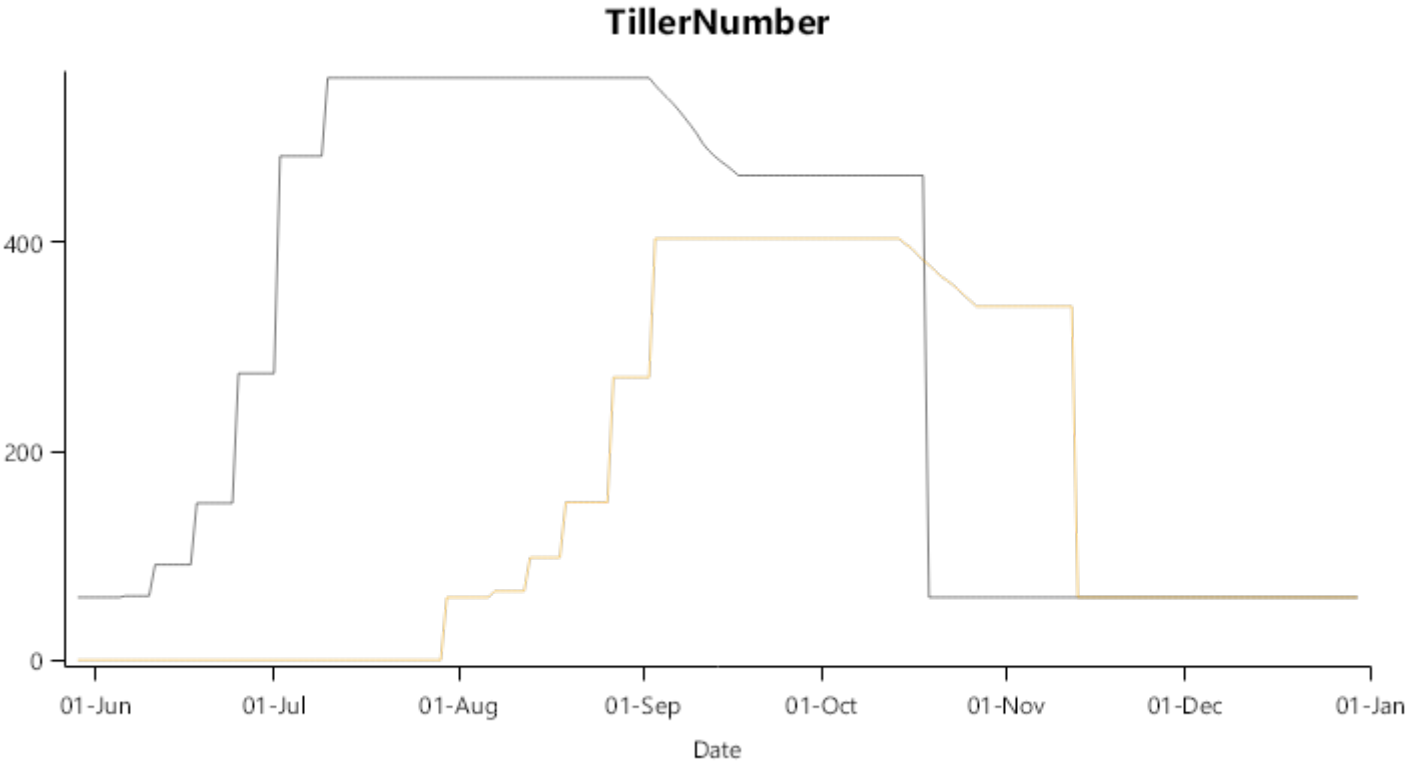


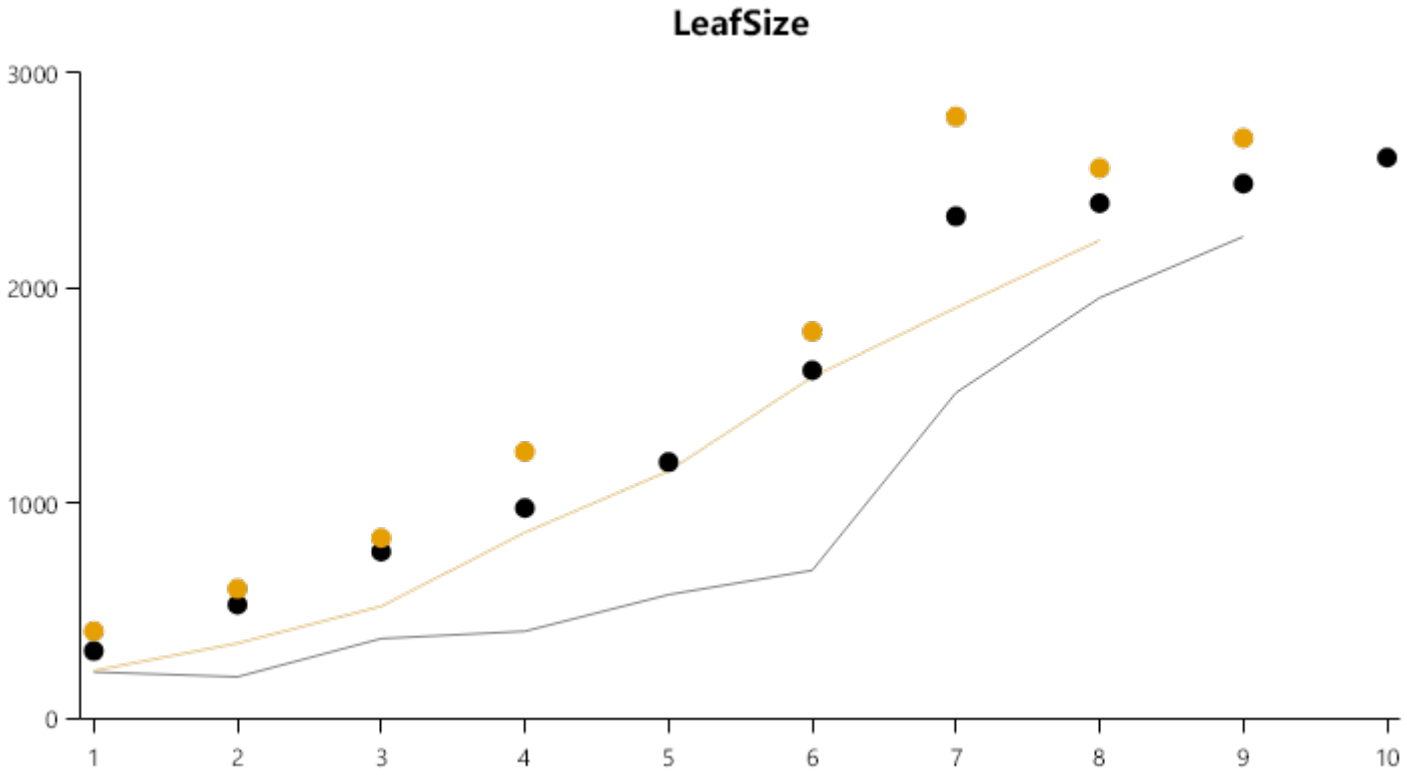
2.2.4 APS2

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.



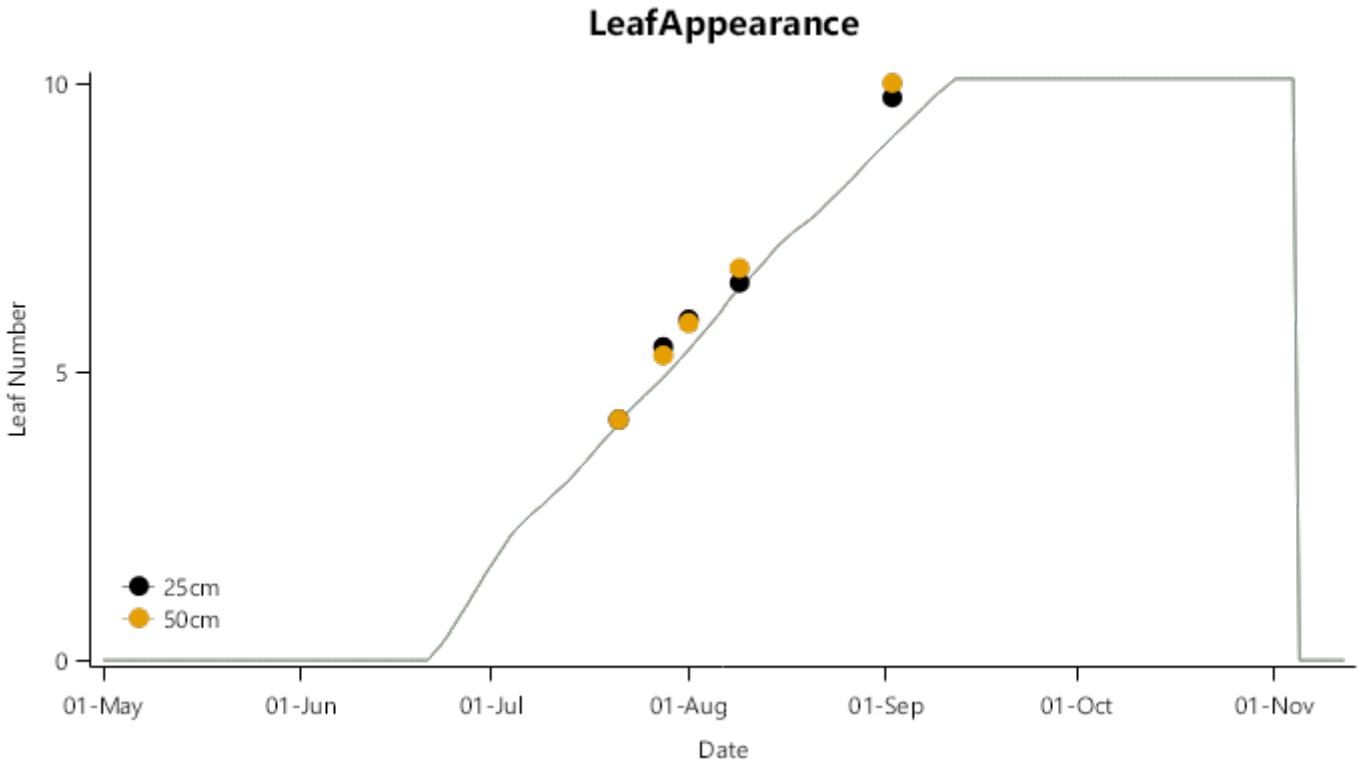

LAI
Leaf Number
6
4
2
0
01-Jun
01-Jul
01-Aug
01-Sep
01-Oct
01-Nov
01-Dec
01-Jan
Date

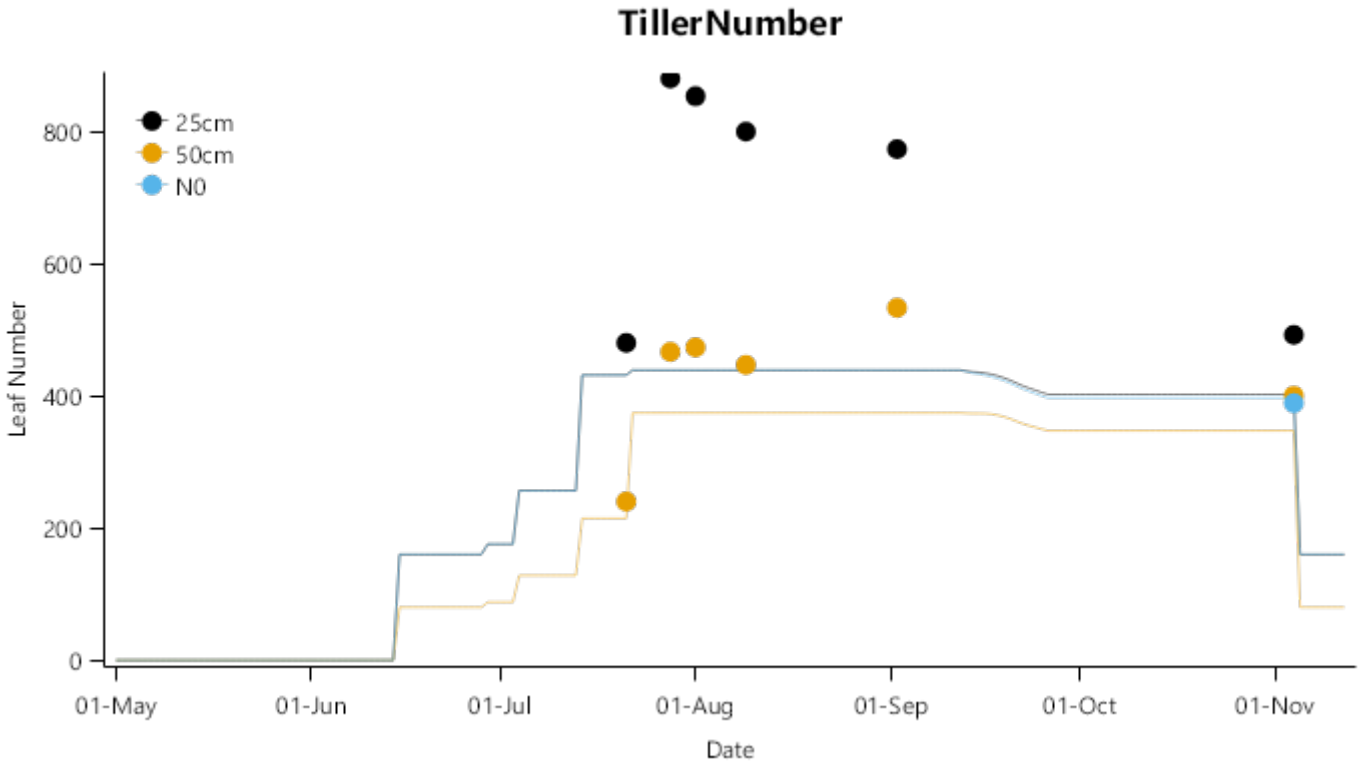

TillerNumber
400
200
0
01-Jun
01-Jul
01-Aug
01-Sep
01-Oct
01-Nov
01-Dec
01-Jan
Date

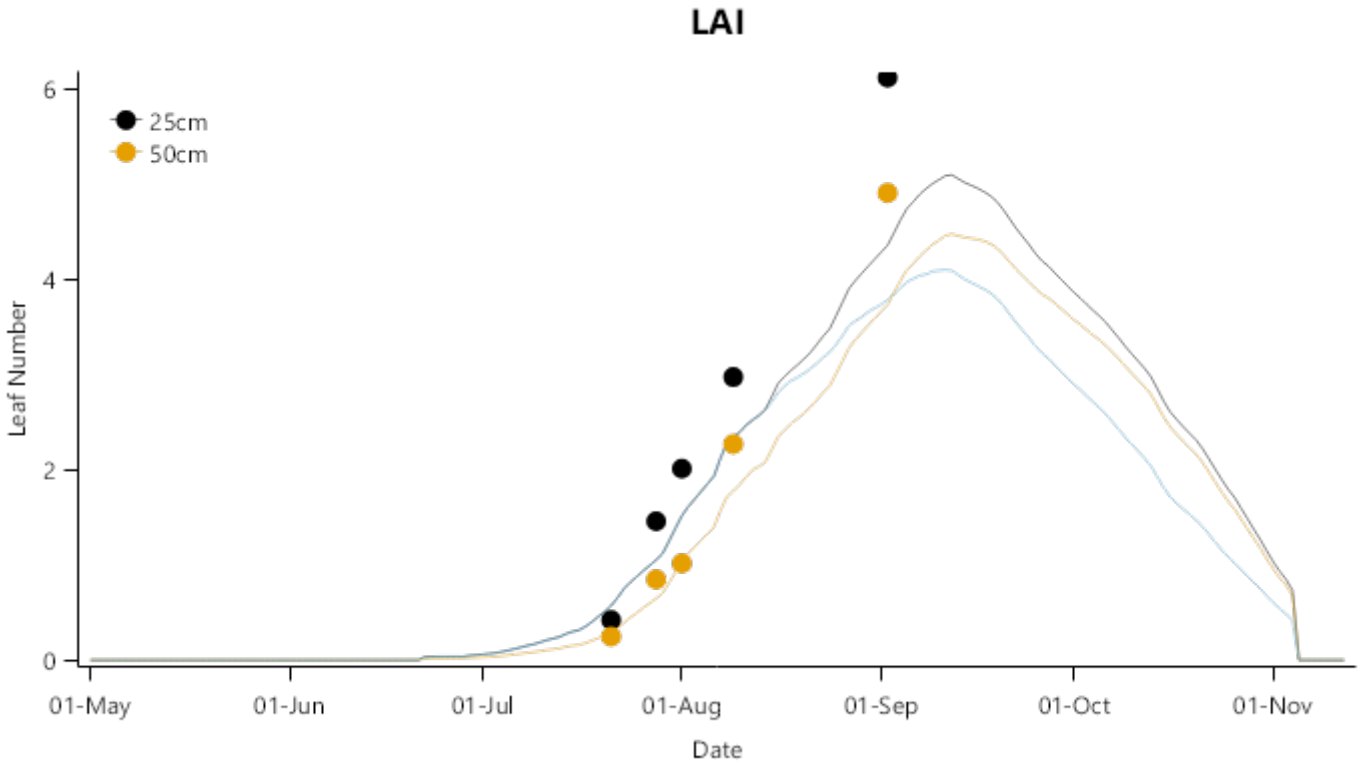


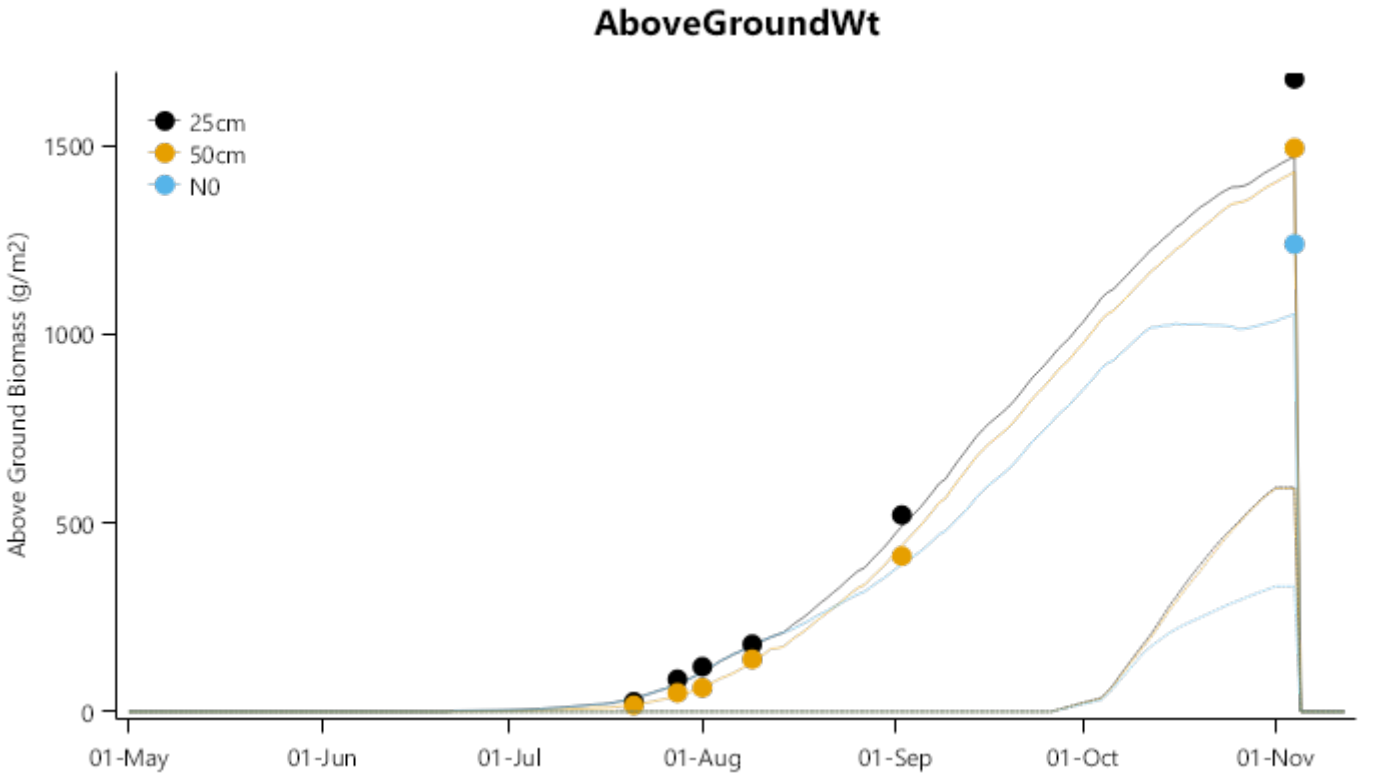
2.2.5 GattonRowSpacing

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.



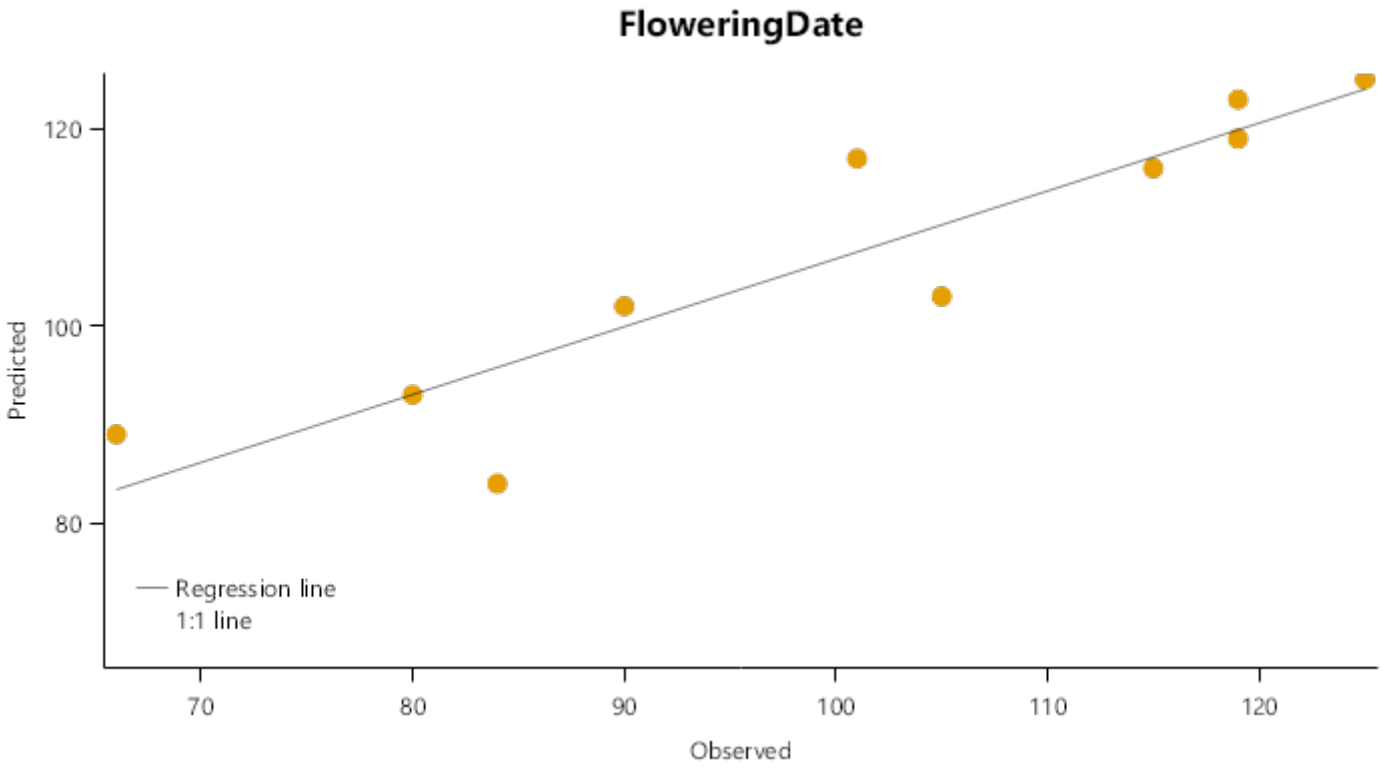

TillerNumber
25cm
50cm
N0
800
600
400
200
0
Leaf Number
01-May
01-Jun
01-Jul
01-Aug
01-Sep
01-Oct
01-Nov
Date

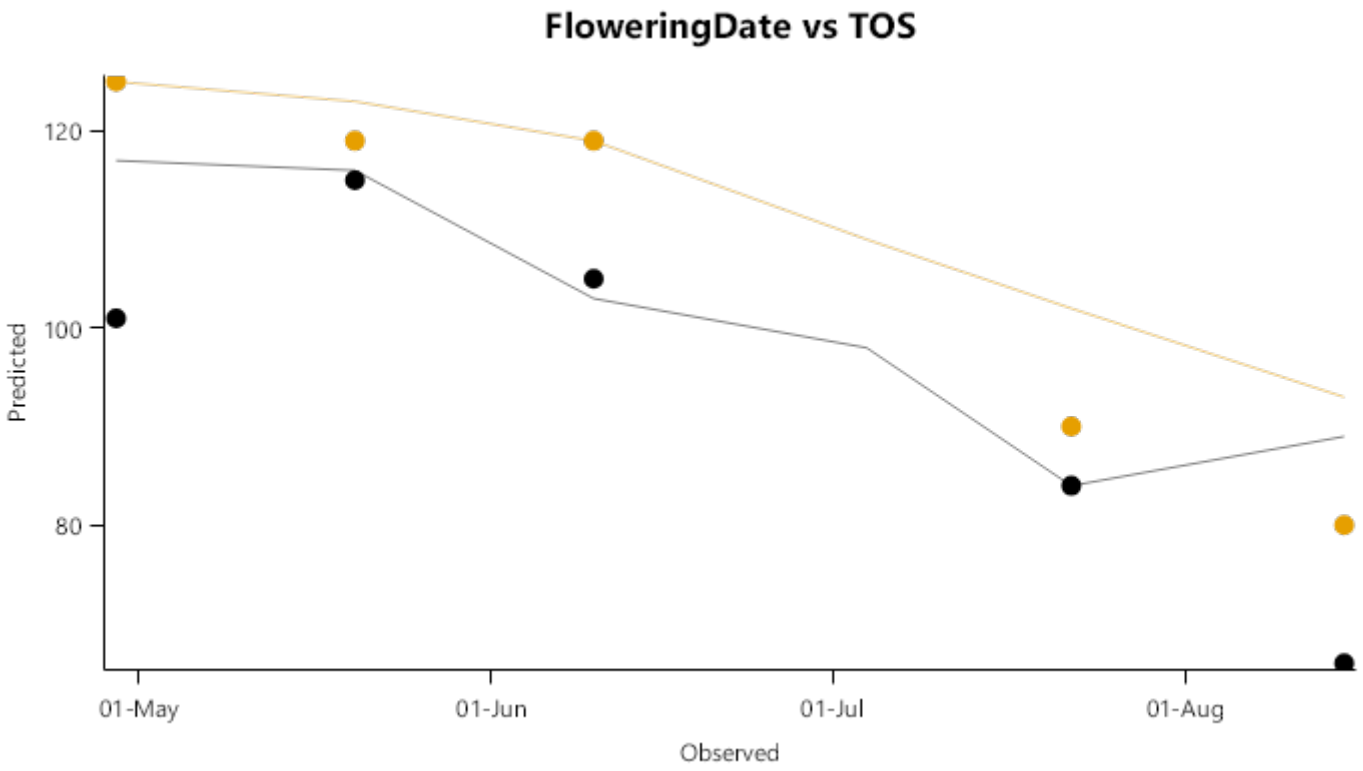

LAI
25cm
50cm
6
4
2
0
Leaf Number
01-May
01-Jun
01-Jul
01-Aug
01-Sep
01-Oct
01-Nov
Date



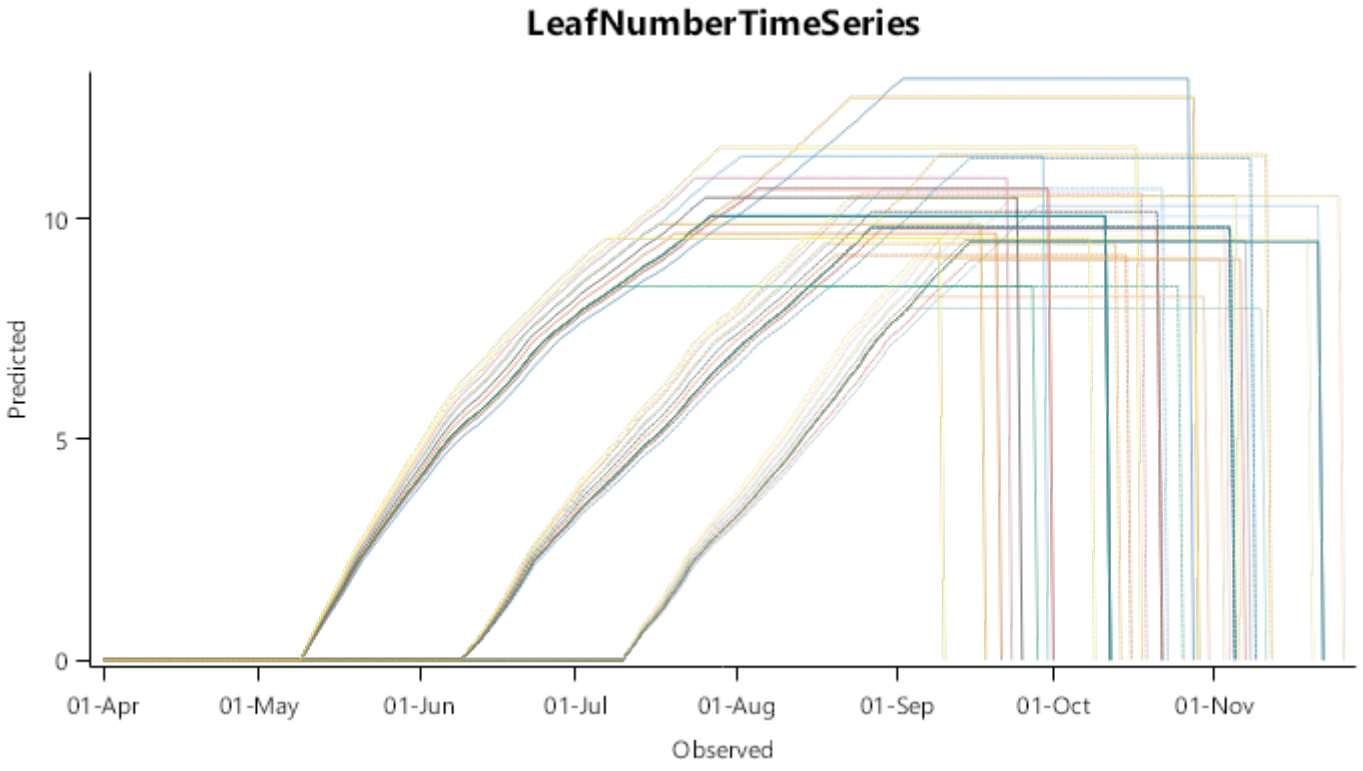
2.2.6 Gatton94

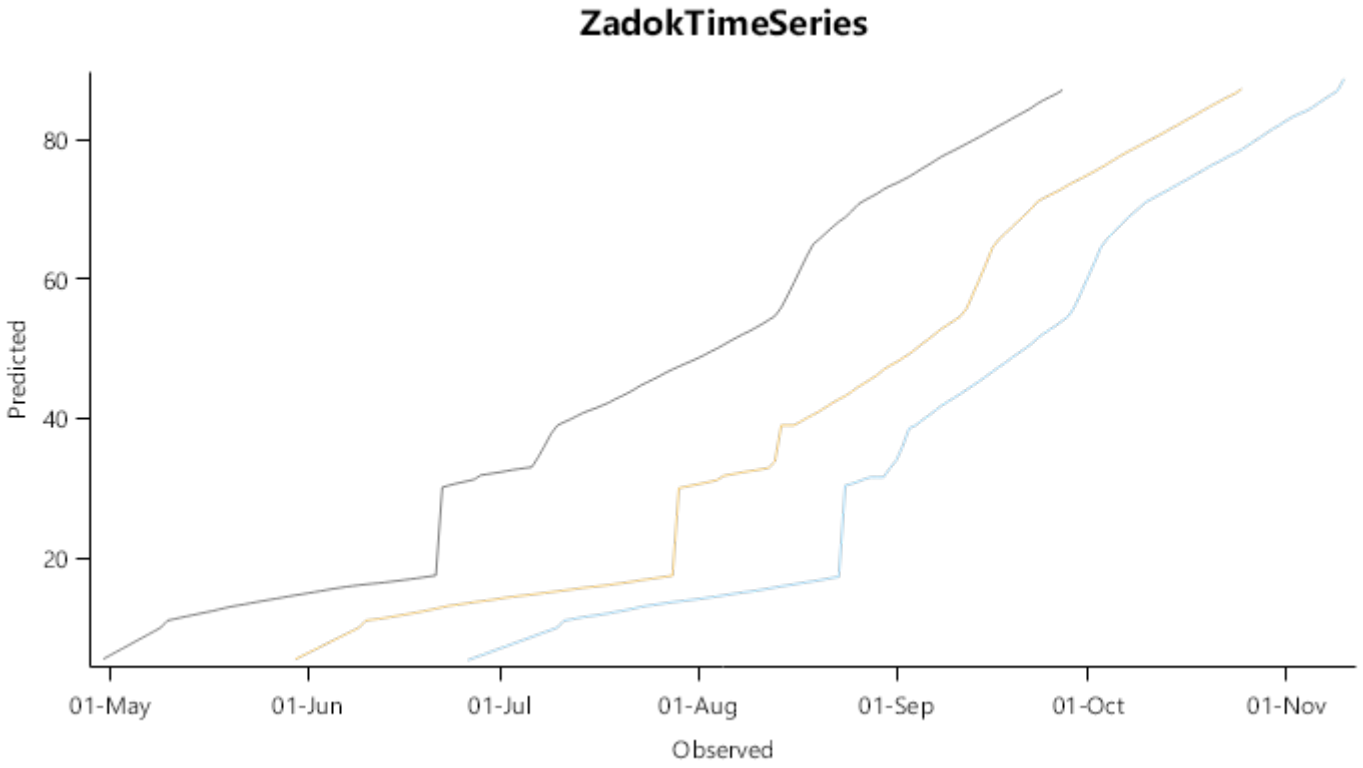
This simple experiment was conducted to investigate the impact of time of sowing on wheat. Wheat (cv. Hartog and Batavia) was sown at Gatton on six dates during 1994. Various data were collected. However final growth data was compromised by mouse damage. The dataset is used here to study the impact of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



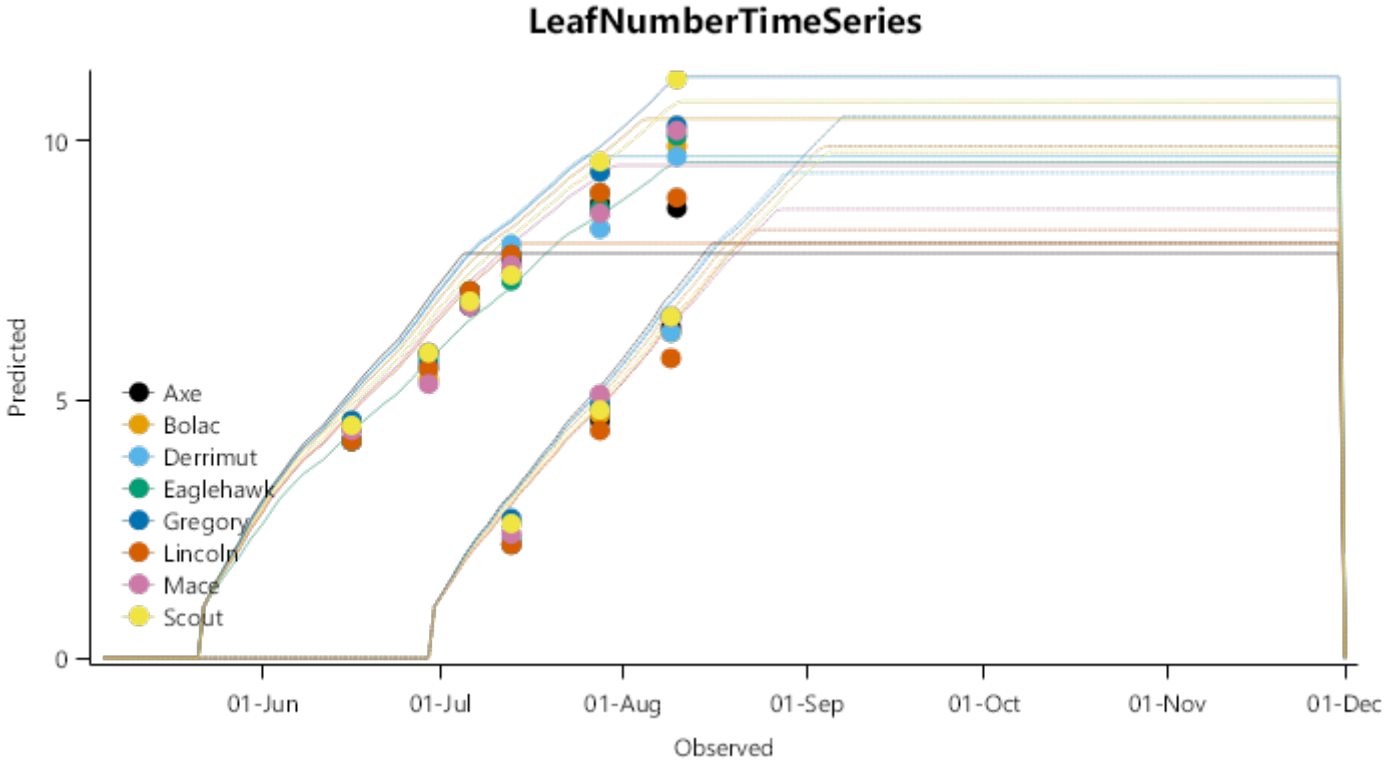


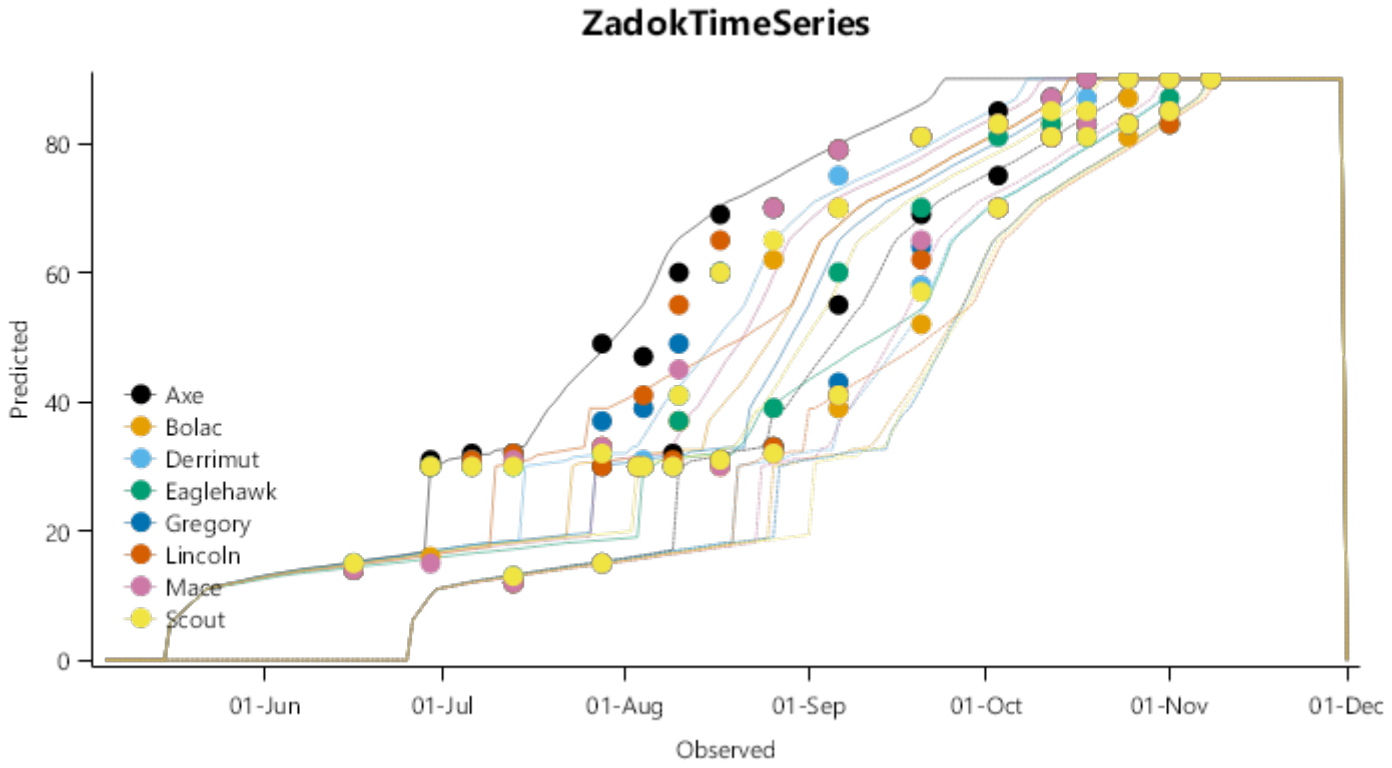
2.2.7 Gatton2009

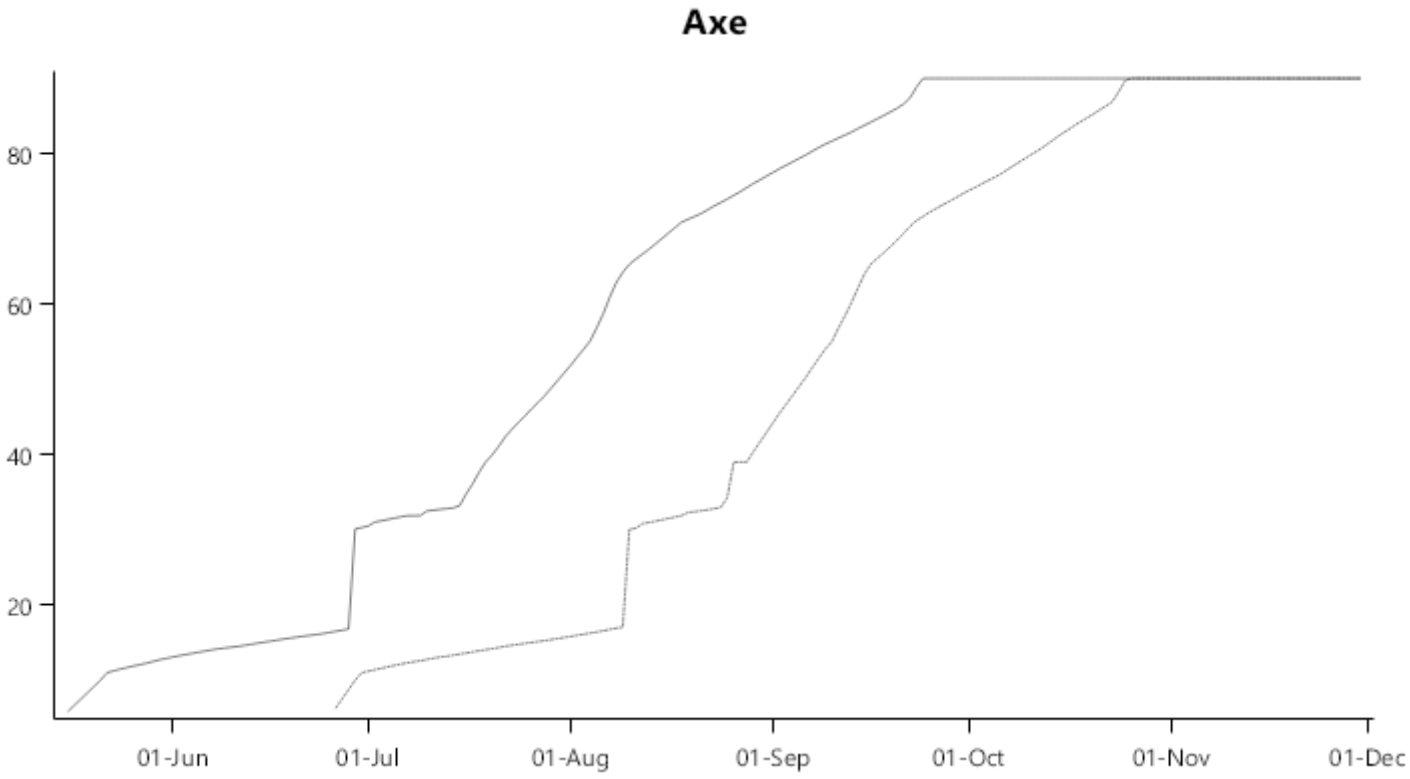




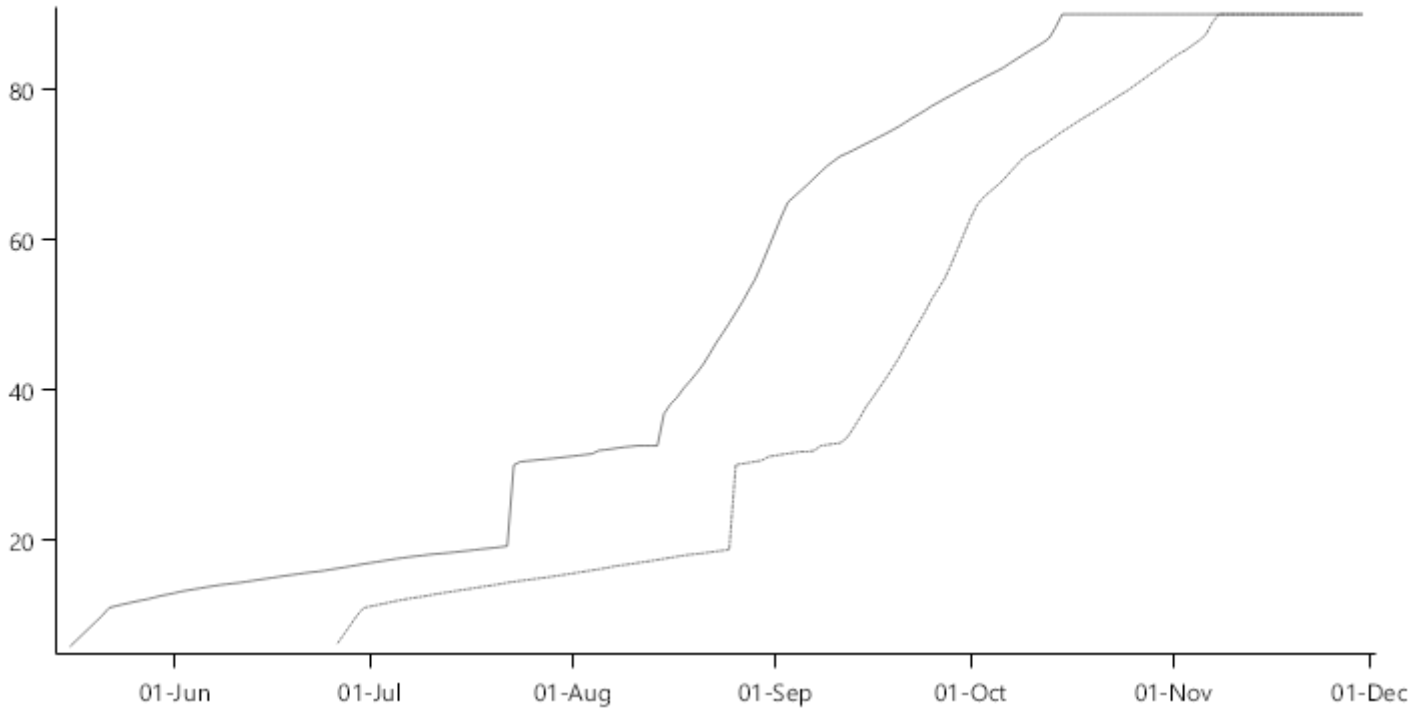
2.2.8 Gatton2011



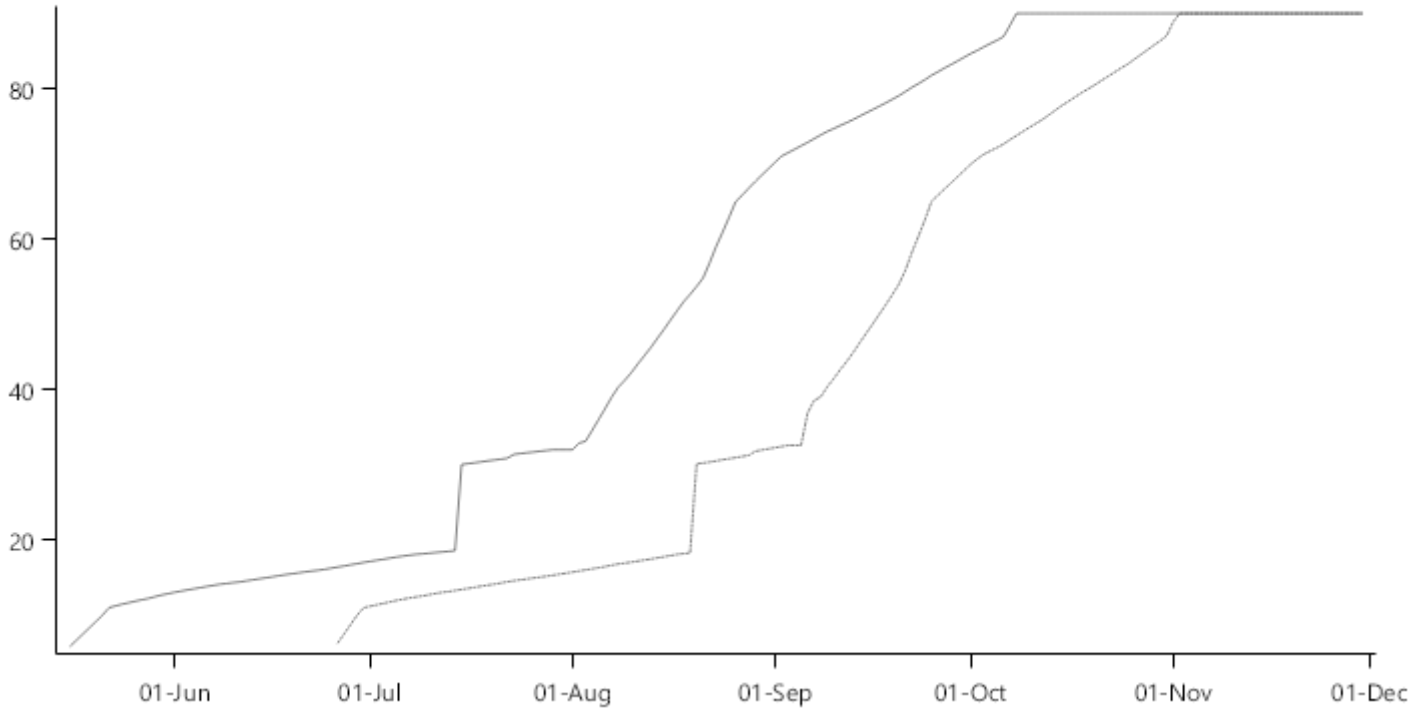

ZadokTimeSeries
Predicted
0
20
40
60
80
Axe
Bolac
Derrimut
Eaglehawk
Gregory
Lincoln
Mace
Scout
01-Jun
01-Jul
01-Aug
01-Sep
01-Oct
01-Nov
01-Dec
Observed


Axe
20
40
60
80
01-Jun
01-Jul
01-Aug
01-Sep
01-Oct
01-Nov
01-Dec

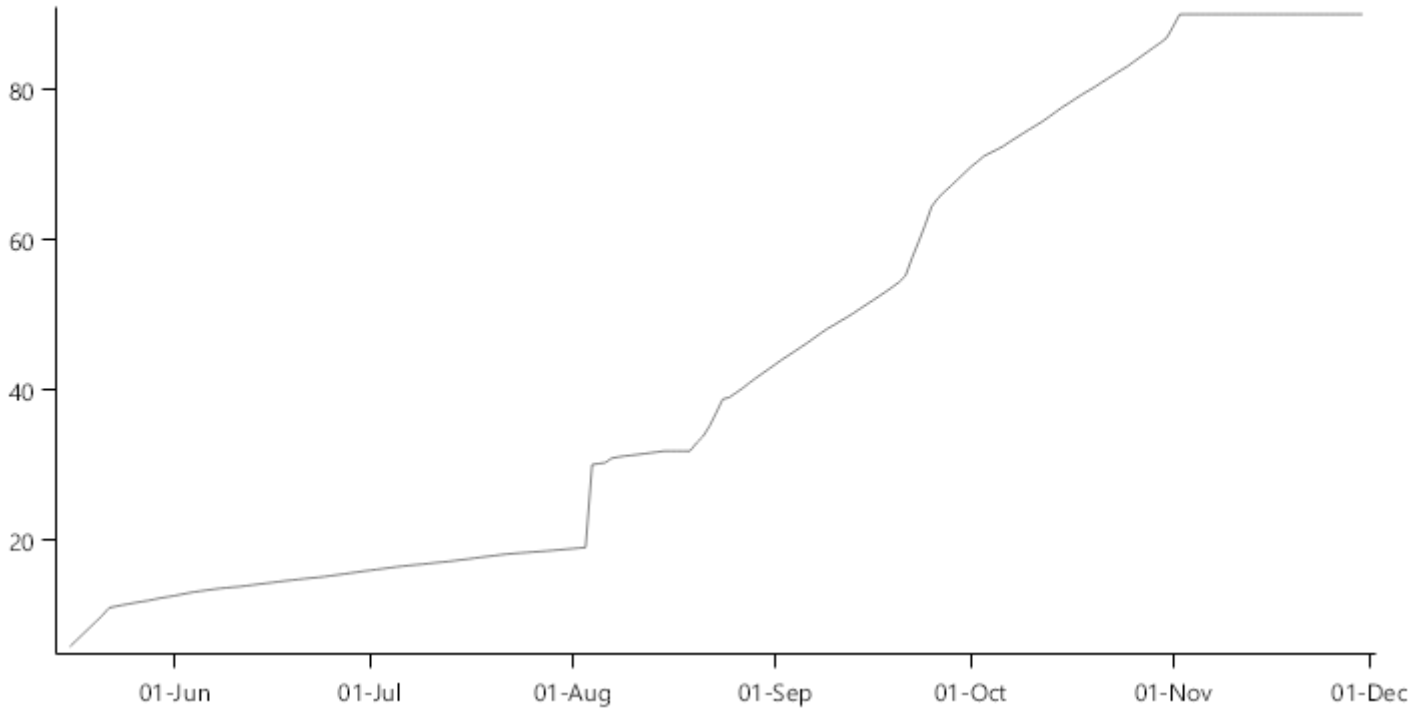
Bolac



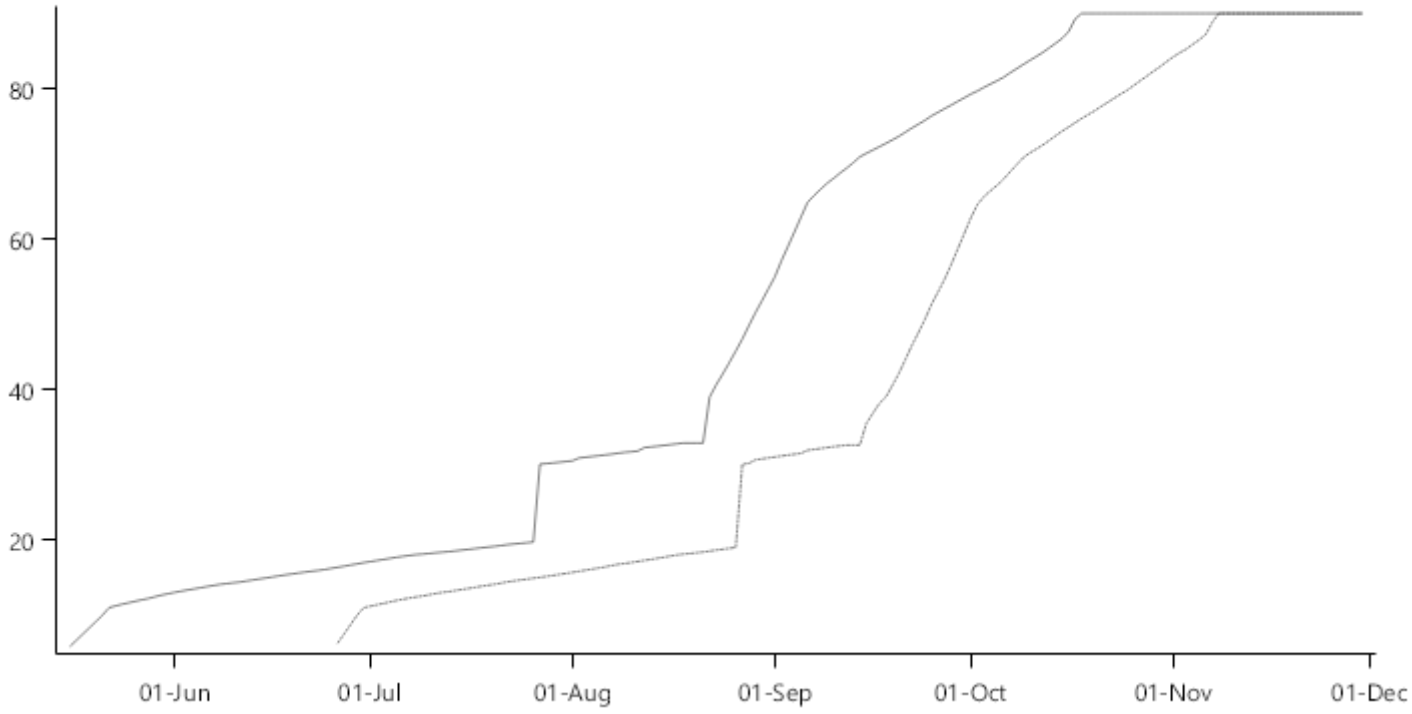
Derrimut



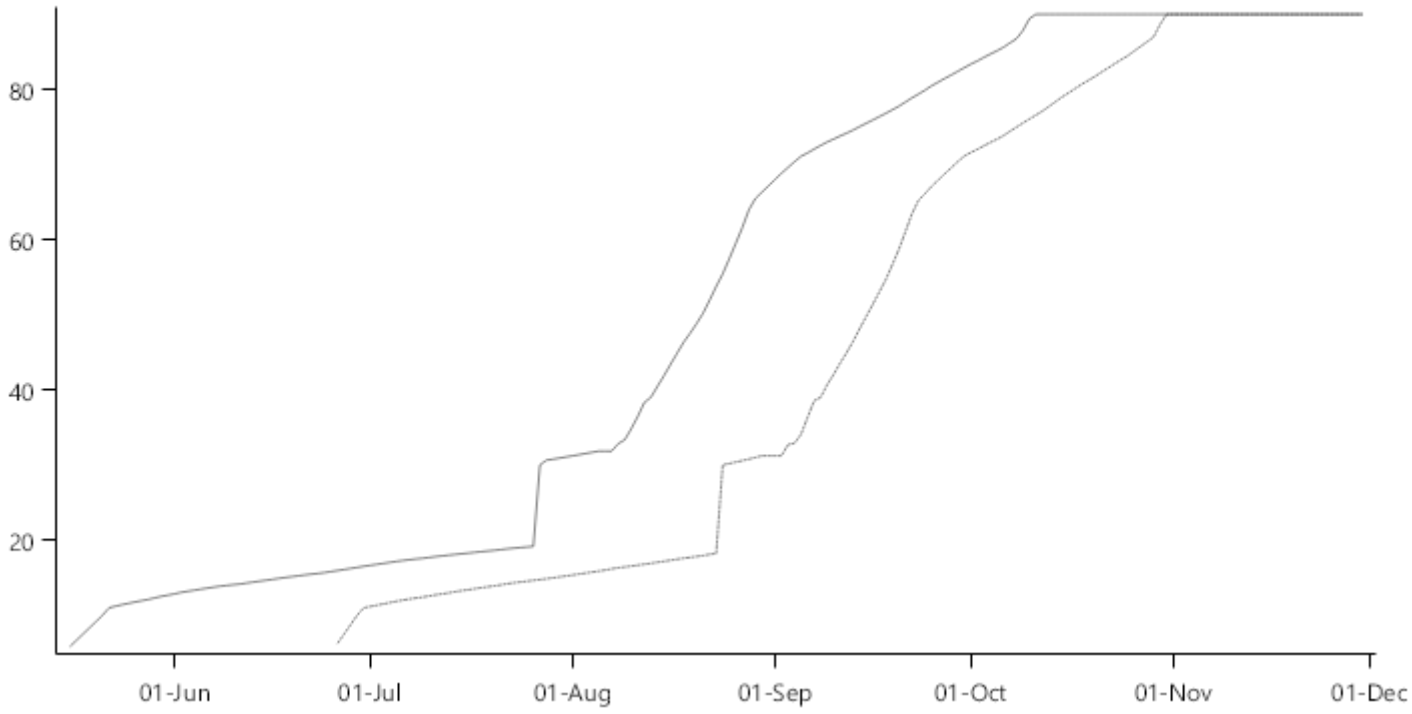
EagleHawk



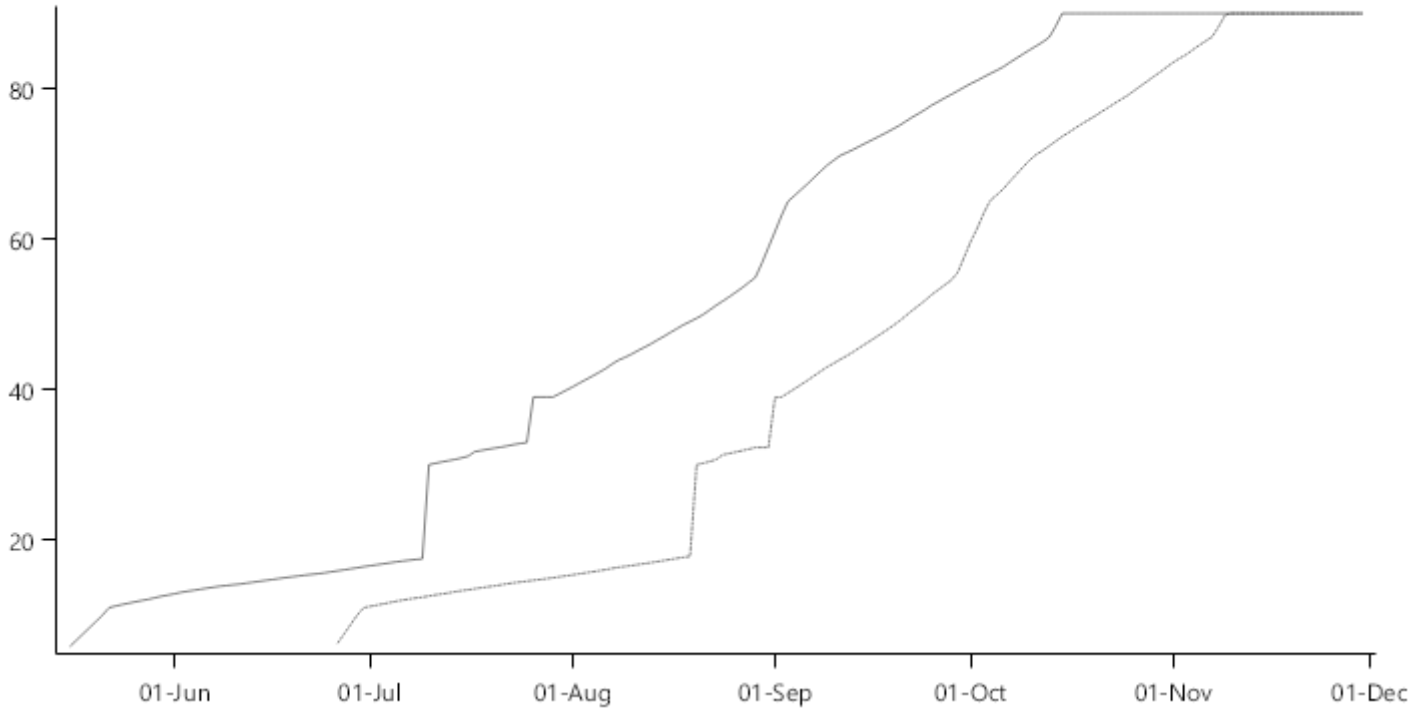
Gregory



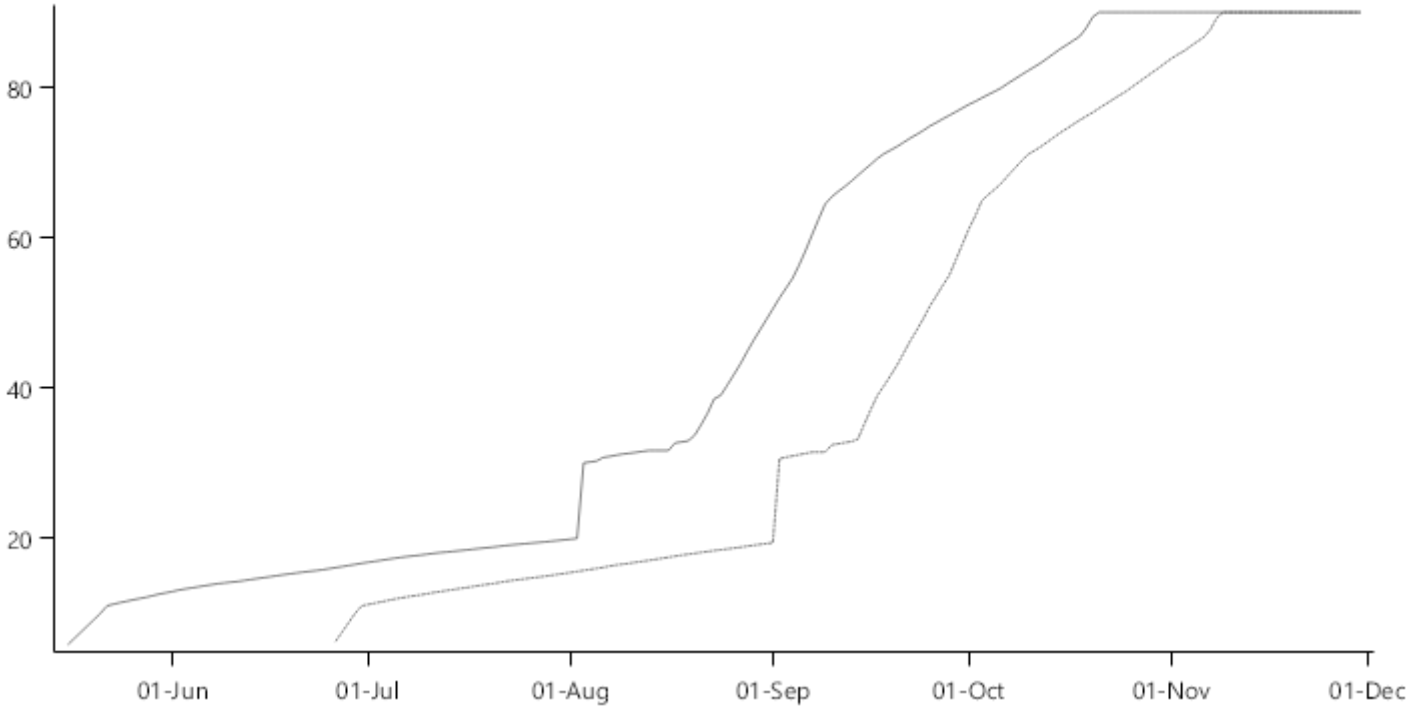
Mace



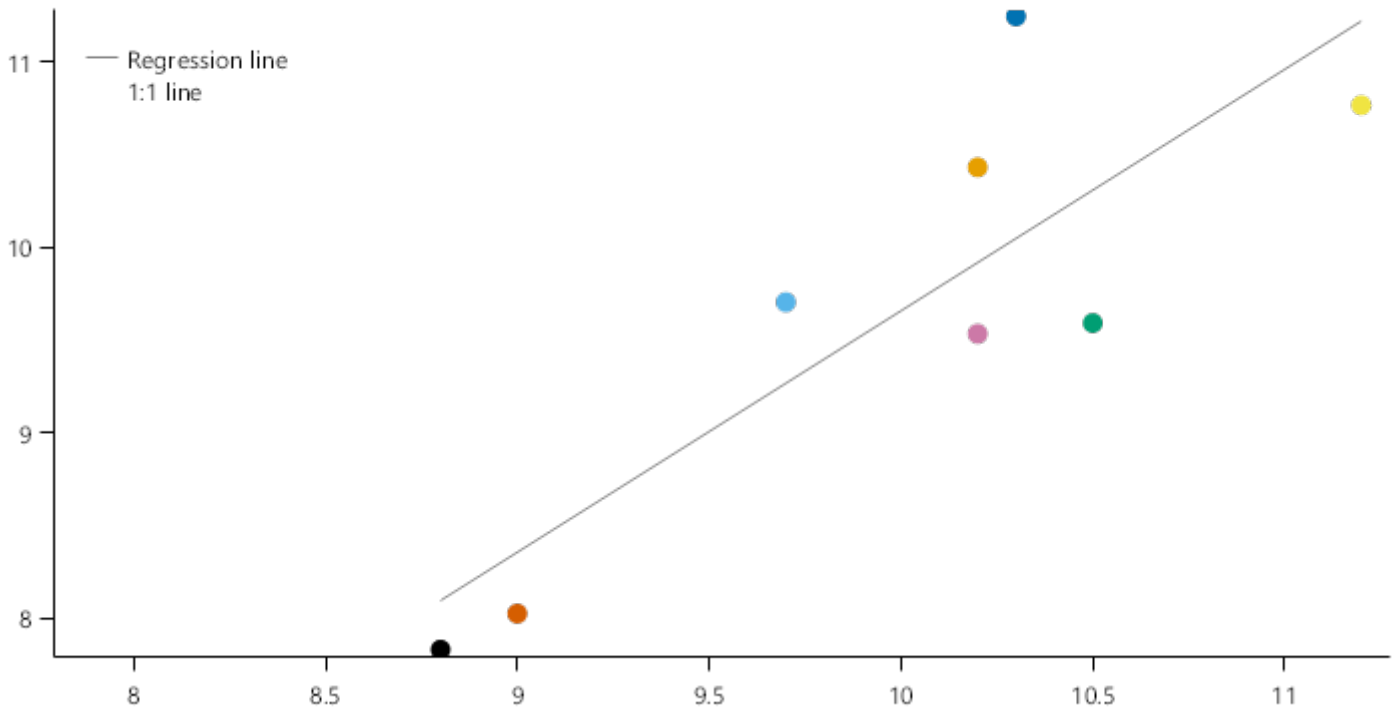
Lincoln



Scout


80
60
40
20
01-Jun
01-Jul
01-Aug
01-Sep
01-Oct
01-Nov
01-Dec

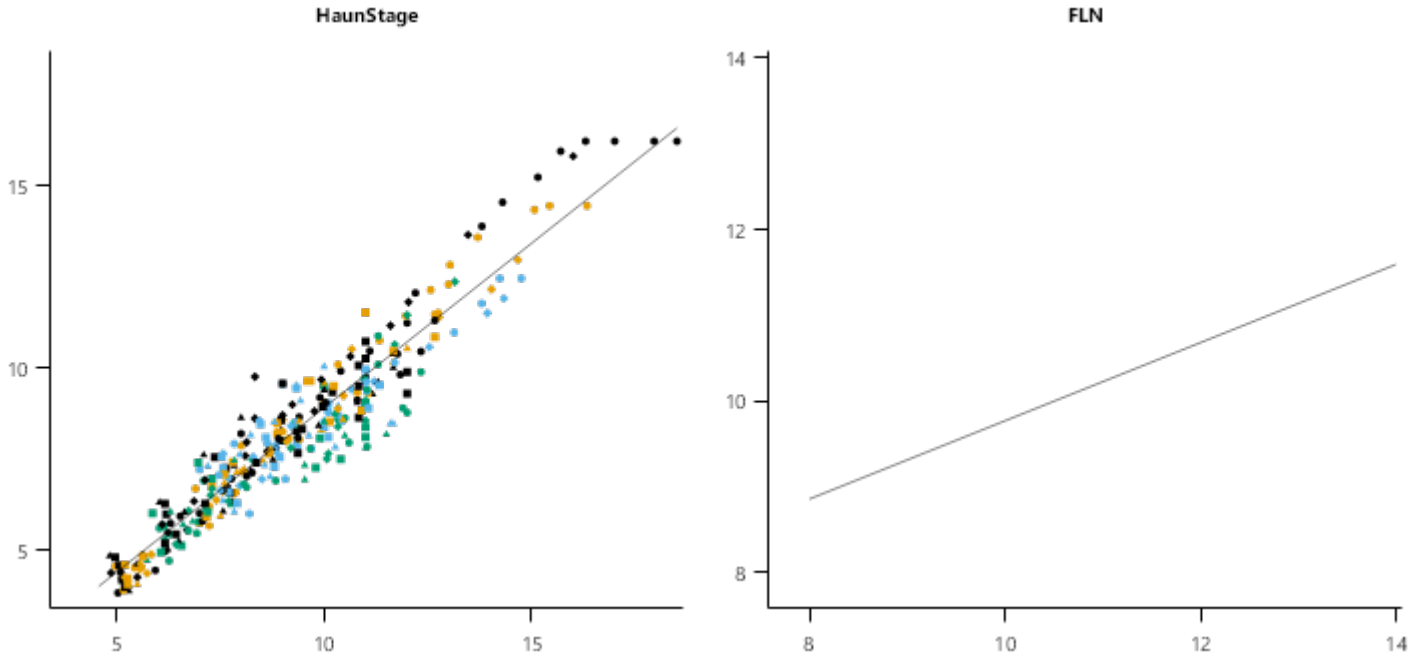
FLN


Regression line
1:1 line
11
10
9
8
8
8.5
9
9.5
10
10.5
11

ZadokTimeSeries1

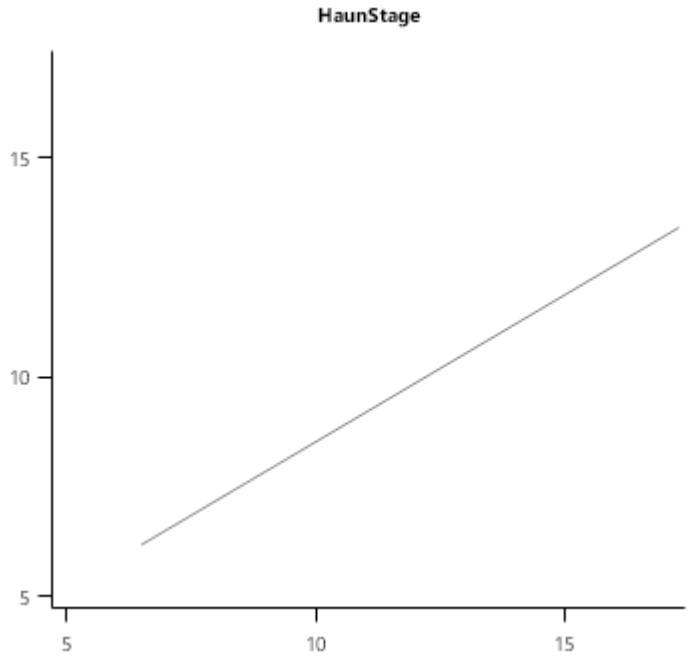
2.2.9 Gatton2014

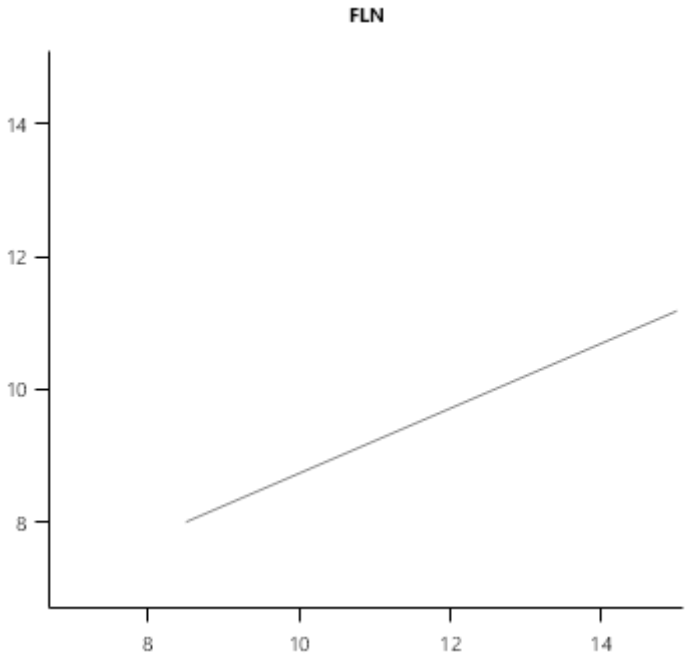
2.2.9.1 PredObs



2.2.10 Gatton2014AE

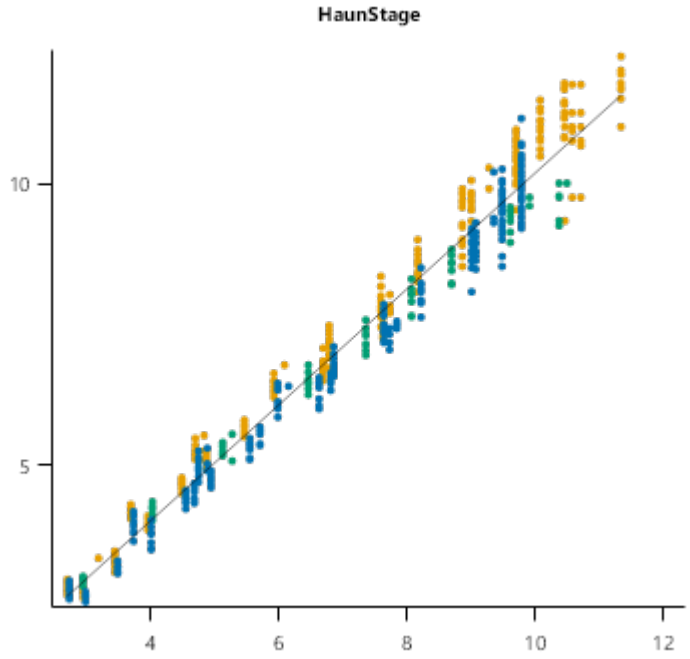
2.2.10.1 PredObs





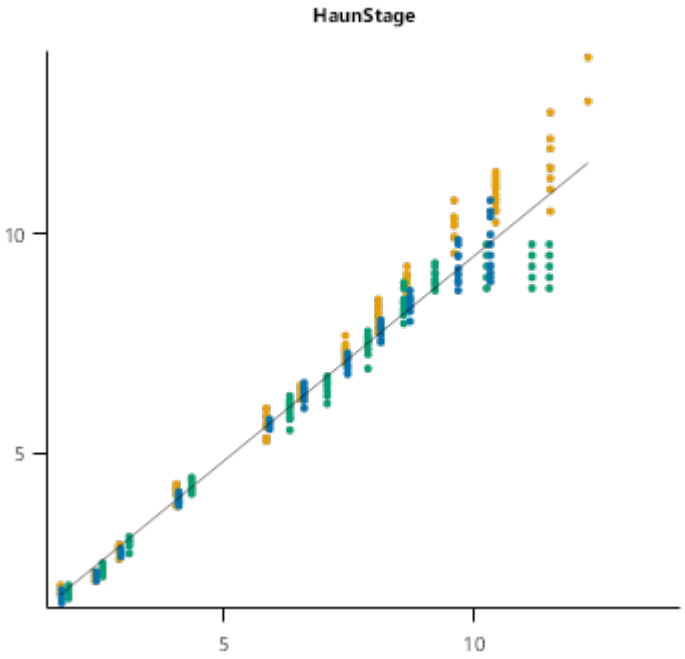
2.2.11 TraitMod2015

2.2.11.1 PredObs



2.2.12 TraitMod2016

2.2.12.1 PredObs



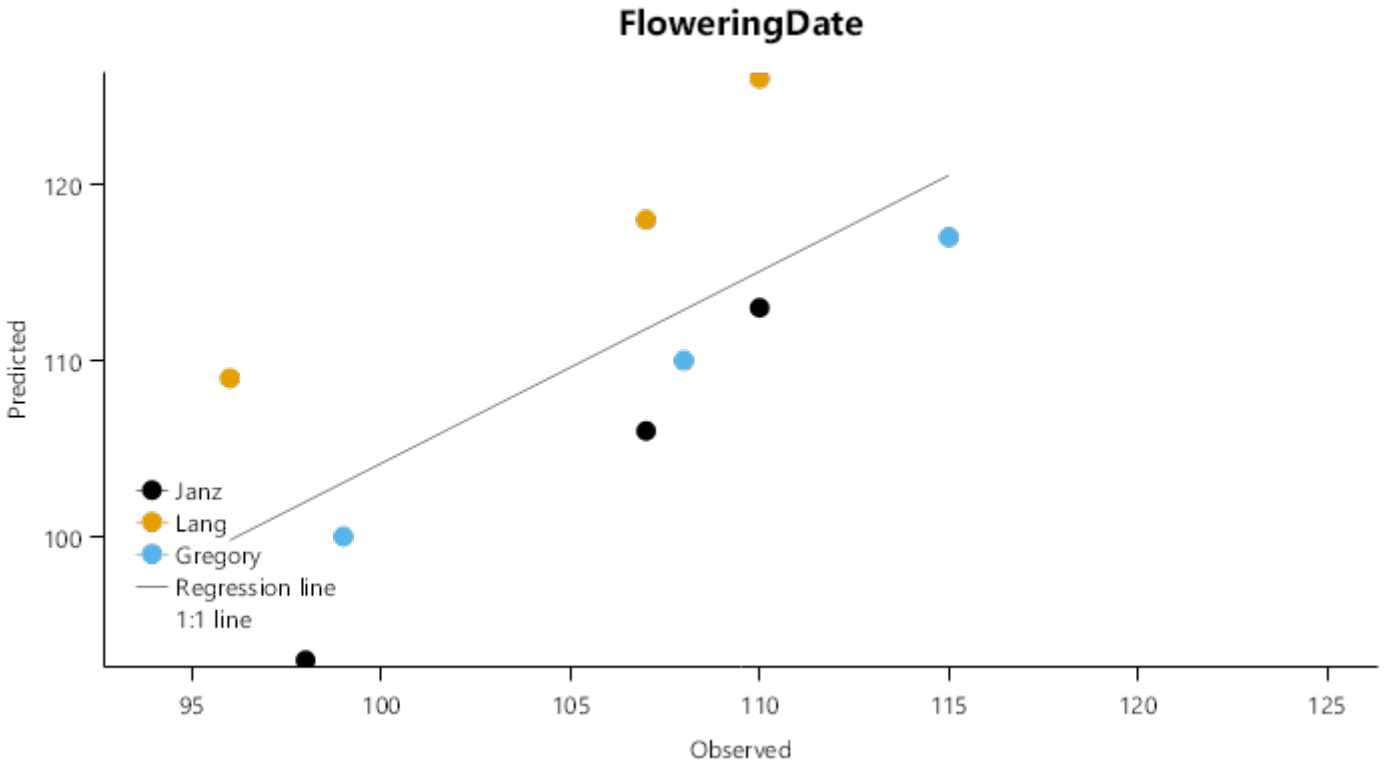
2.2.13 AddingValueToNVT

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.

List of experiments.

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

2.2.13.1 Goondiwindi2011



2.2.13.2 Nagwee2012

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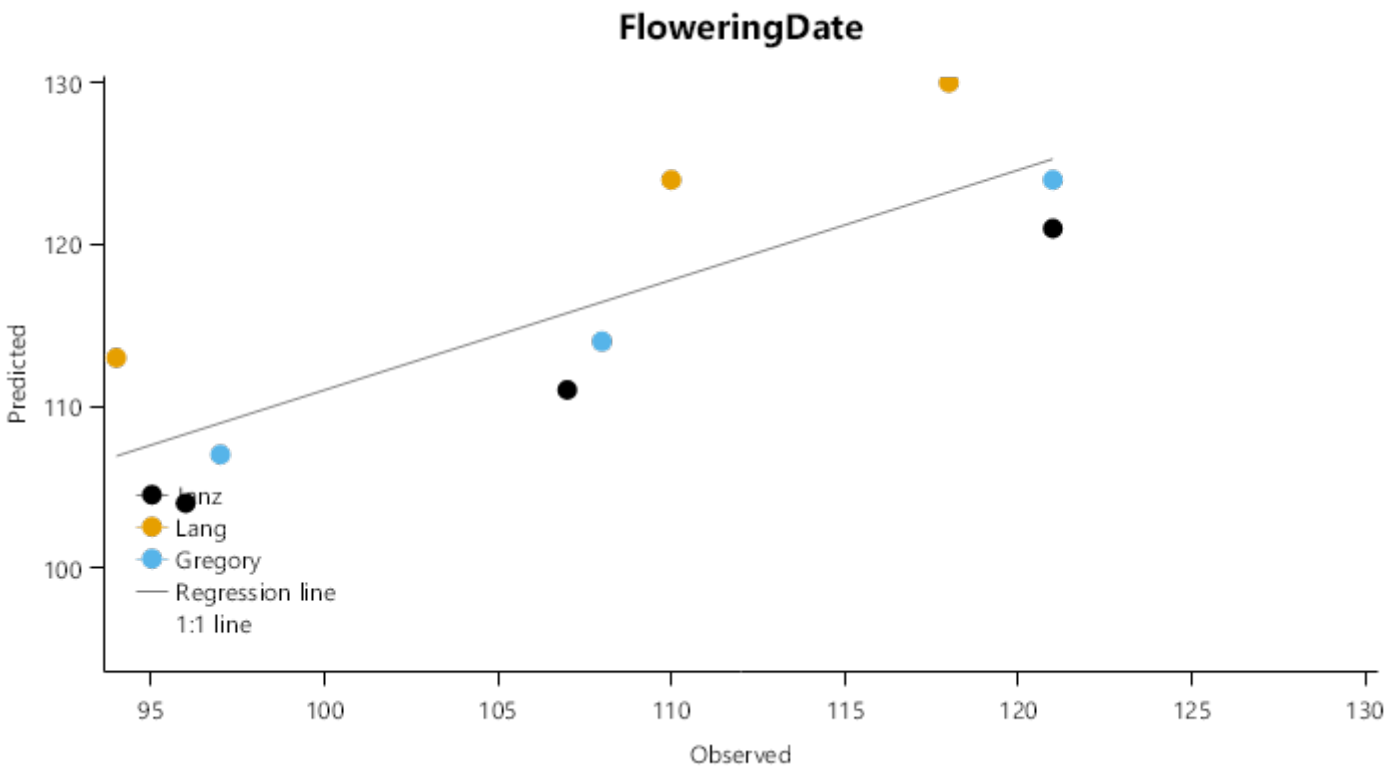
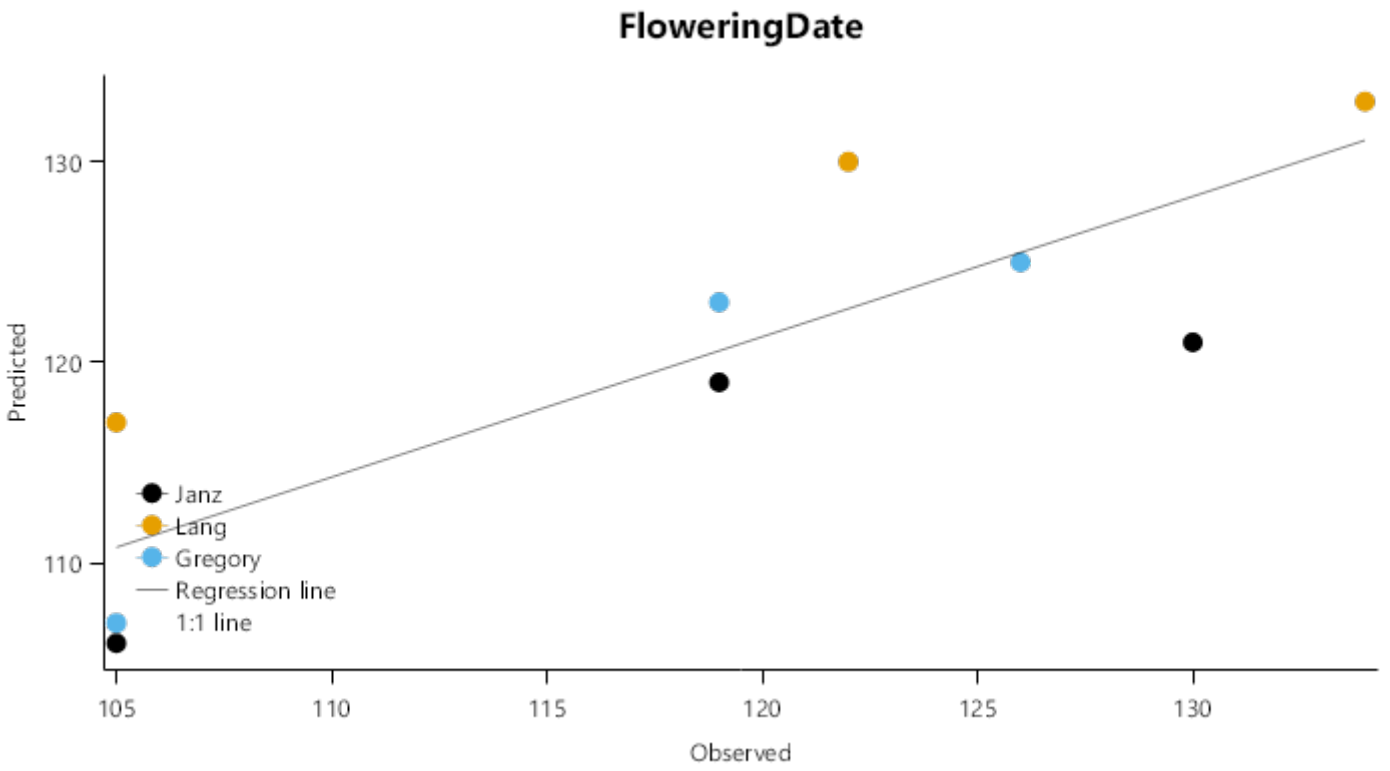


2.2.13.3 Bungunya2012

INSERT TEXT HERE



2.2.14 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.

List of experiments.

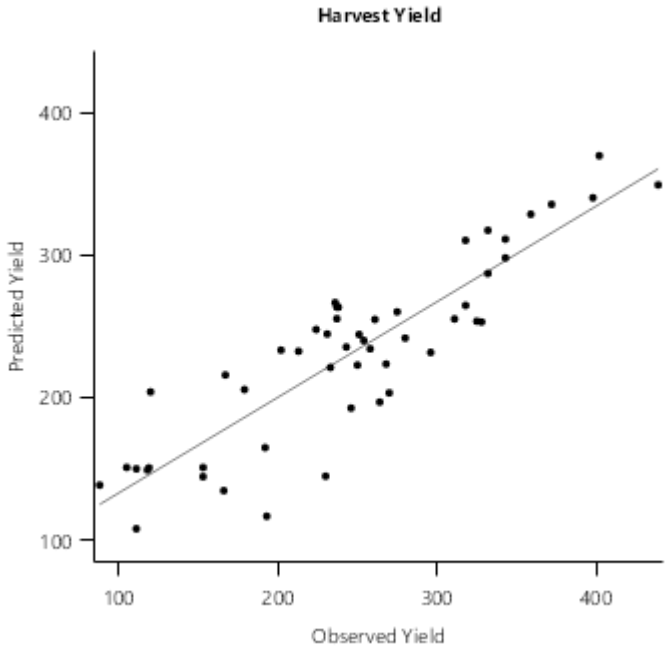
Experiment Name	Design (Number of Treatments)
Goondiwindi1996	Cv x TOS (18)
Miles1996	Cv x TOS (30)
Emerald1996	Cv x TOS (24)
Biloela1996	Cv x TOS (30)
Moree1996	Cv x TOS (18)

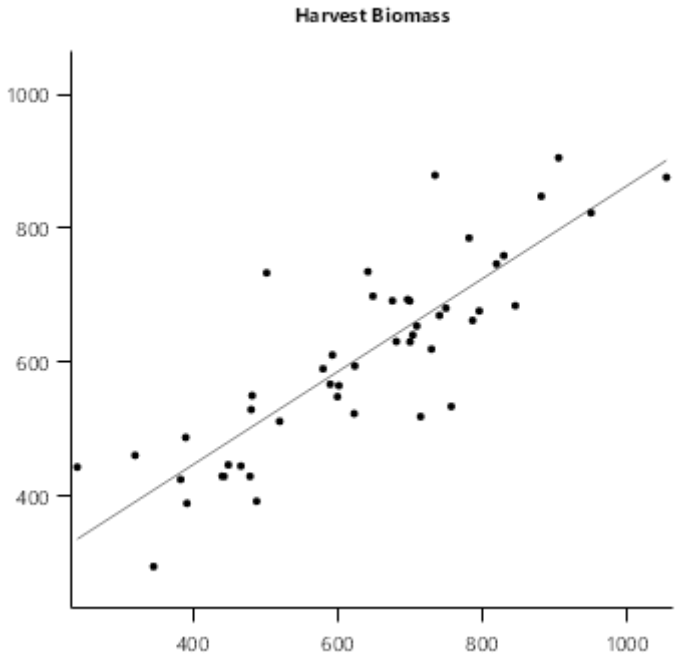
2.3 Western Australia

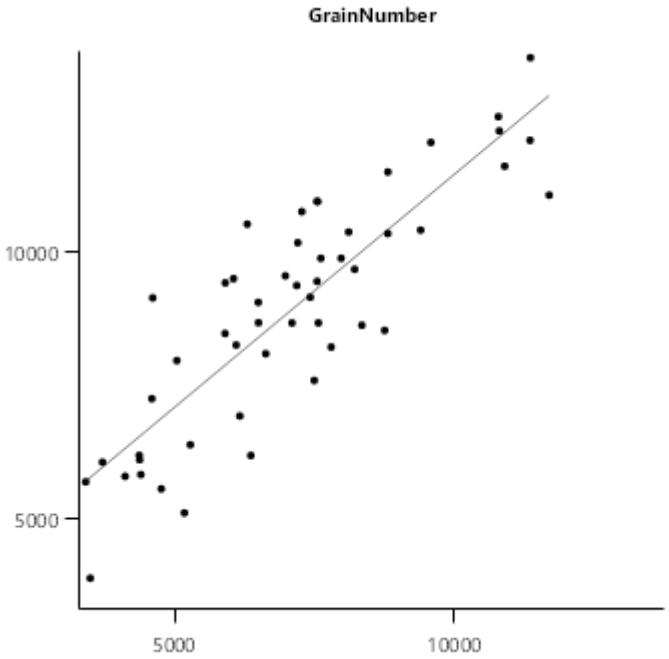
The wheat belt of Western Australia has a Mediteranean climate (winter dominant rainfall patterns) with mostly sandy soils. Data from S Asseng et al., 1998. and some more recent studies have been included to extend the range of conditions studied and to include more modern cultivars.

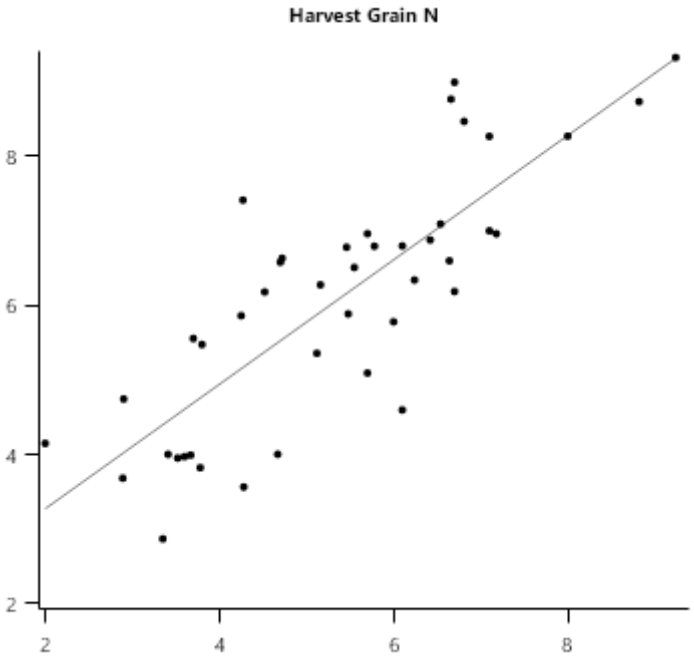
List of experiments.

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)

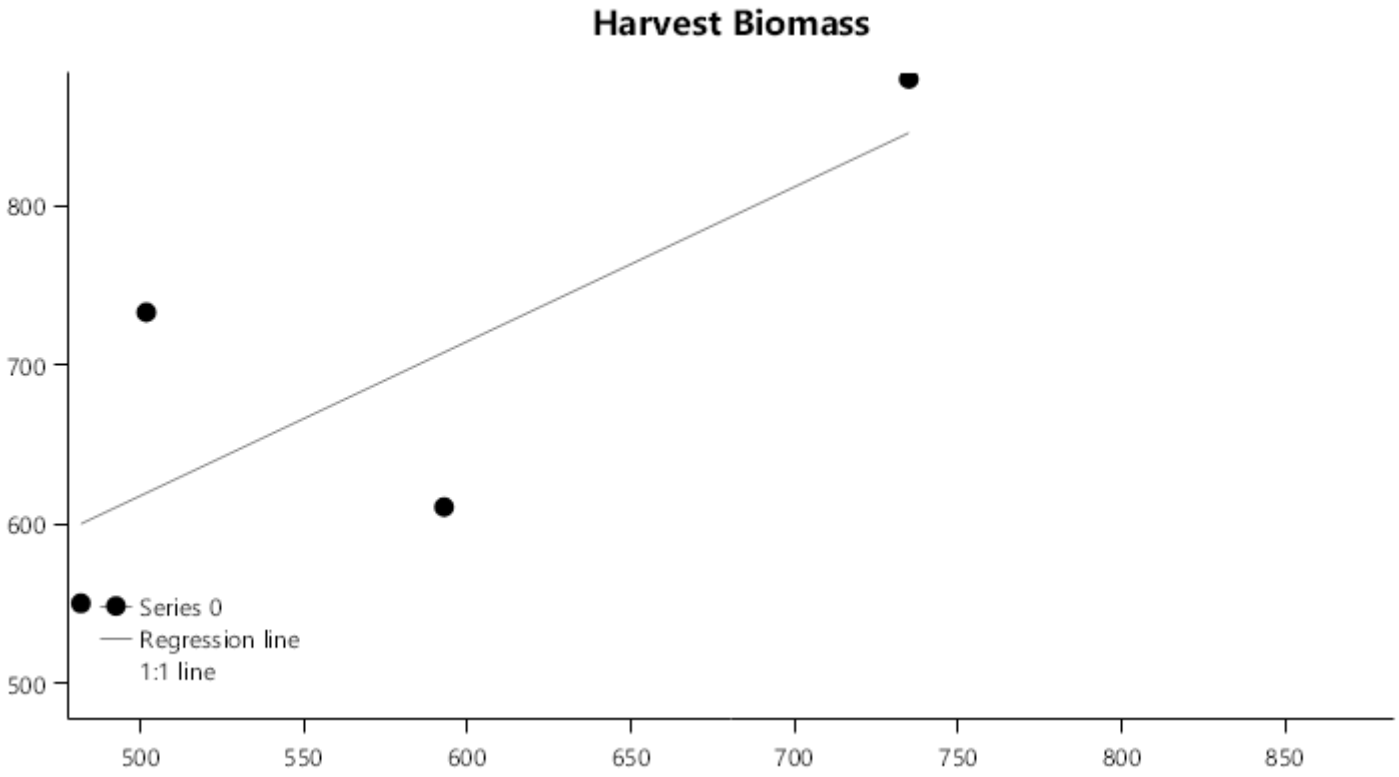

Harvest Yield
Predicted Yield
Observed Yield
100
200
300
400


Harvest Biomass
400
600
800
1000

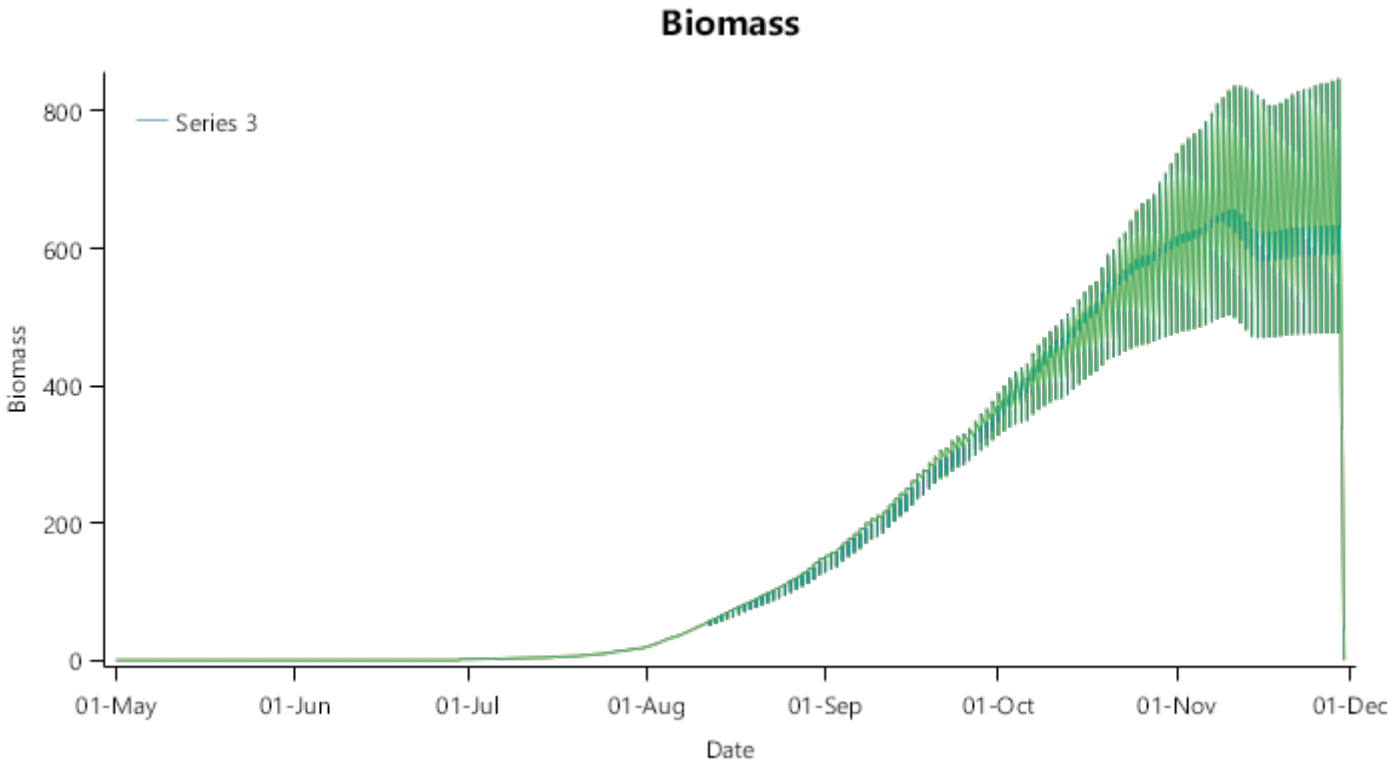

GrainNumber
5000
10000

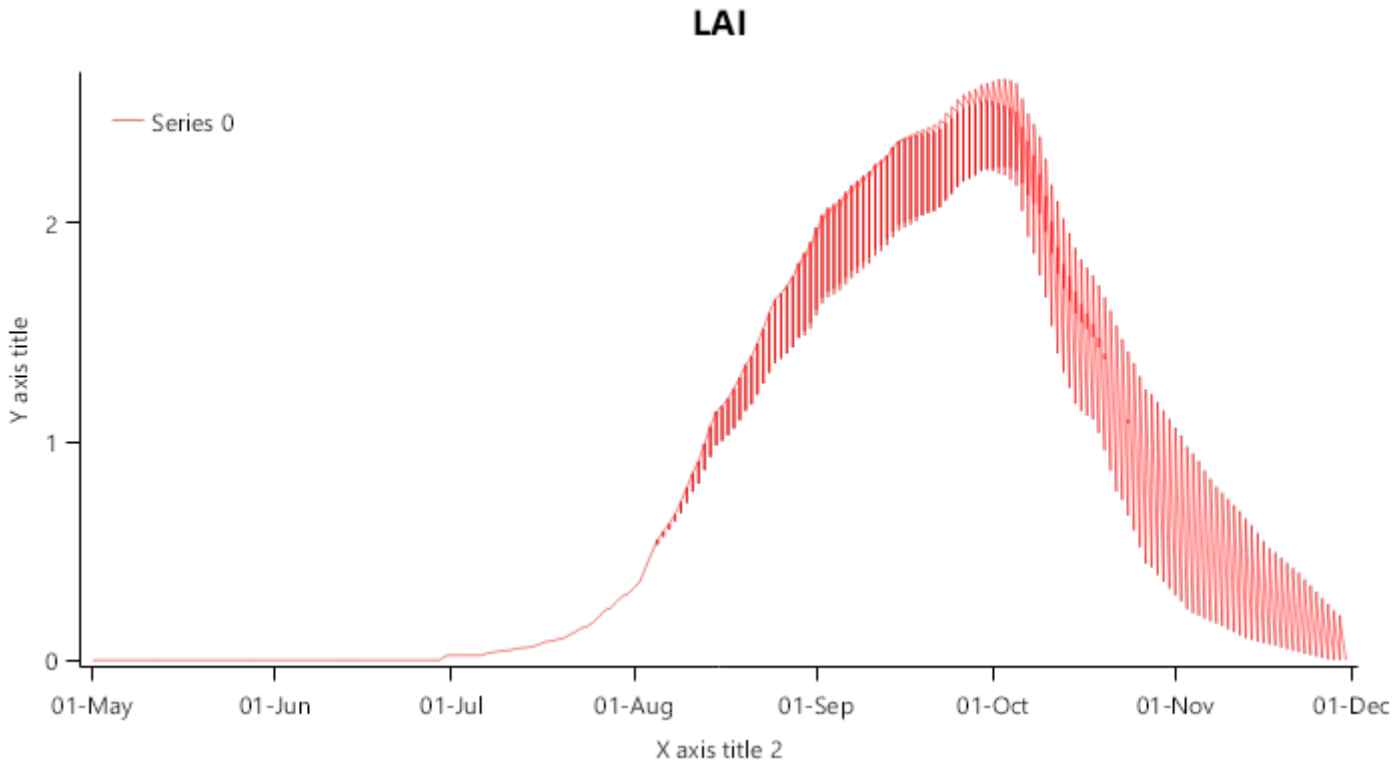

Harvest Grain N
2
4
6
8

2.3.1 Mer86

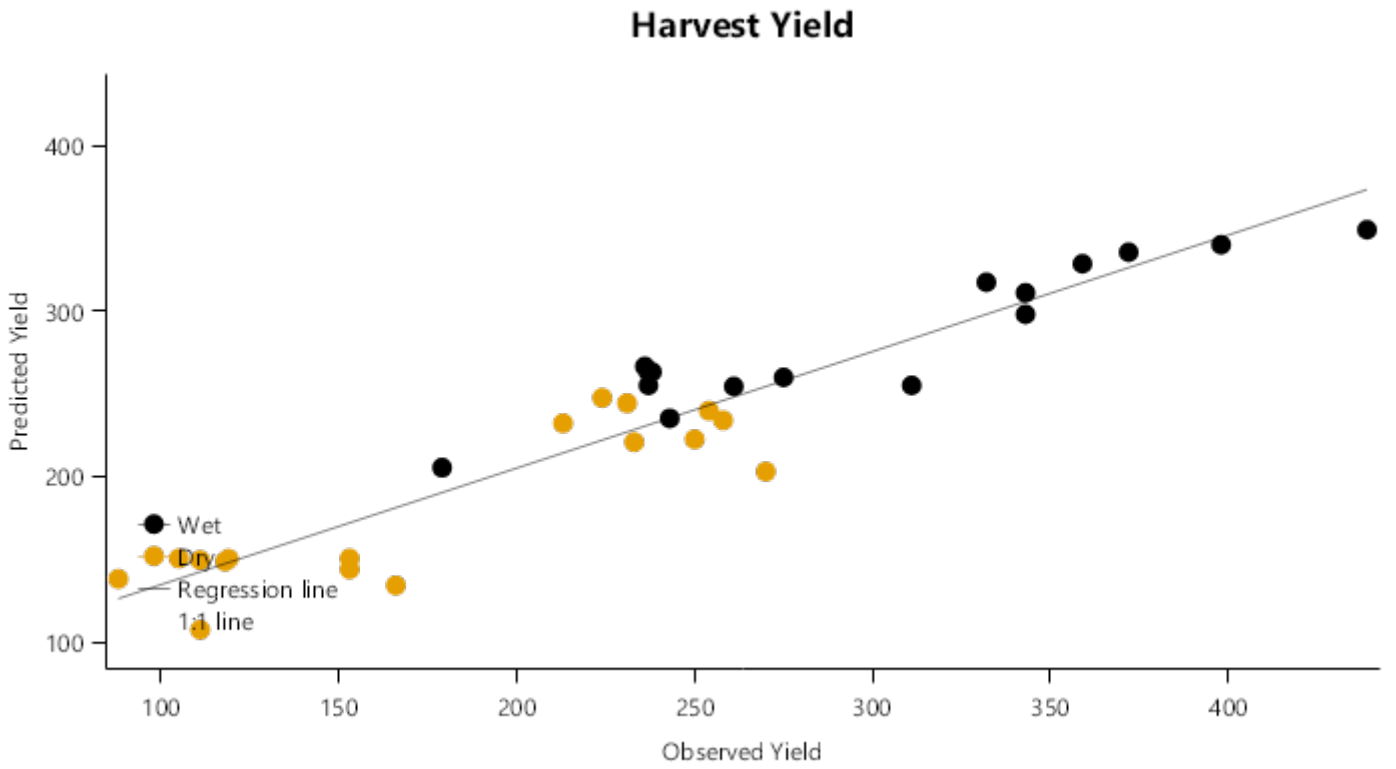

Harvest Biomass
800
700
600
500
Series 0
Regression line
1:1 line
500
550
600
650
700
750
800
850

2.3.2 Mer73

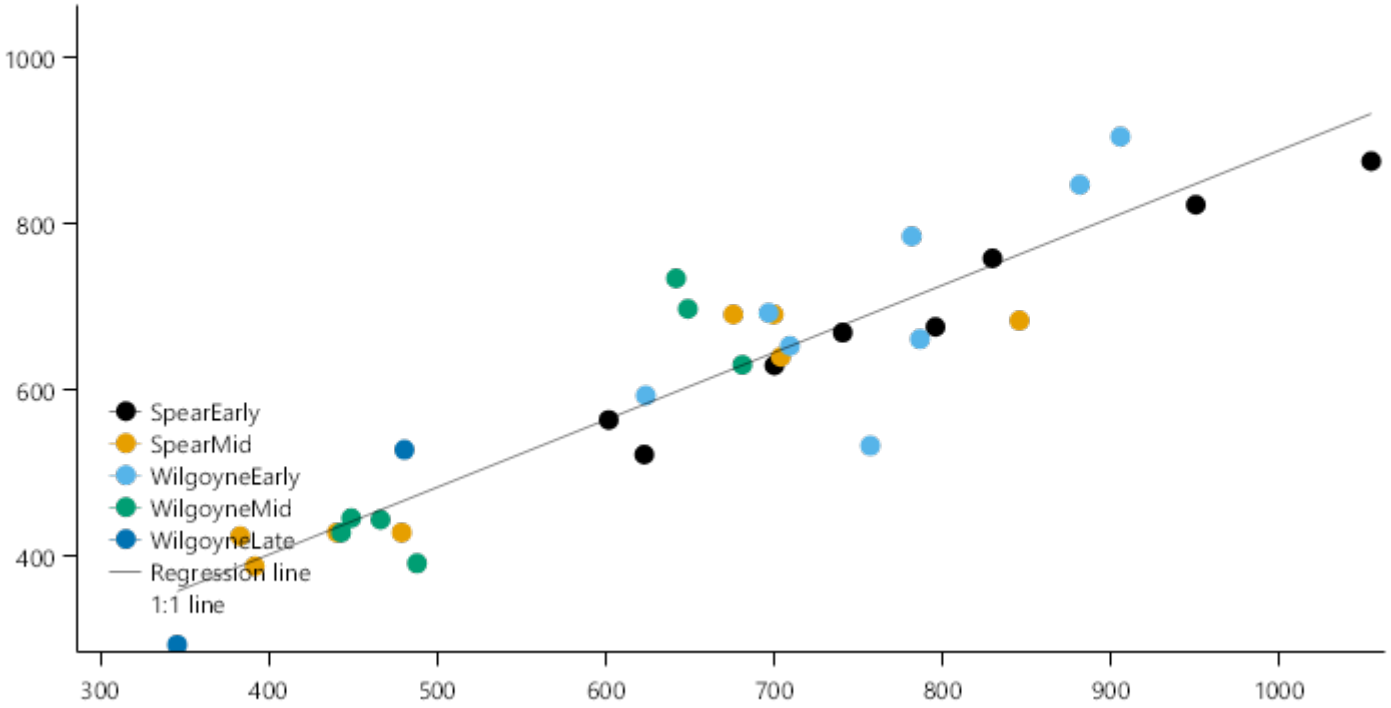

Biomass
Series 3
800
600
400
200
0
Biomass
01-May
01-Jun
01-Jul
01-Aug
01-Sep
01-Oct
01-Nov
01-Dec
Date



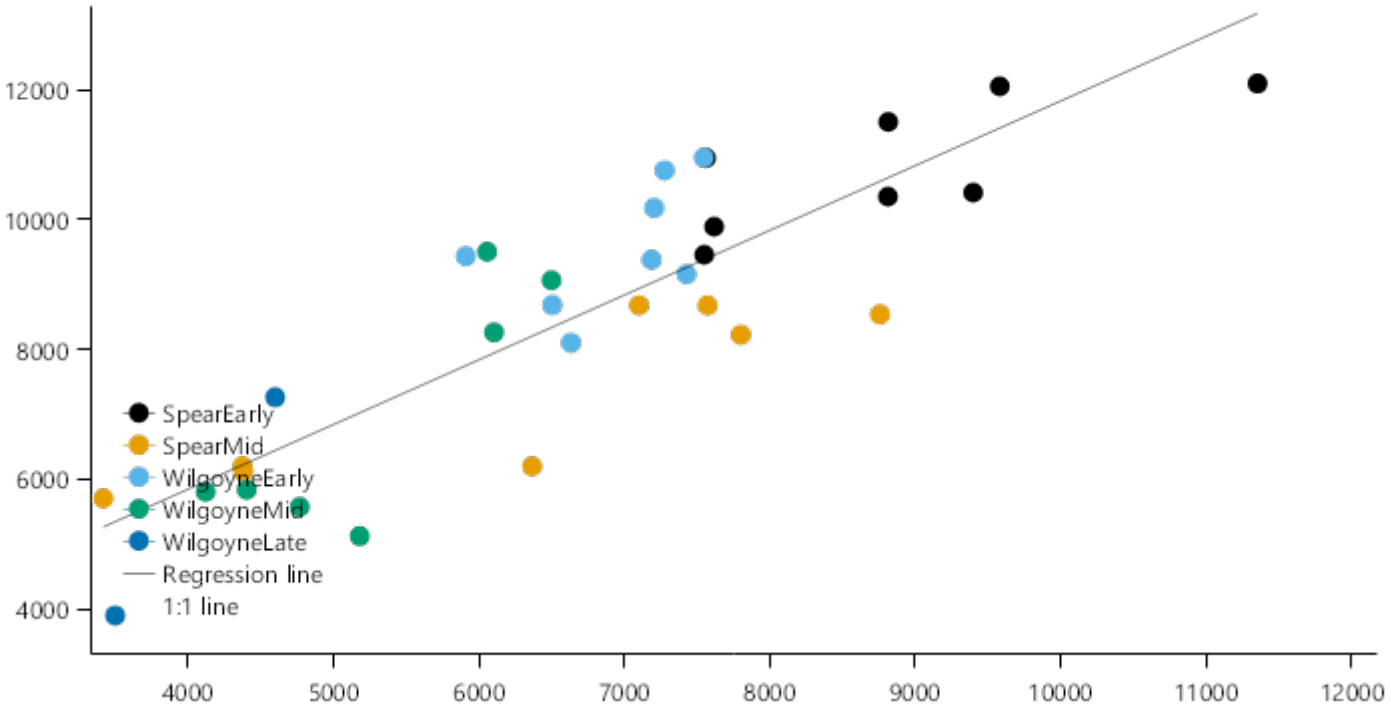
2.3.3 Cunderdin97

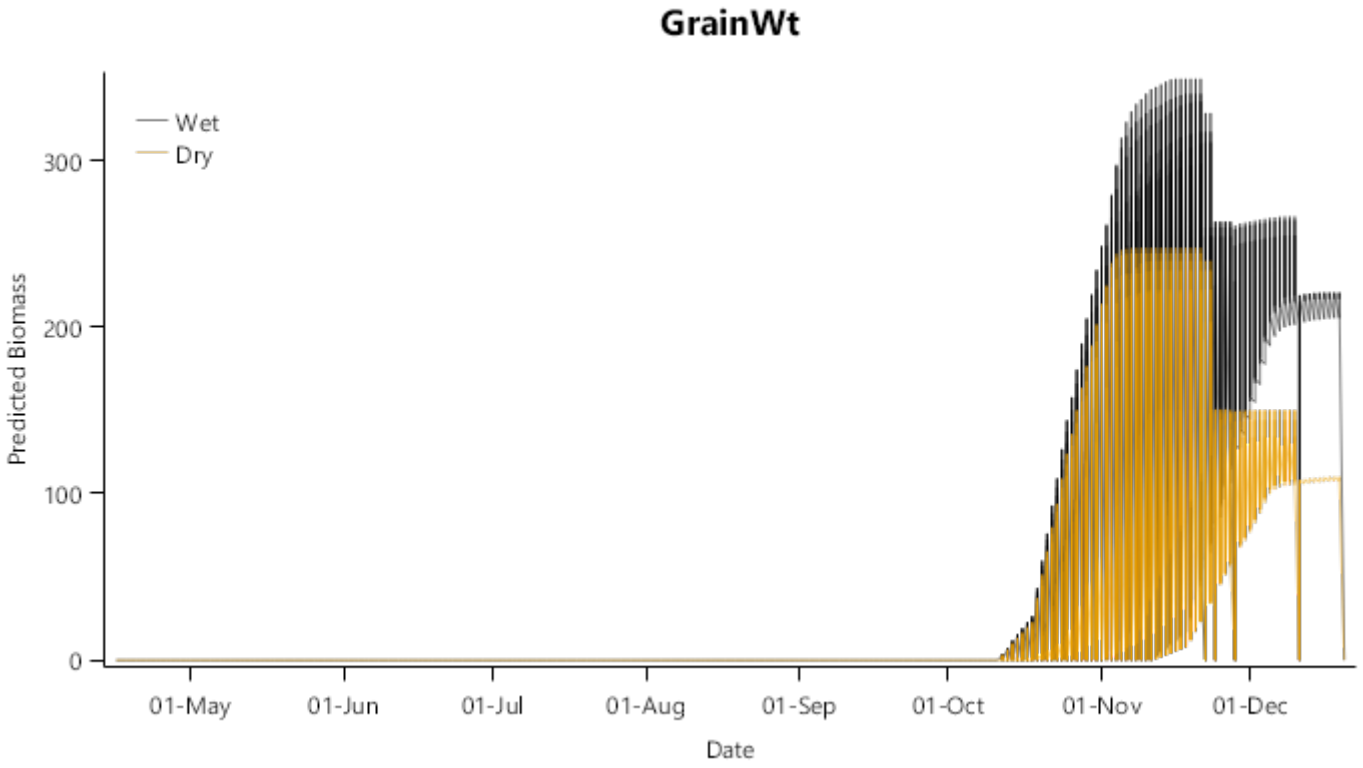


Harvest Biomass

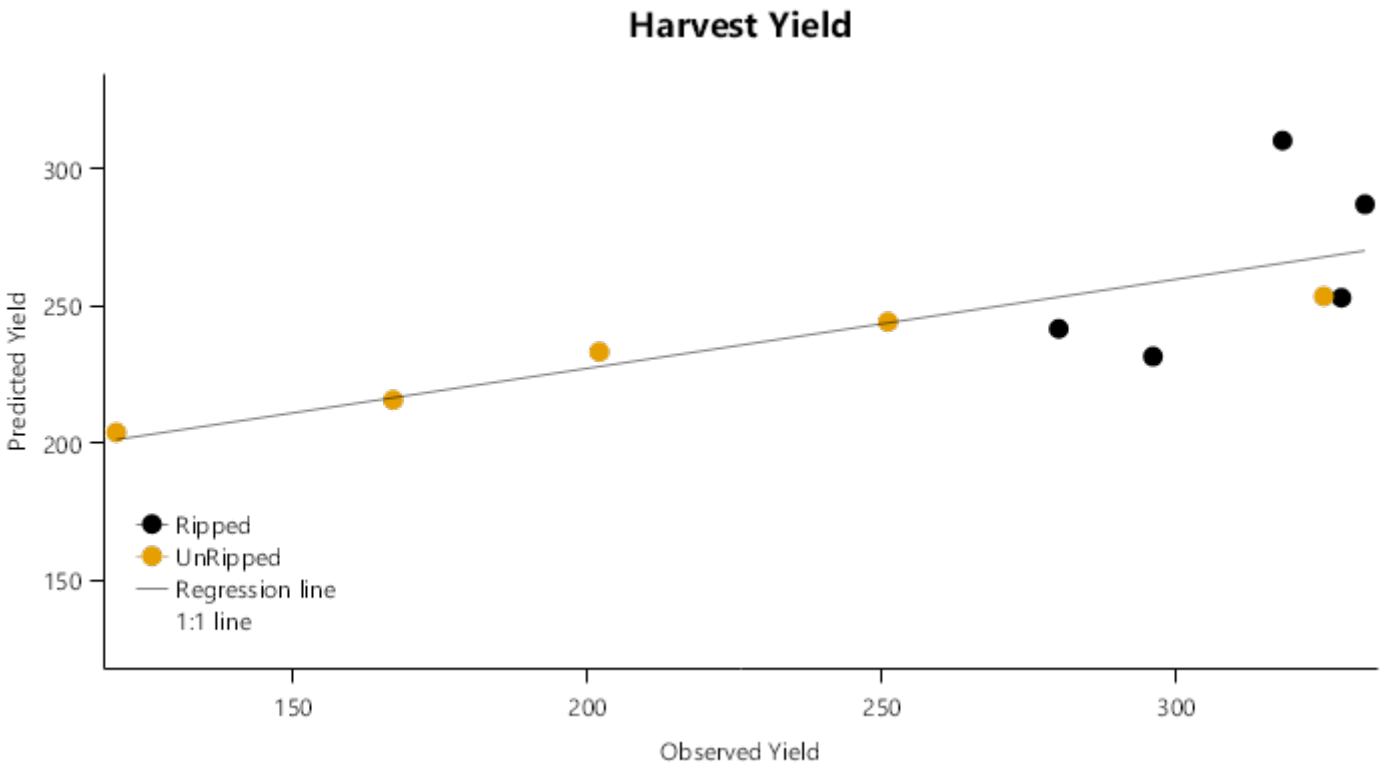


GrainNumber

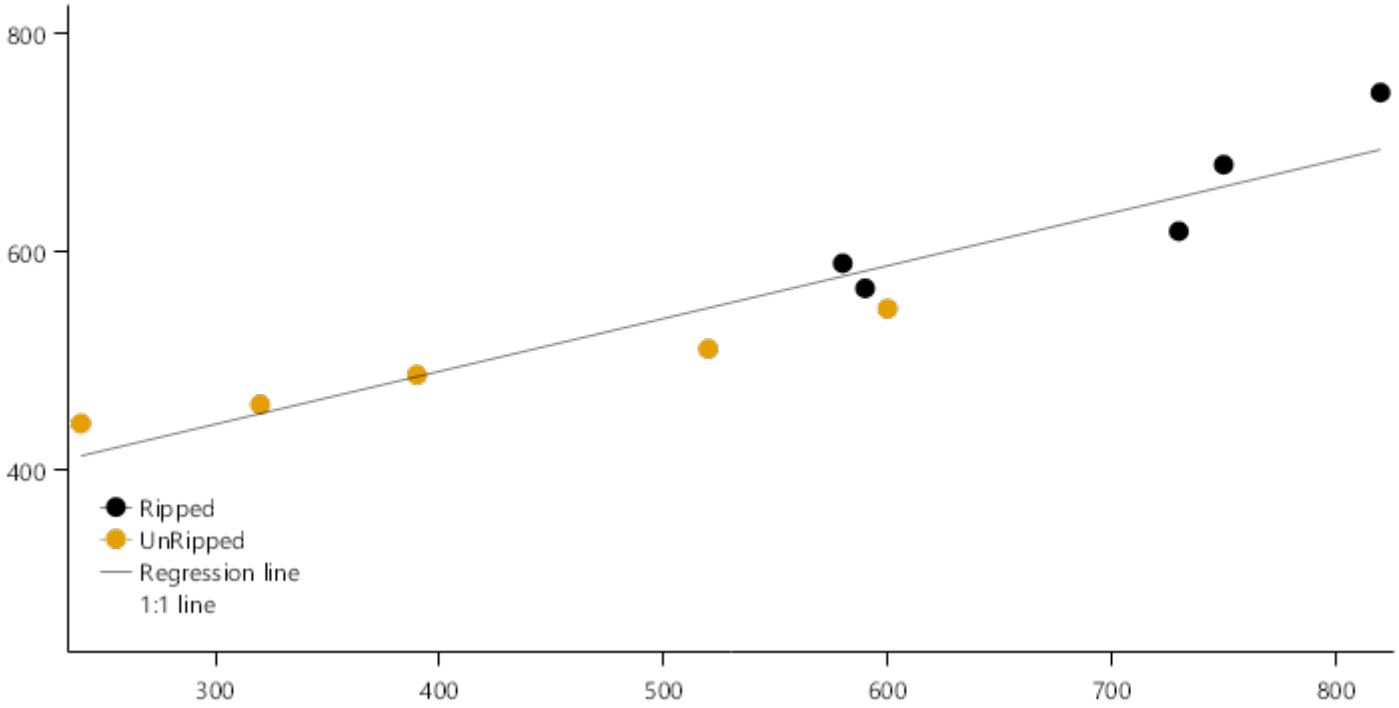




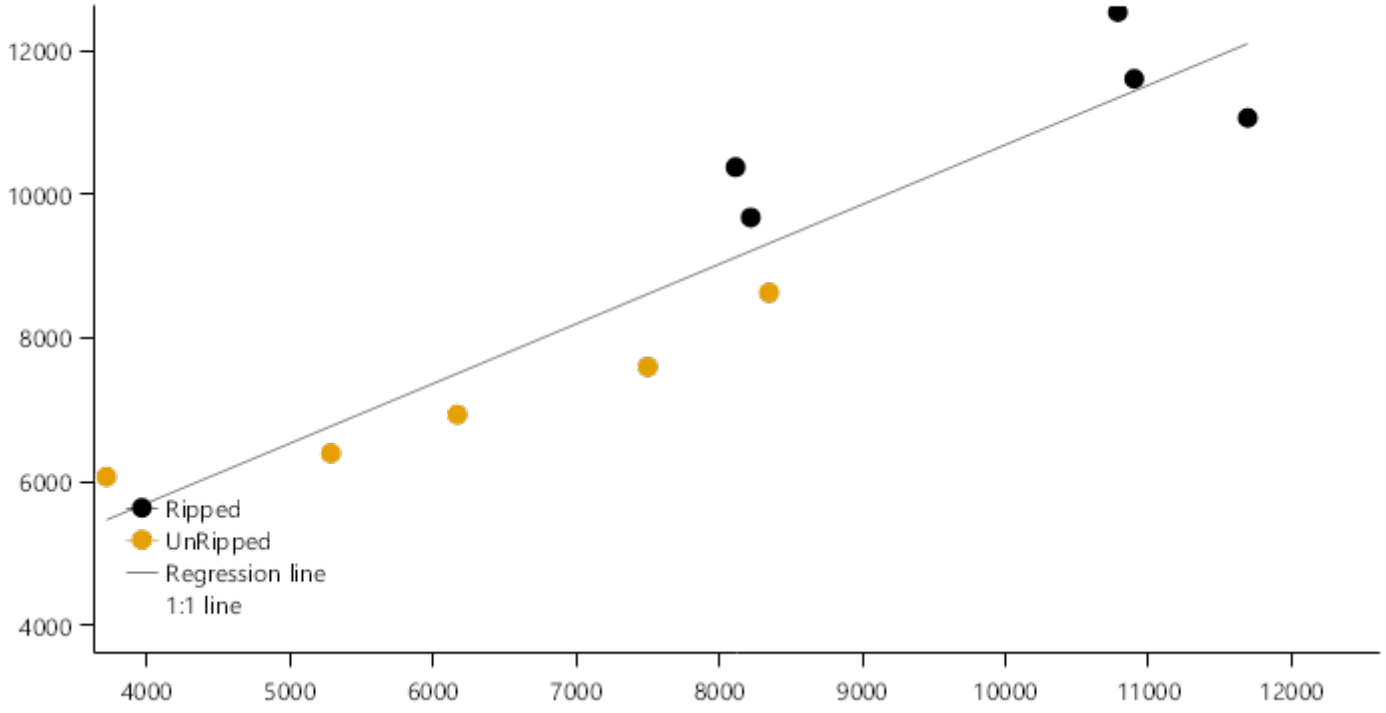
2.3.4 Wongan83



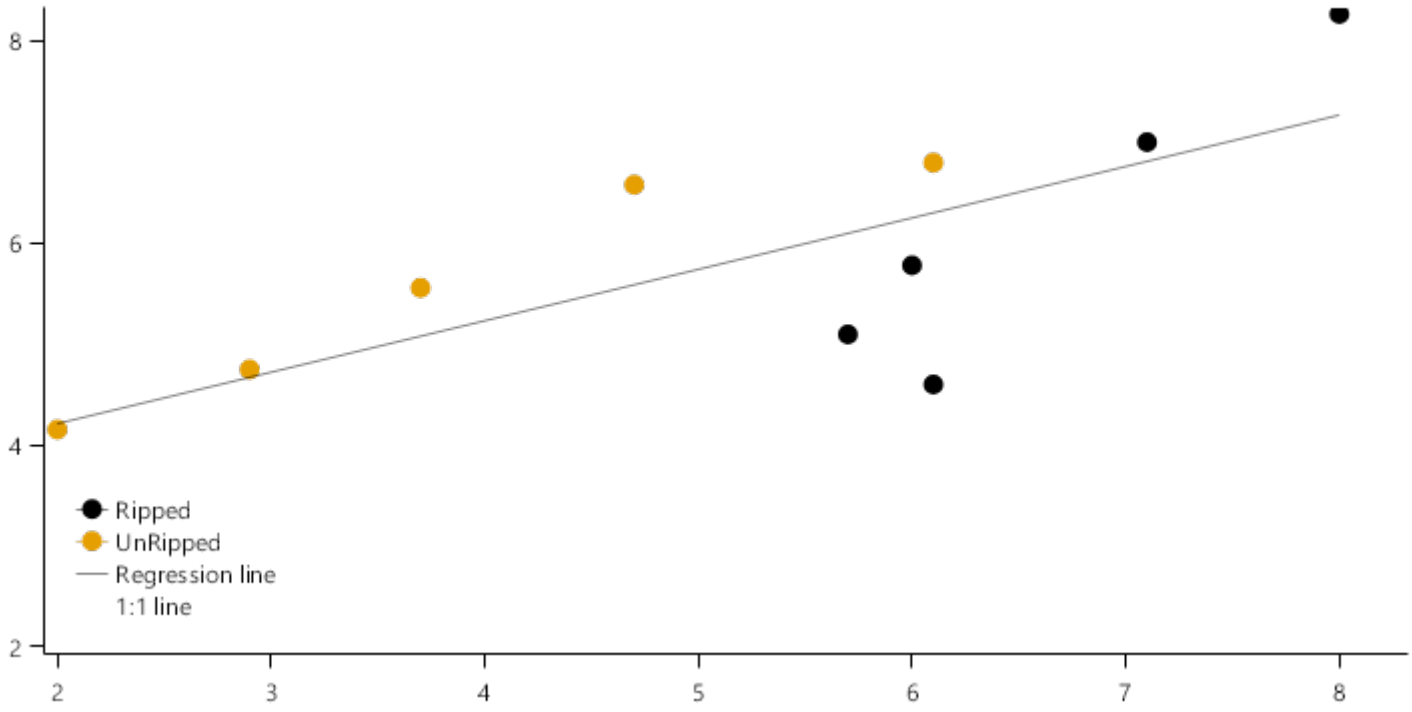
Harvest Biomass



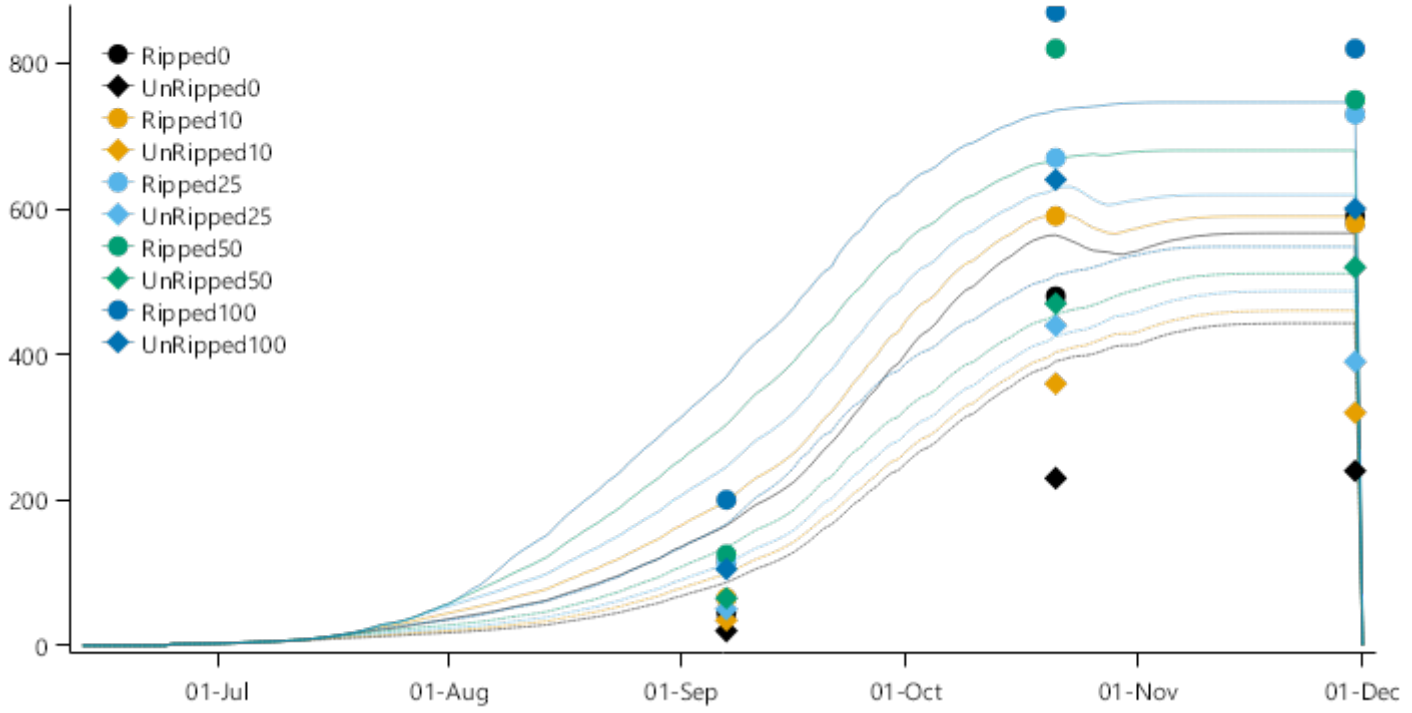
GrainNumber



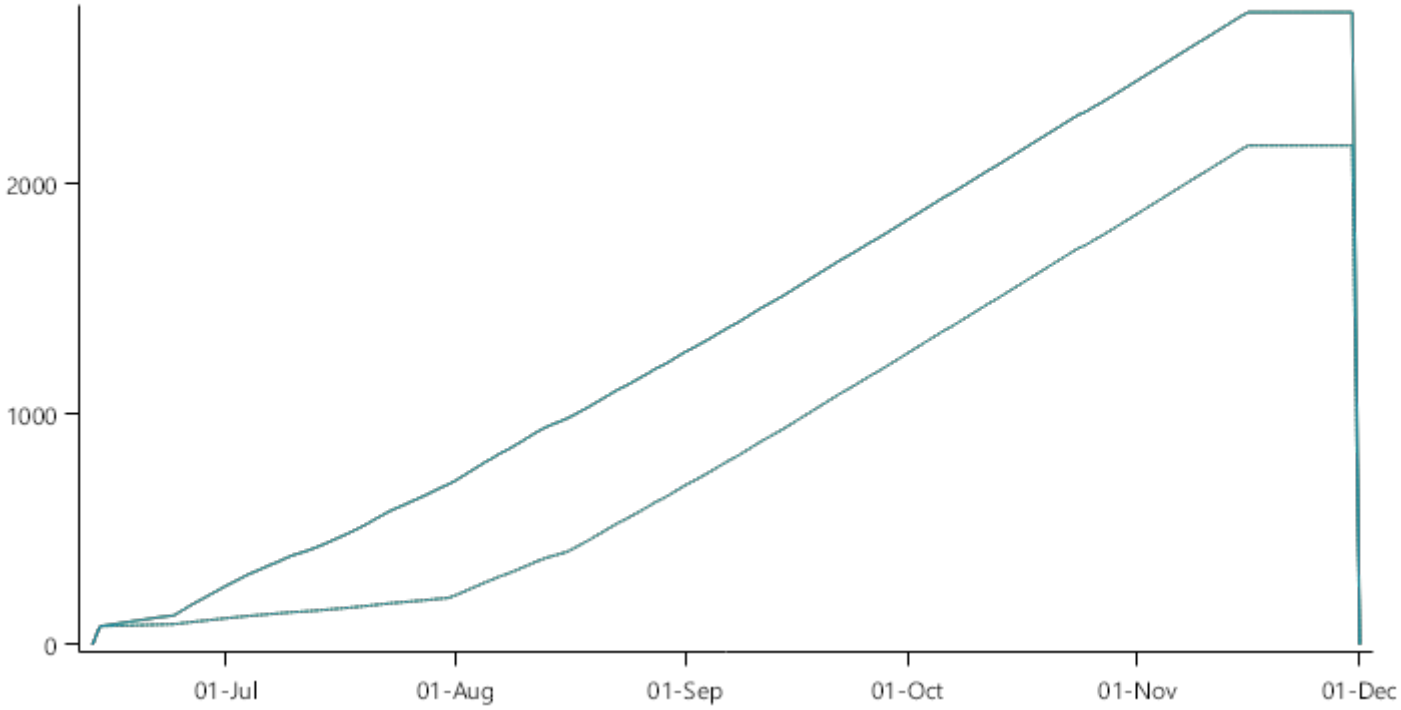
GrainN



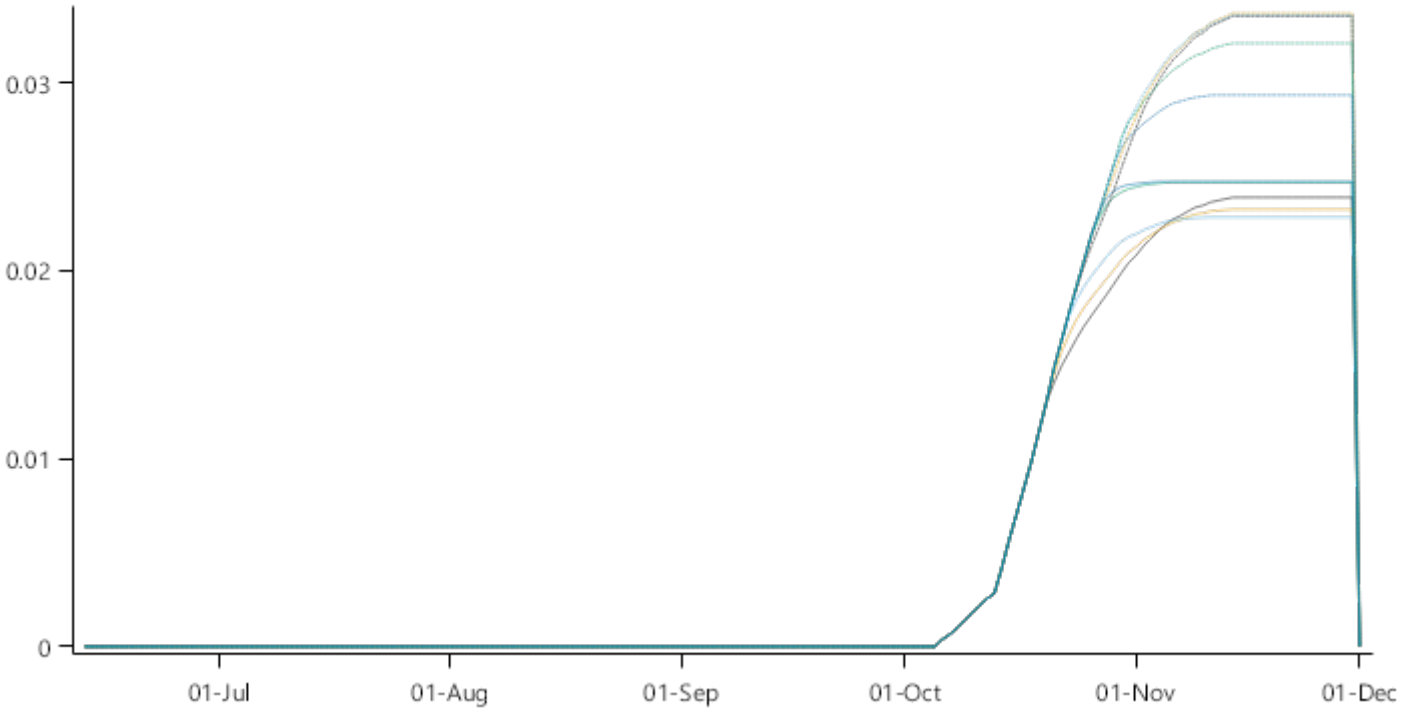
Biomass

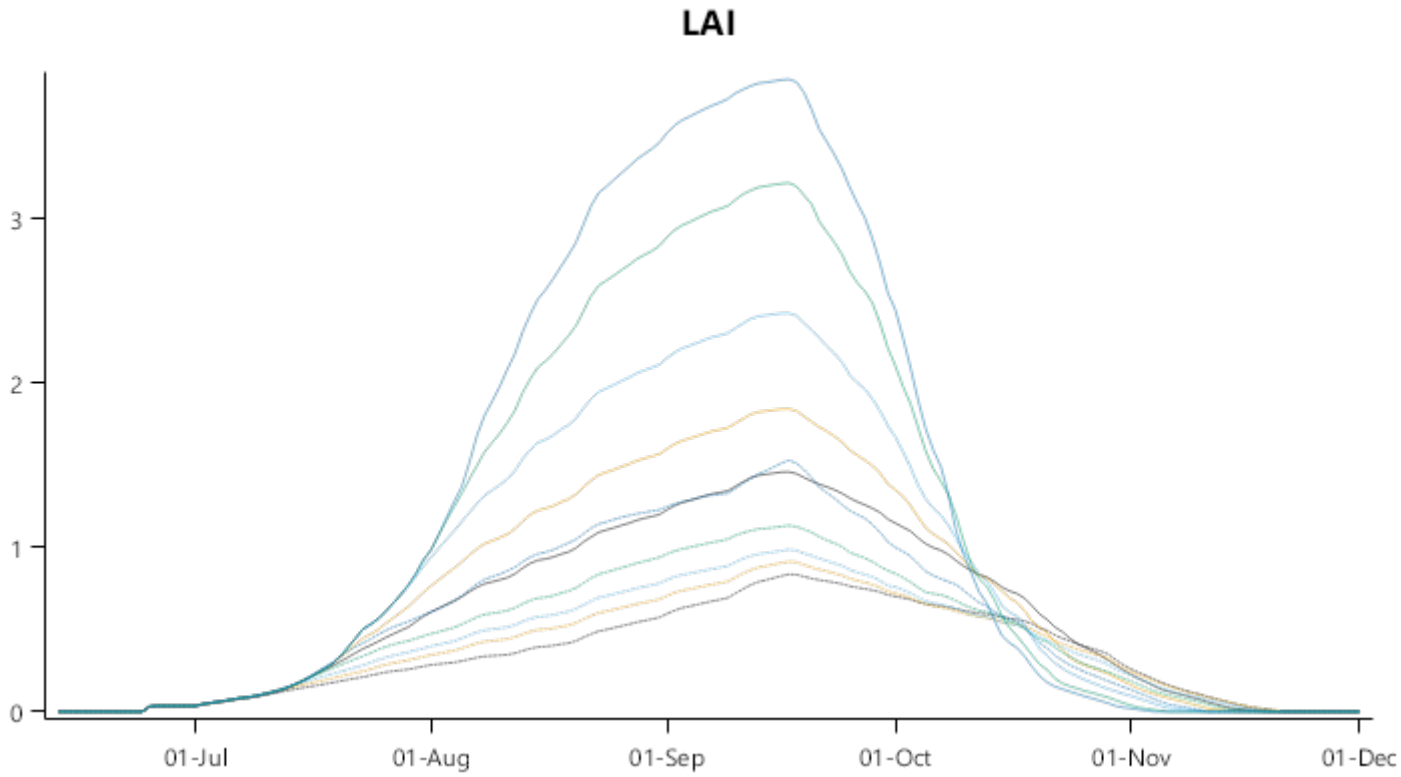


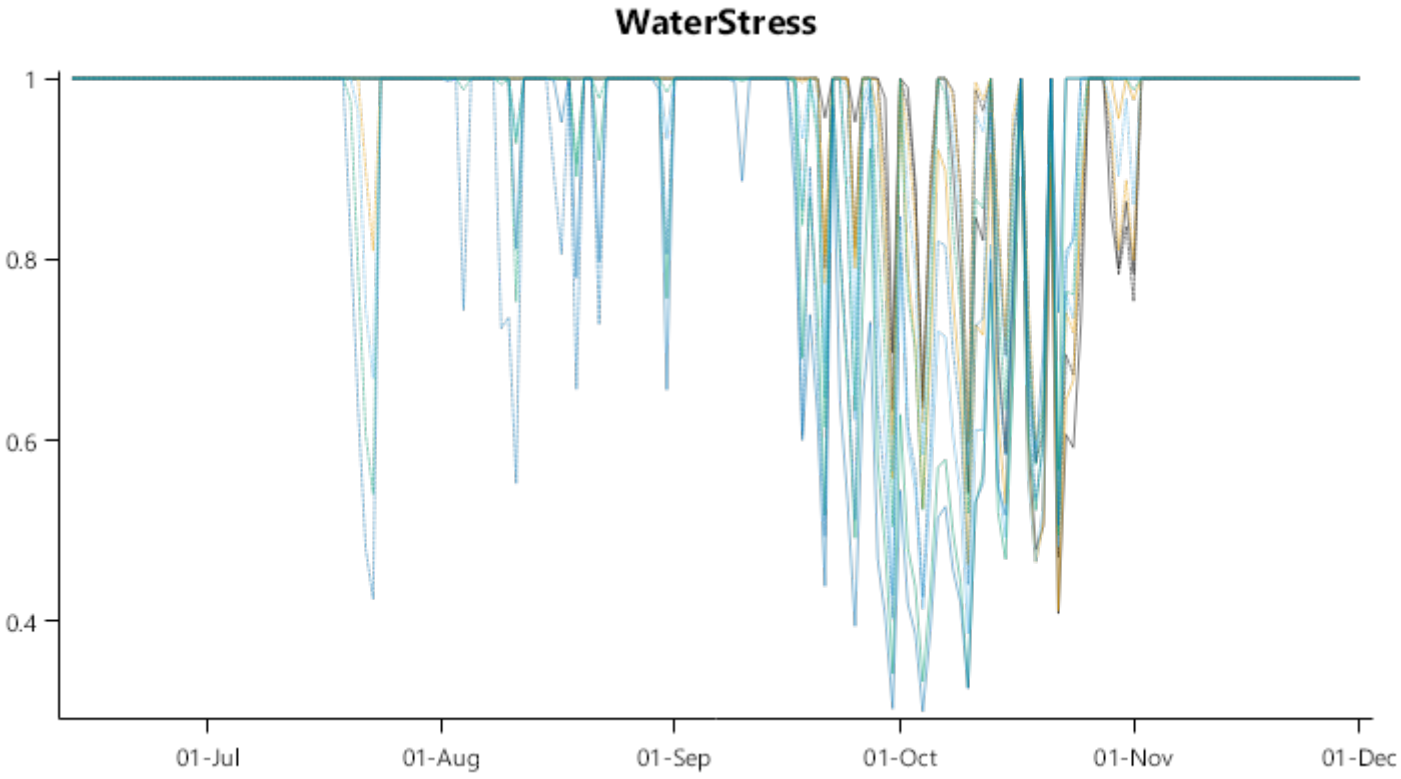
RootDepth

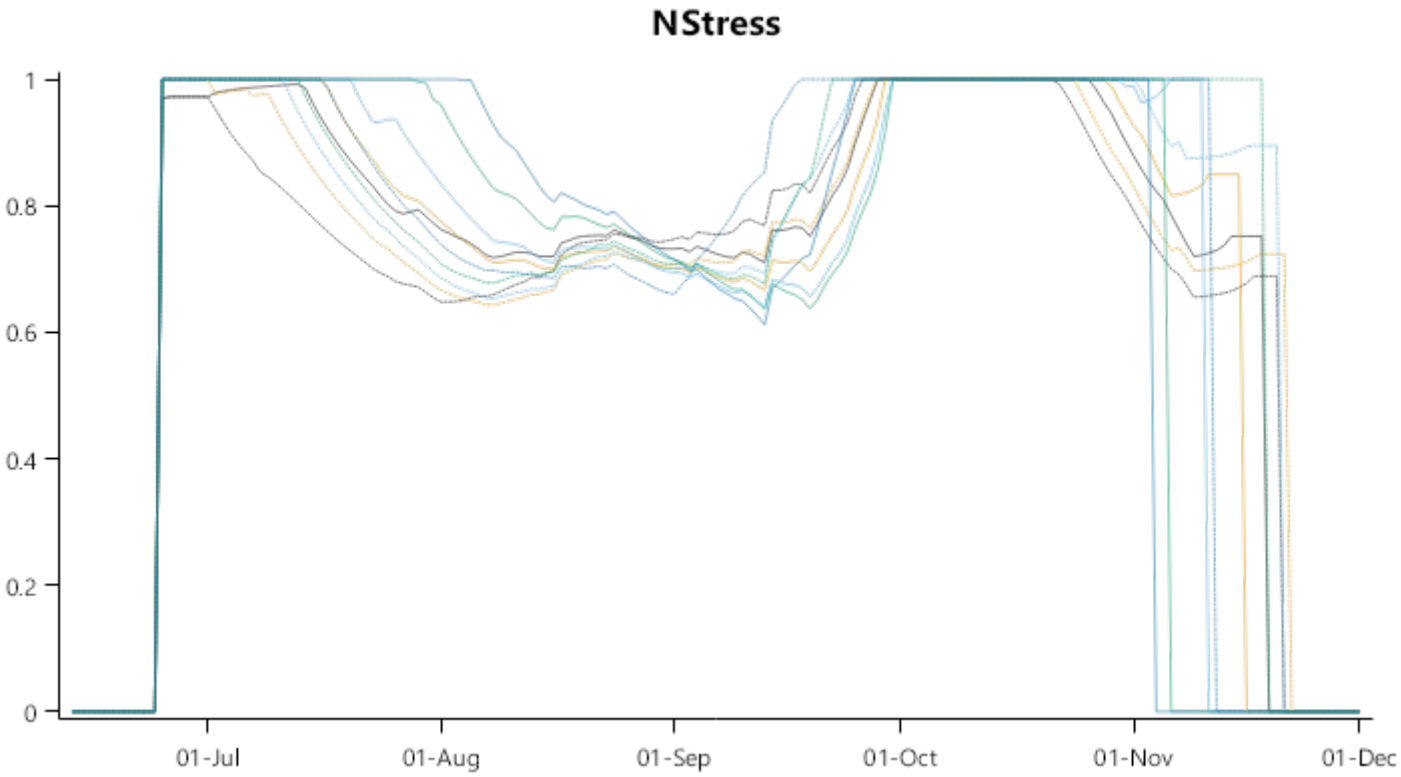


GrainSize




LAI
3
2
1
0
01-Jul
01-Aug
01-Sep
01-Oct
01-Nov
01-Dec


WaterStress
1
0.8
0.6
0.4
01-Jul
01-Aug
01-Sep
01-Oct
01-Nov
01-Dec

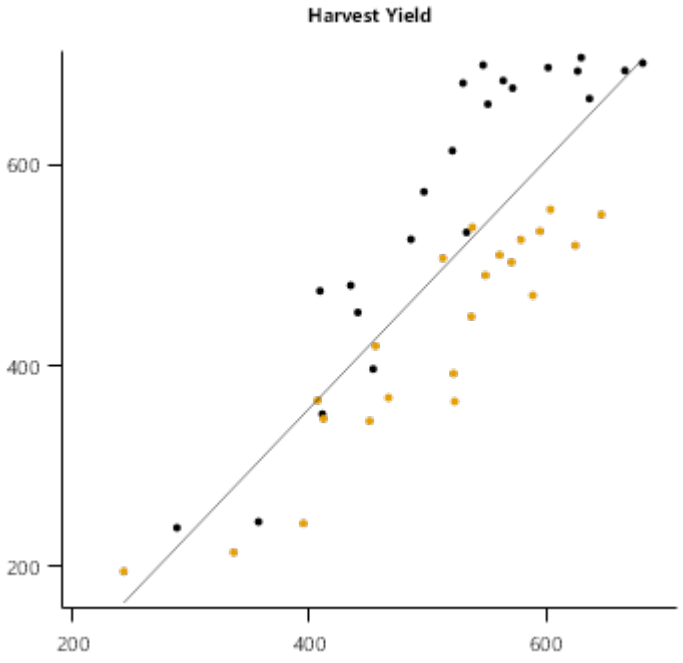


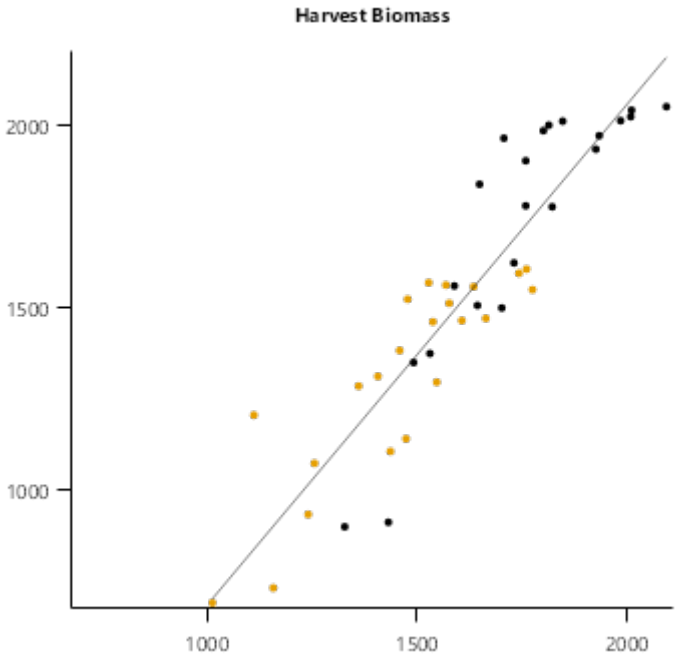
2.4 Turkey

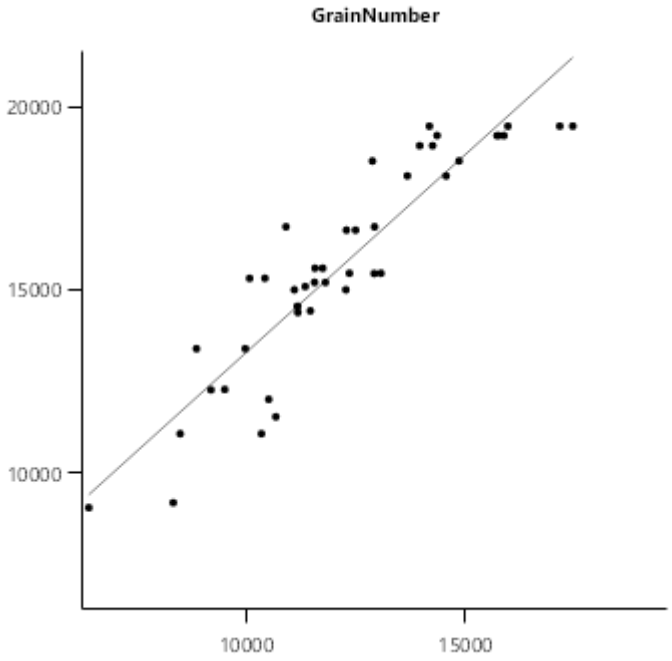
The dataset of Ali Fuat Tari, 2016 includes 4 irrigation deficit treatments applied at each of 3 plant growth stages. The experiment was conducted at Konya in the Central Anatolia region of Turkey. Yields ranged from 2.88 t/ha to 6.82 t/ha. These treatments were reproduced over two growing seasons, resulting 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.

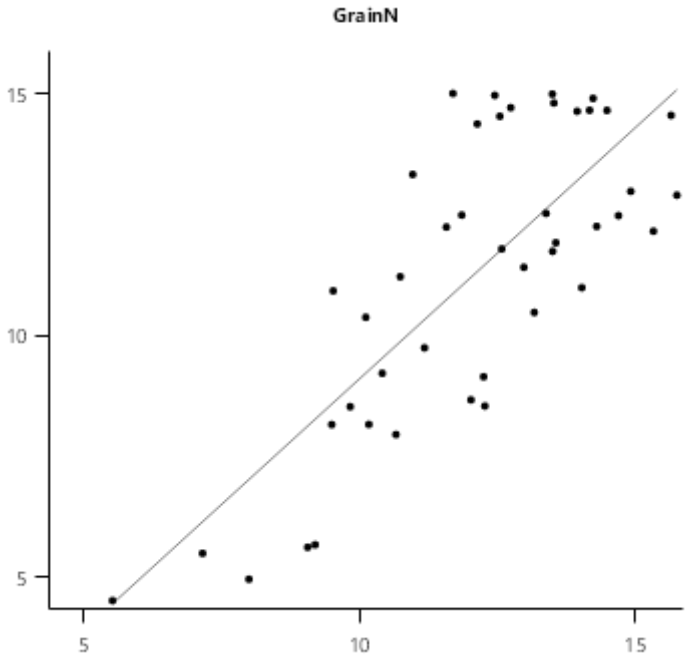
List of experiments.

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


Harvest Yield
600
400
200
200
400
600

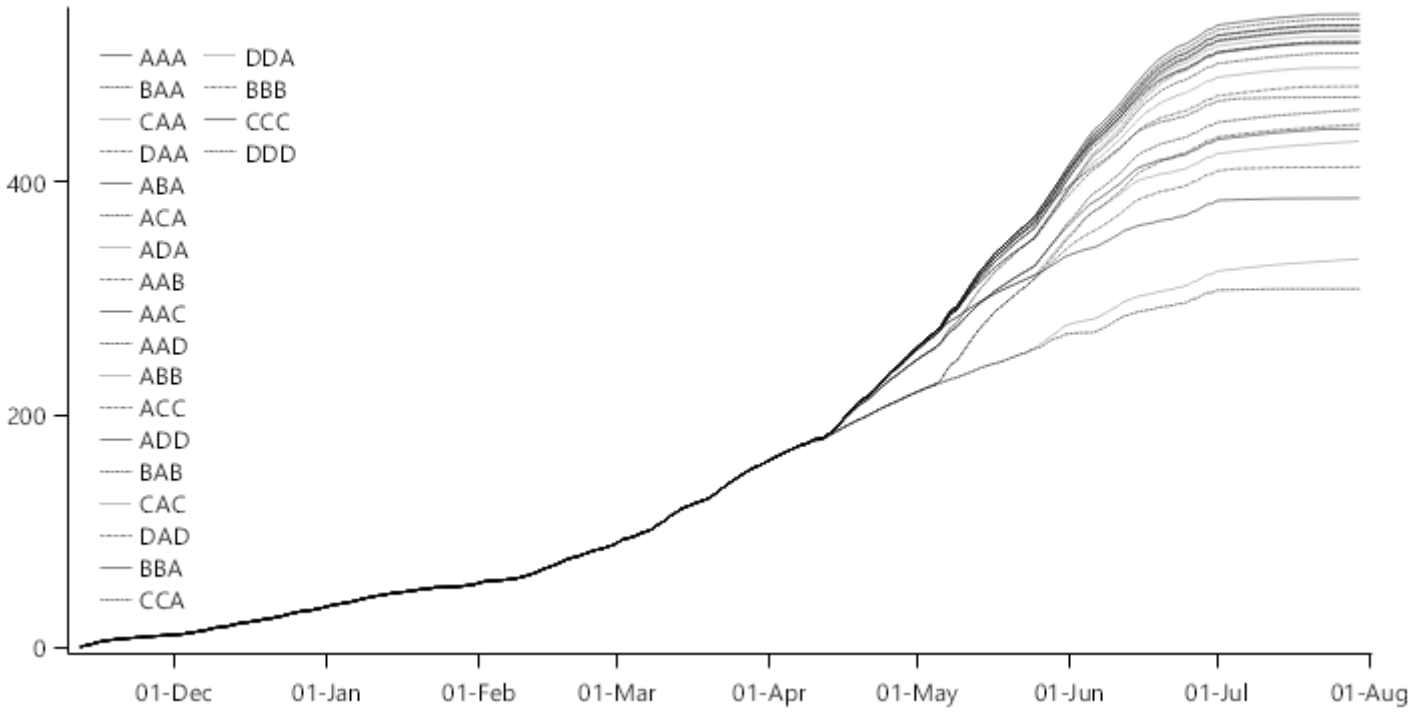

Harvest Biomass
2000
1500
1000
1000
1500
2000


GrainNumber
20000
15000
10000
10000
15000

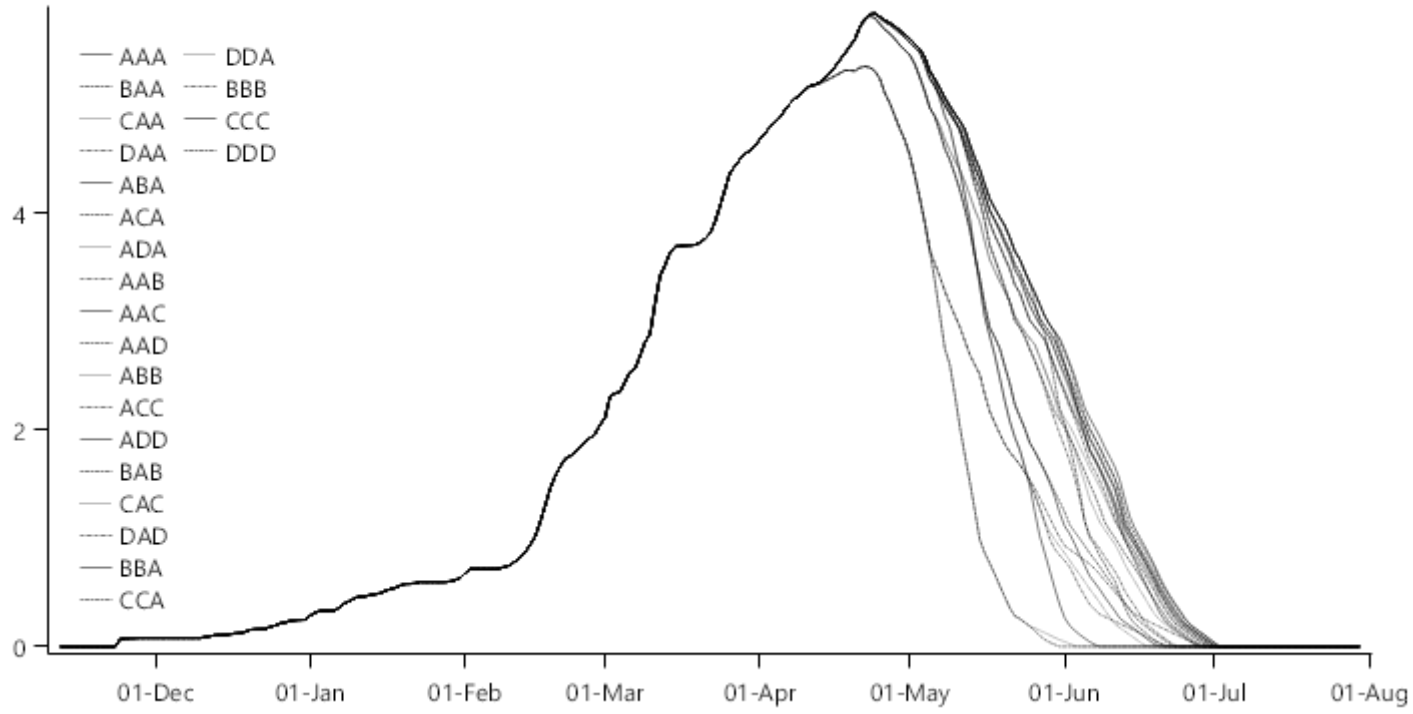

GrainN
15
10
5
5
10
15

2.4.1 Konya09

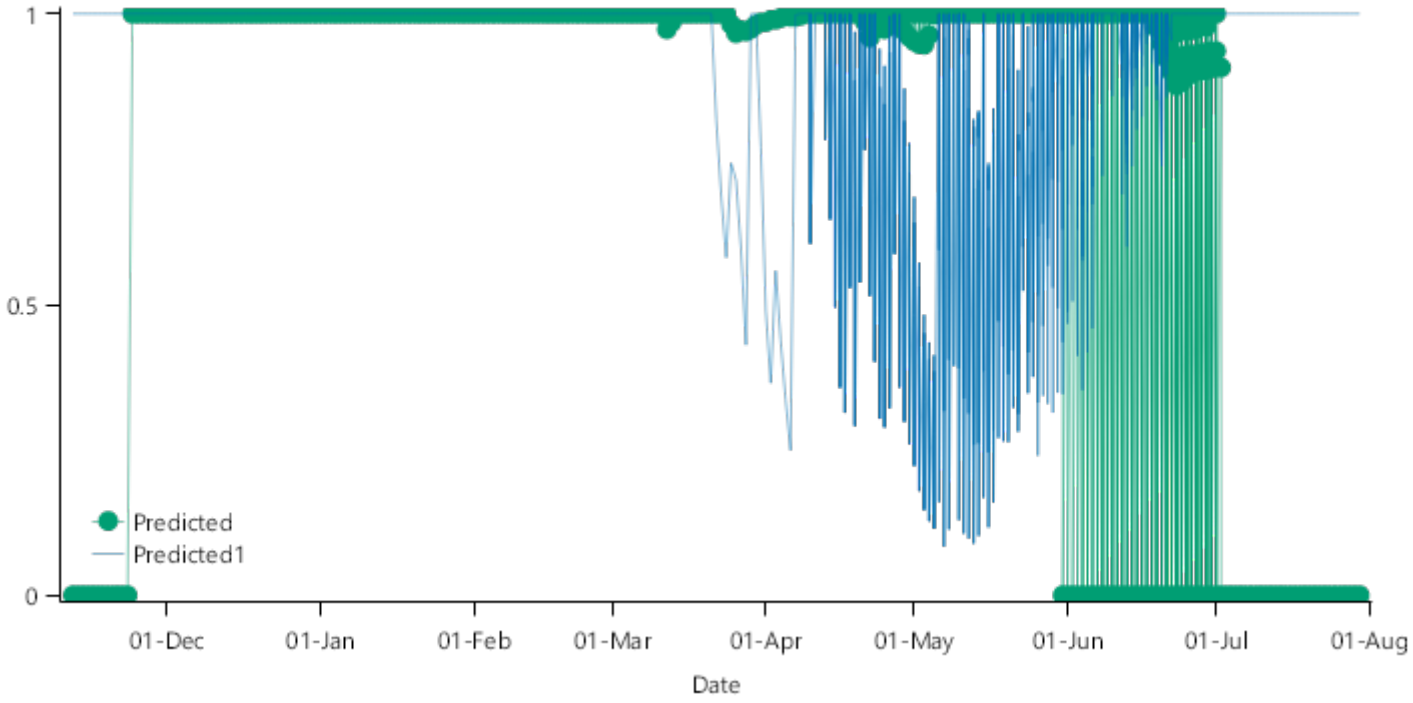
TotalSW


AAA
BAA
CAA
DAA
ABA
ACA
ADA
AAB
AAC
AAD
ABB
ACC
ADD
BAB
CAC
DAD
BBA
CCA
DDA
BBB
CCC
DDD
400
200
0
01-Dec
01-Jan
01-Feb
01-Mar
01-Apr
01-May
01-Jun
01-Jul
01-Aug

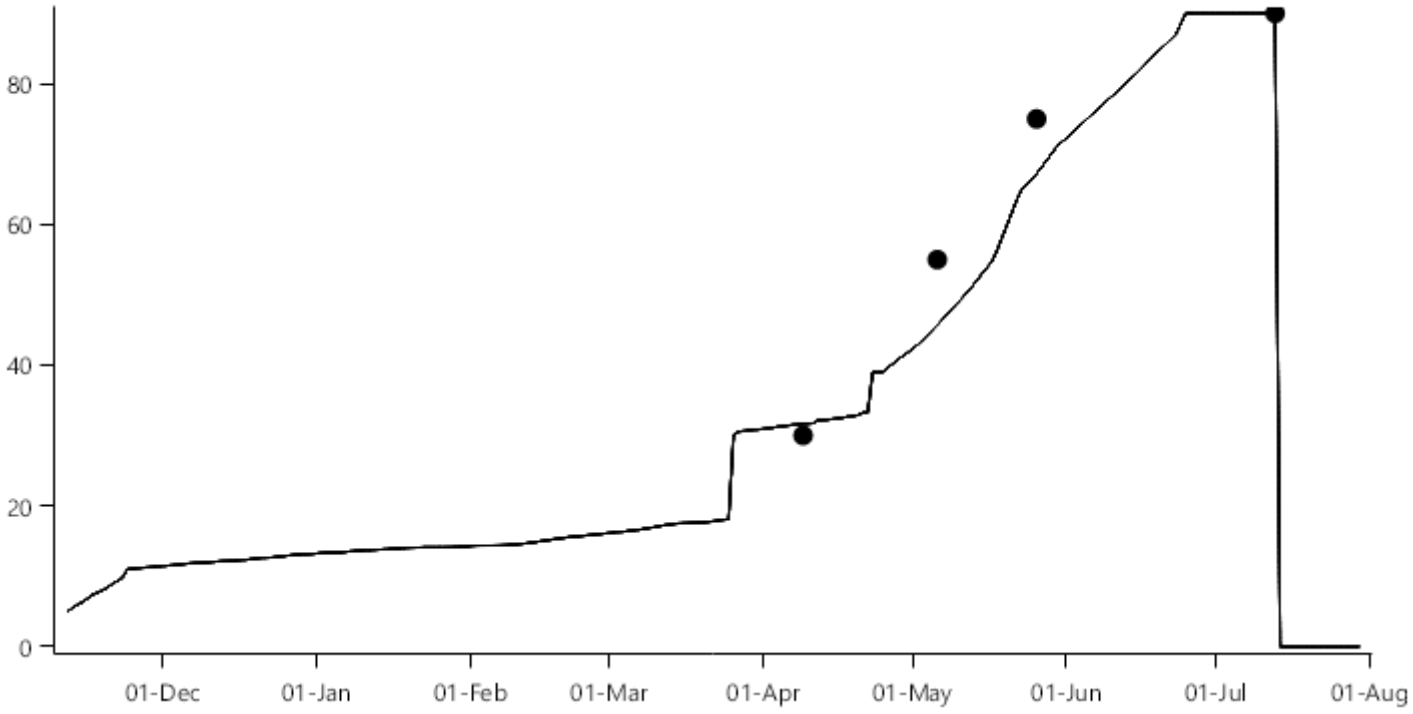
LAI


AAA
BAA
CAA
DAA
ABA
ACA
ADA
AAB
AAC
AAD
ABB
ACC
ADD
BAB
CAC
DAD
BBA
CCA
DDA
BBB
CCC
DDD
4
2
0
01-Dec
01-Jan
01-Feb
01-Mar
01-Apr
01-May
01-Jun
01-Jul
01-Aug

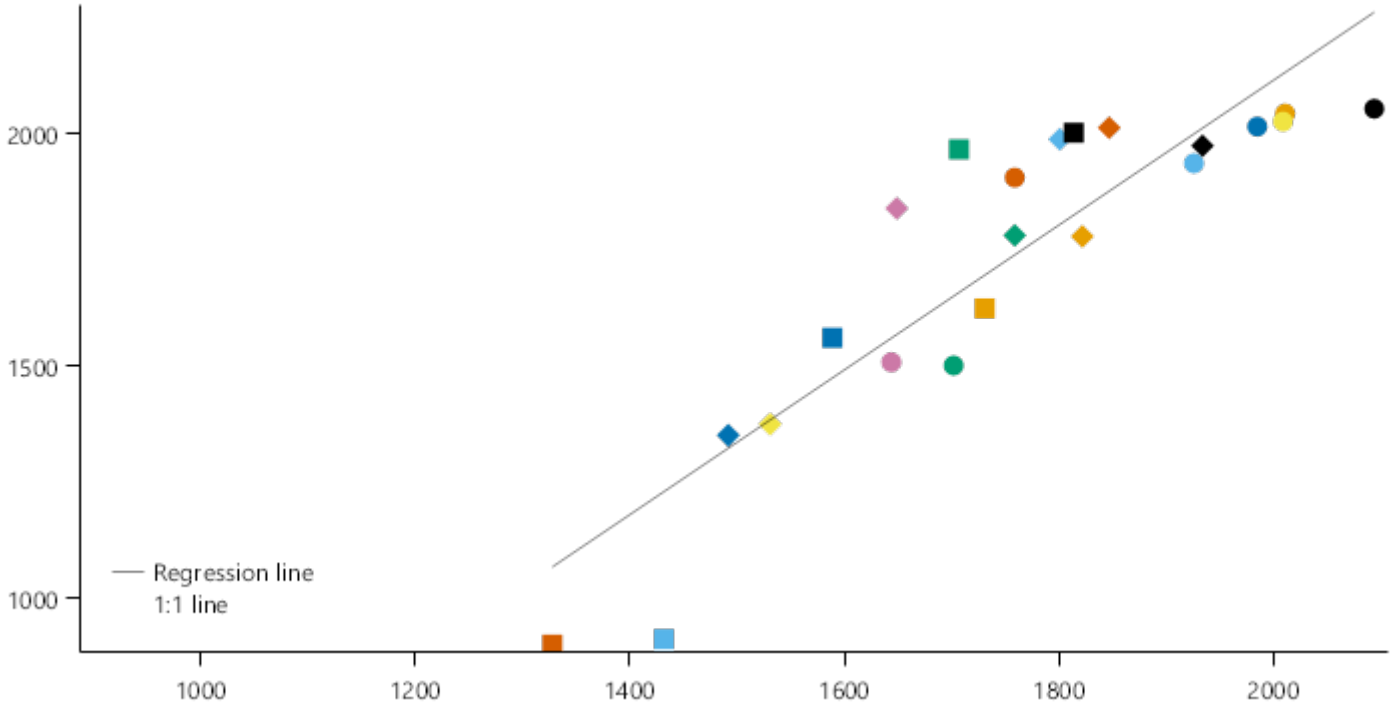
Stress



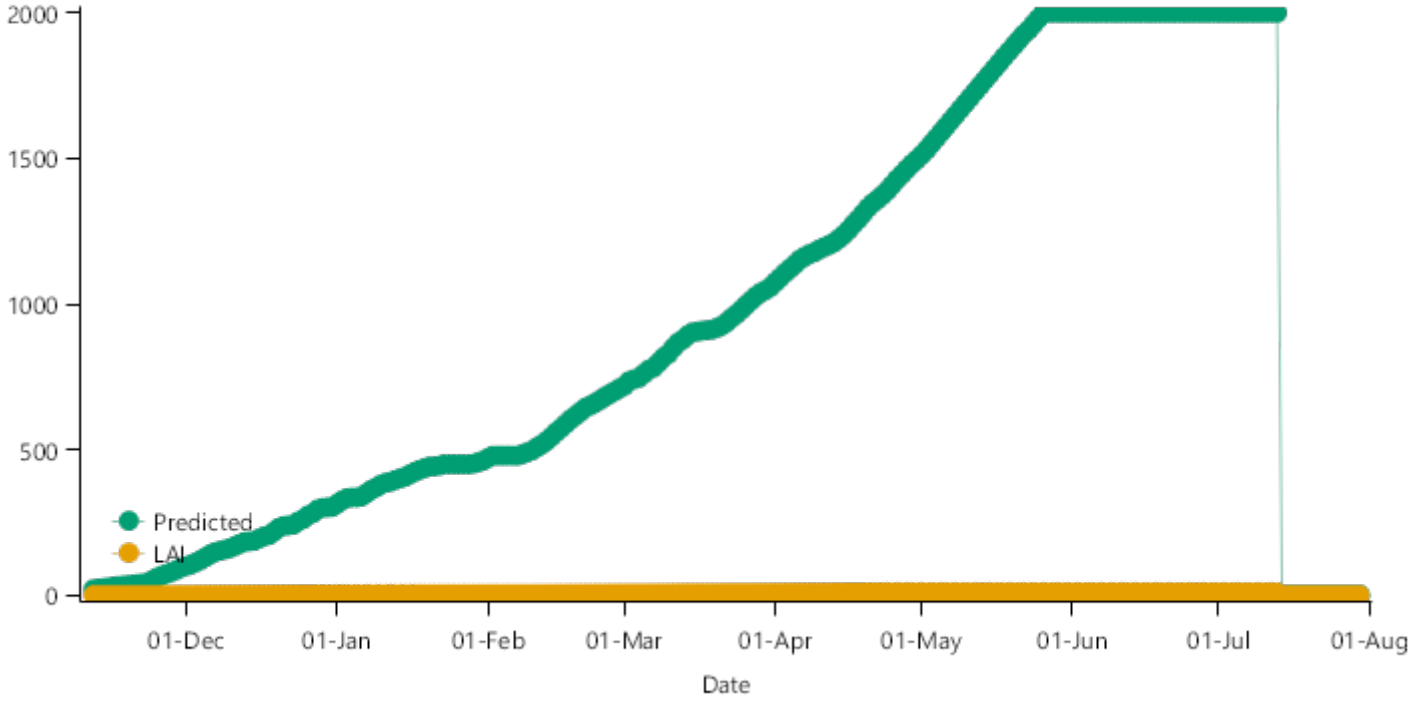
ZadokStage



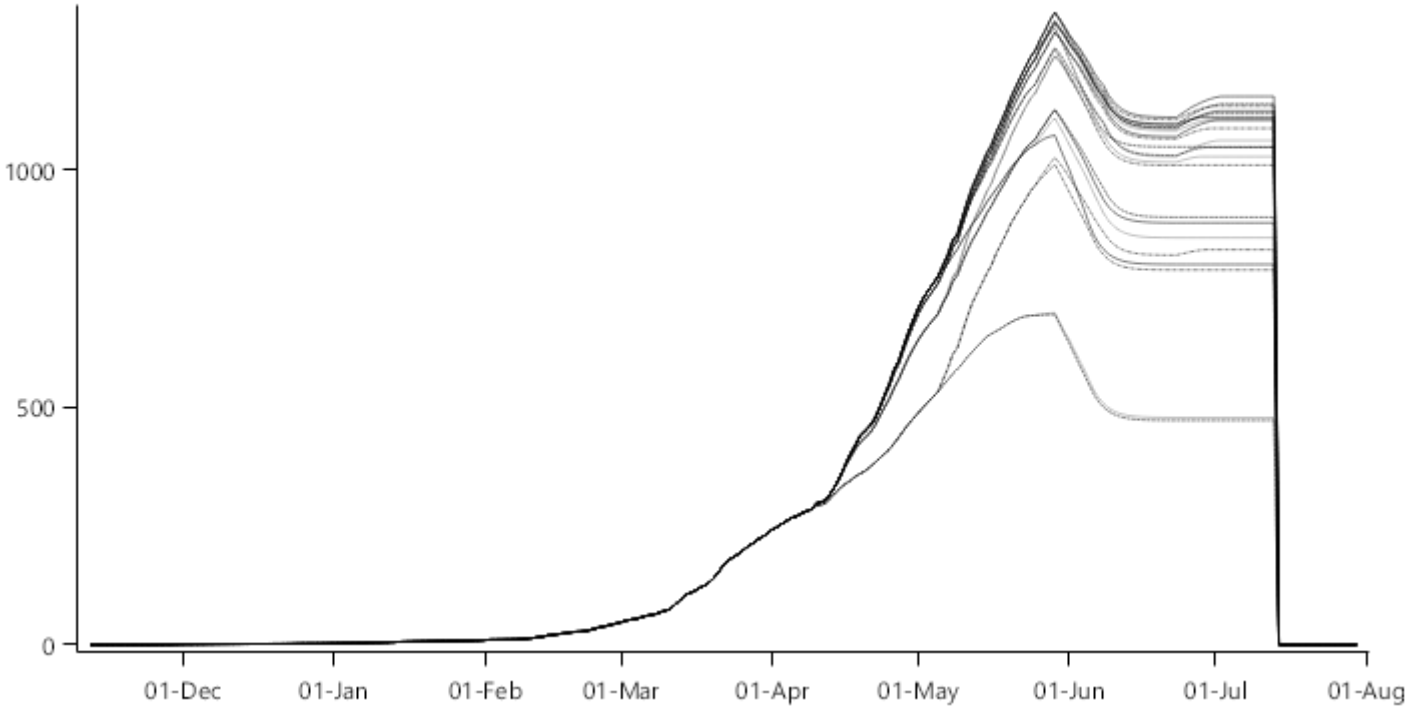
Harvest Biomass



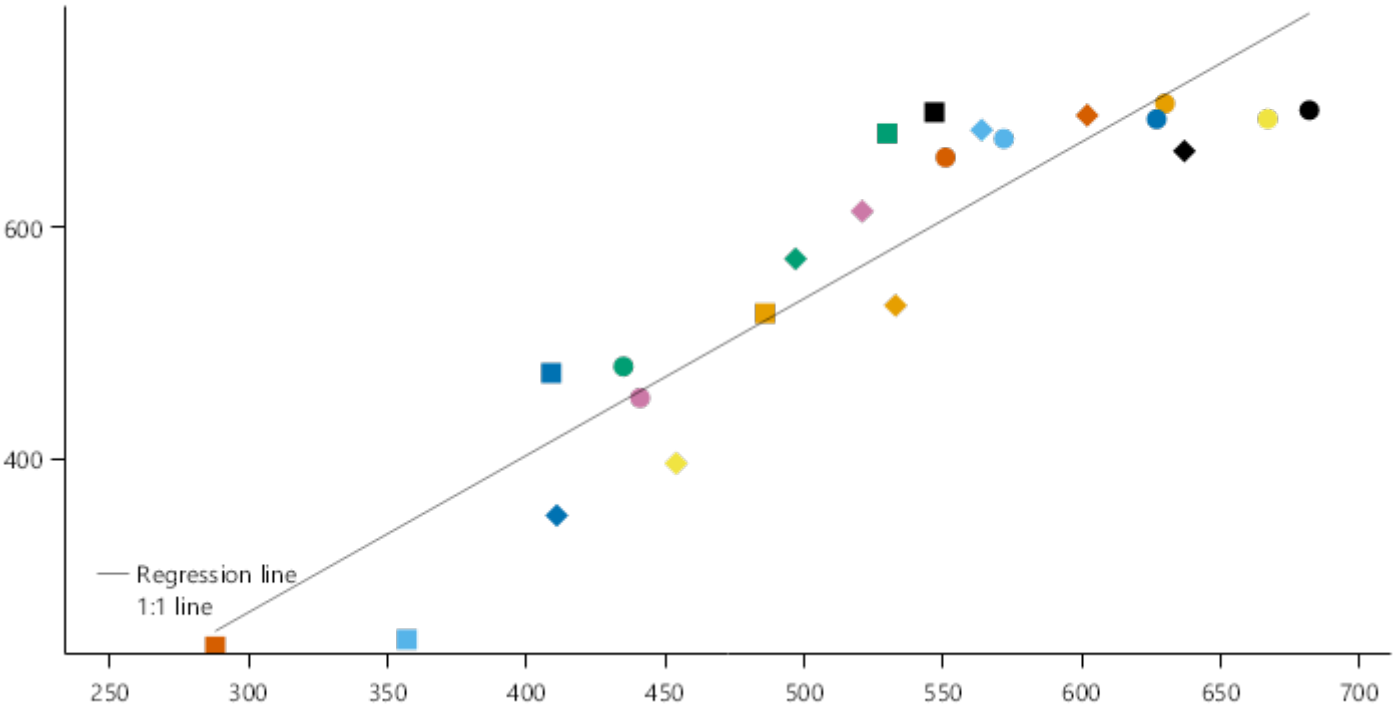
RootDepth

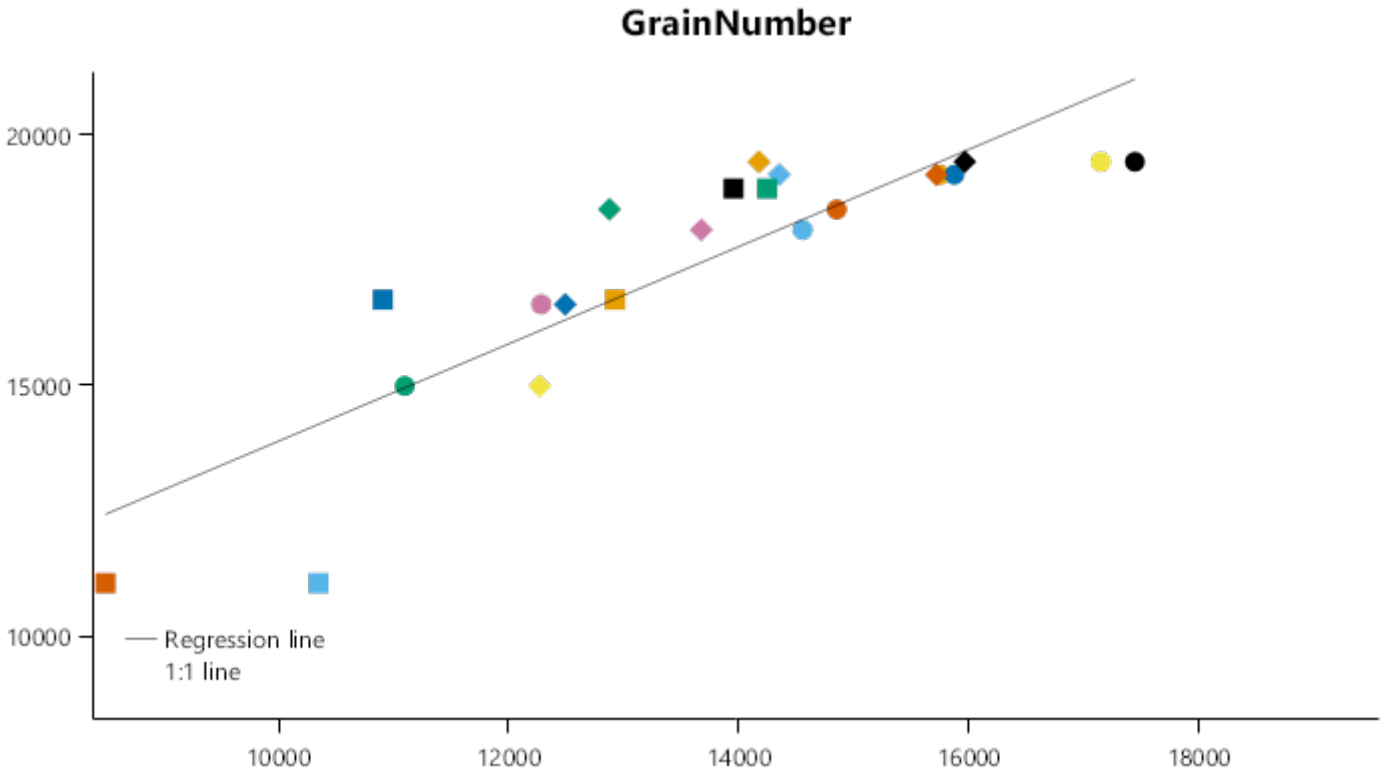


StemWt



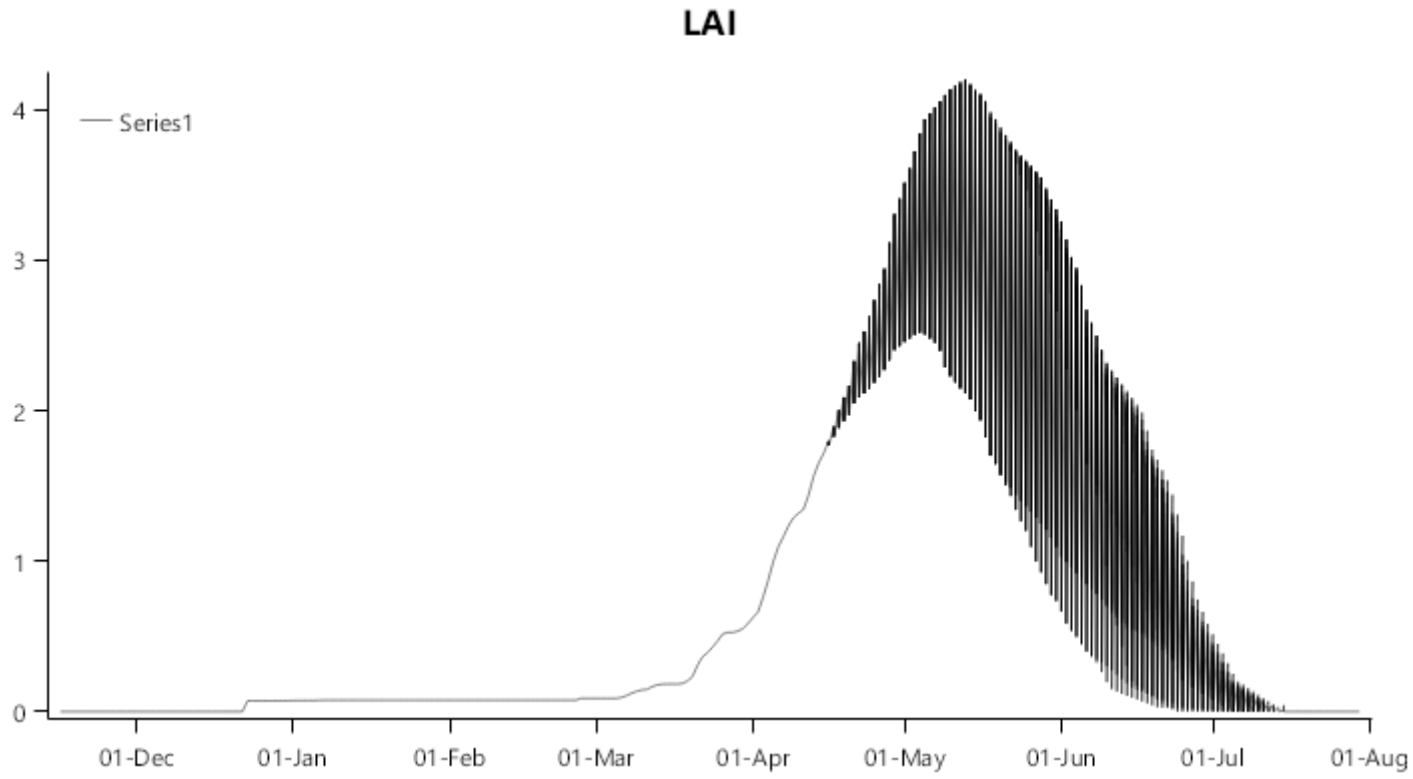
Harvest Grain

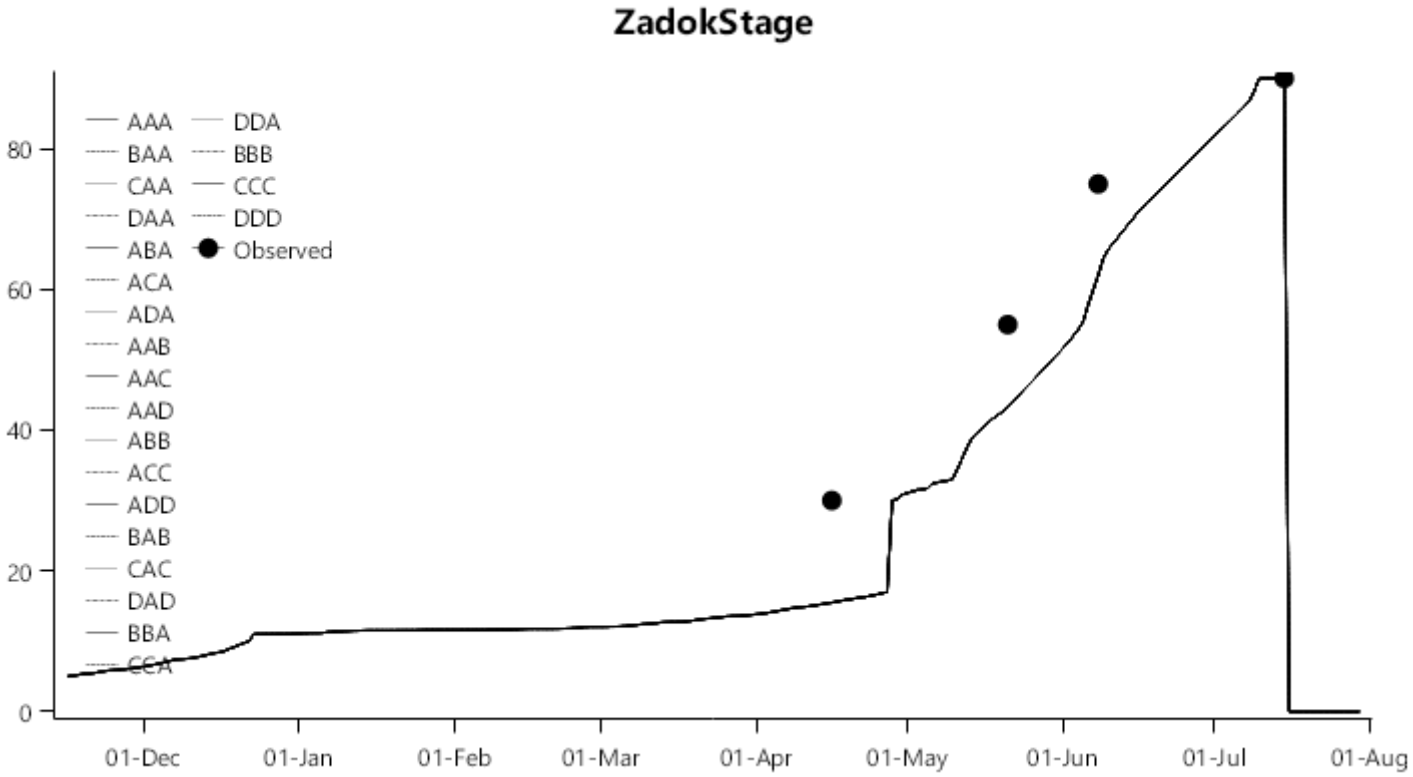



GrainNumber
20000
15000
10000
Regression line
1:1 line
10000
12000
14000
16000
18000

2.4.2 Konya11


TotalSW



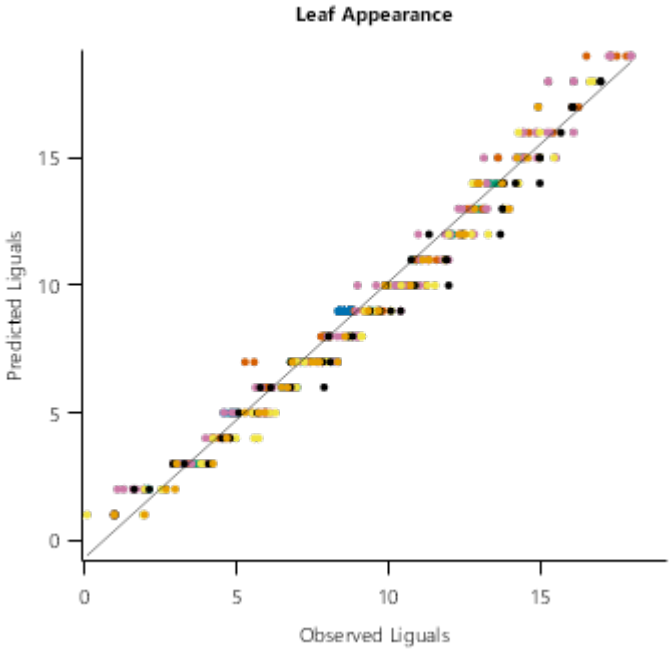


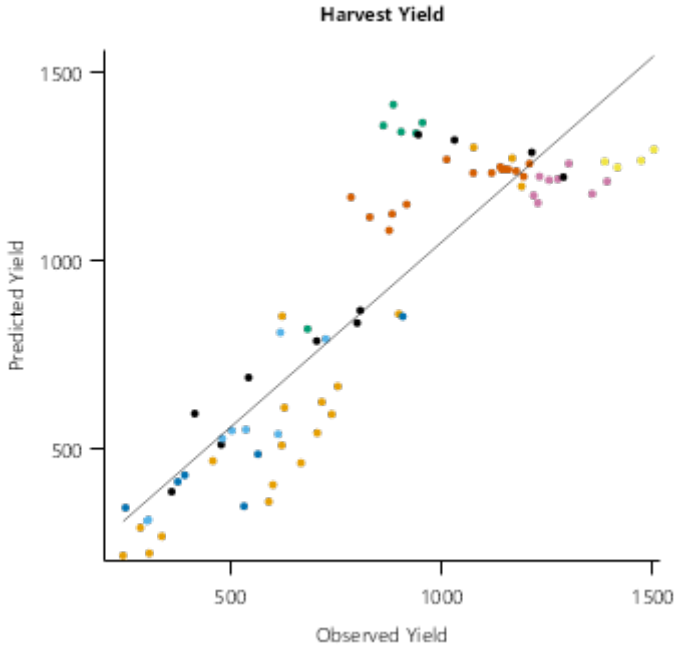
2.5 New Zealand

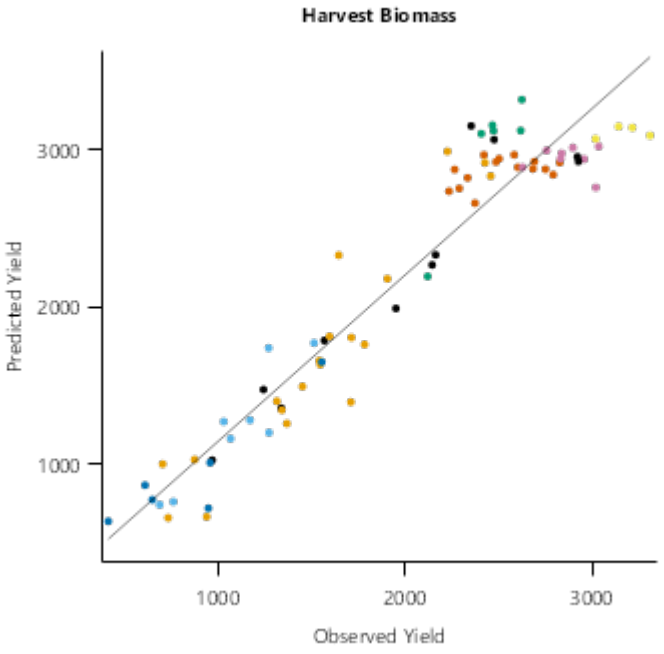
List of experiments.

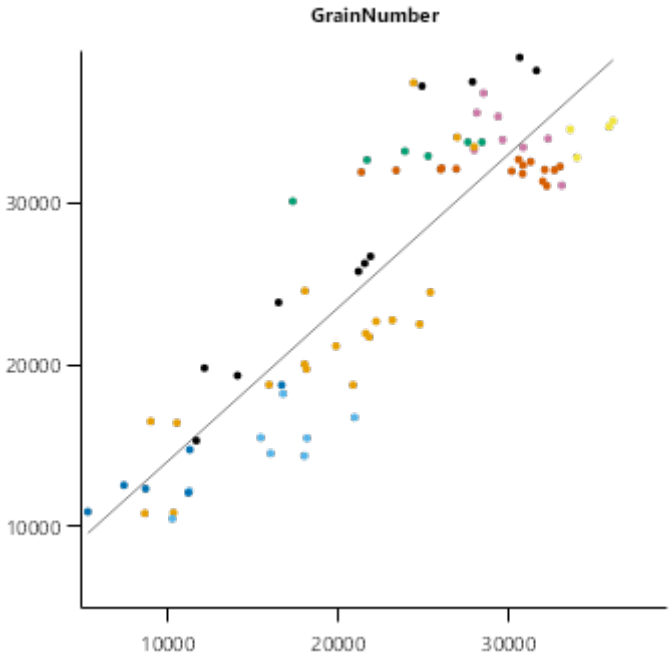
Experiment Name	Design (Number of Treatments)
Lincoln9192	Irrig (7)
Lincoln1992	Sow x Irr x Nit (16)
Lincoln2010	Sow x Irr (8)
Lincoln2014	Irrig (6)

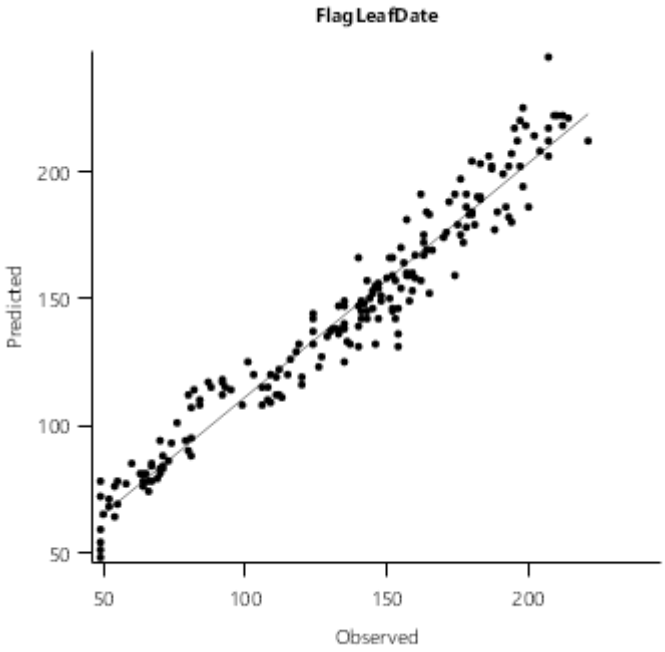
Experiment Name	Design (Number of Treatments)
Lincoln2015	Nit x Irr (6)
Leeston2013	Sow x Popn (15)
Leeston2014	Sow x Popn (8)
Wakanui2015	Sow x Cm (4)
Wakanui2016	Sow x Cm (4)
Wakanui2017	Sow x Cm (3)
PalmerstonNorth1989	Sow x Cv (18)
Lincoln1994	Sow x Cv (10)

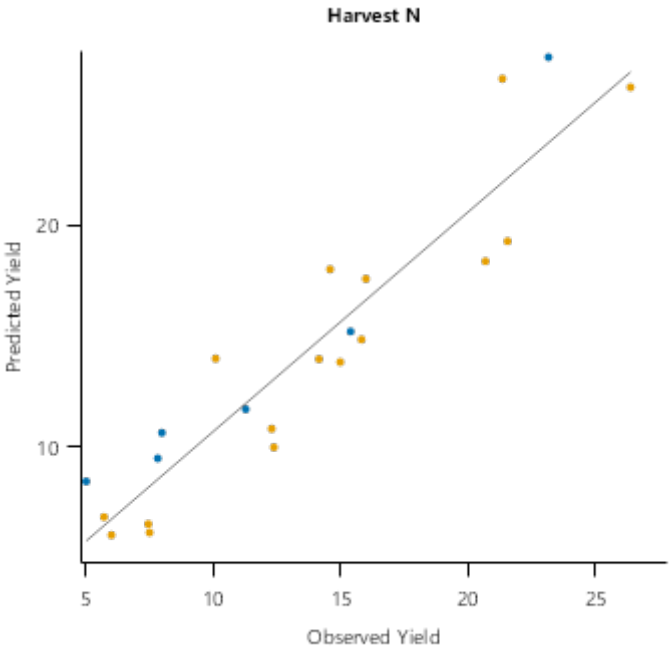


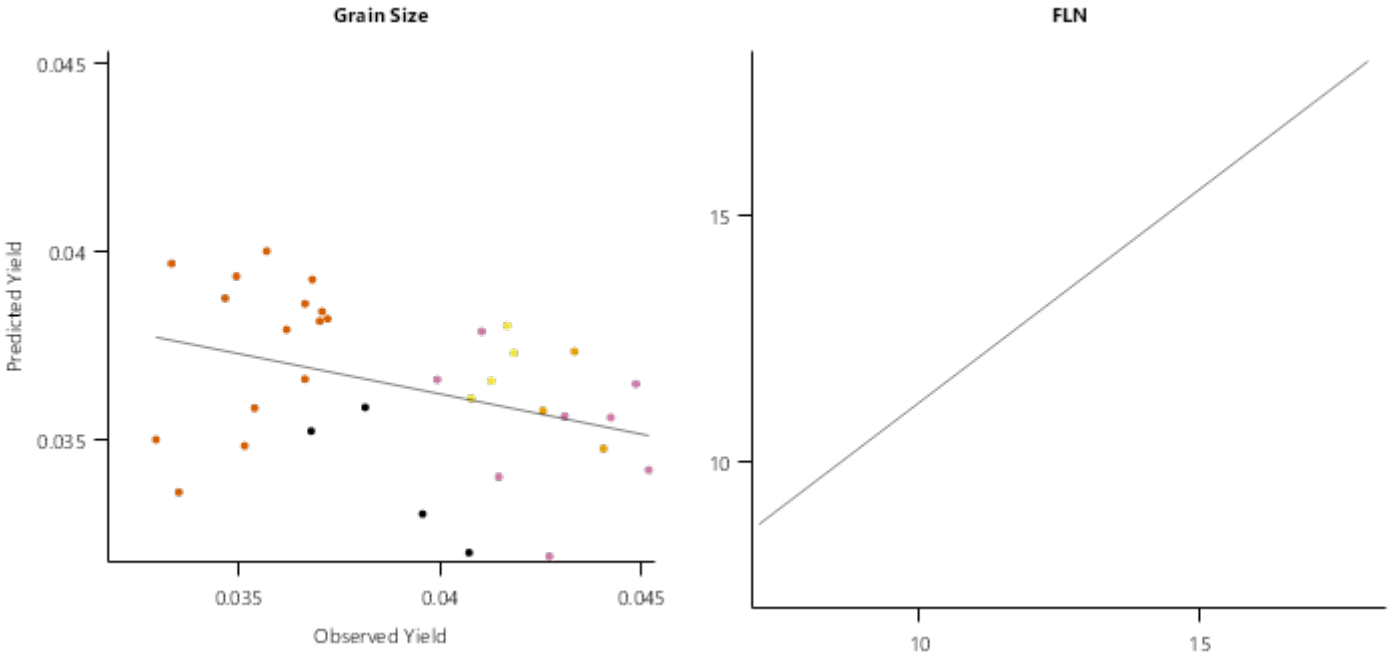



Harvest Biomass
Predicted Yield
Observed Yield
1000
2000
3000


GrainNumber
10000
20000
30000


FlagLeafDate
Predicted
Observed
50
100
150
200


Harvest N
Predicted Yield
Observed Yield
5
10
15
20
25



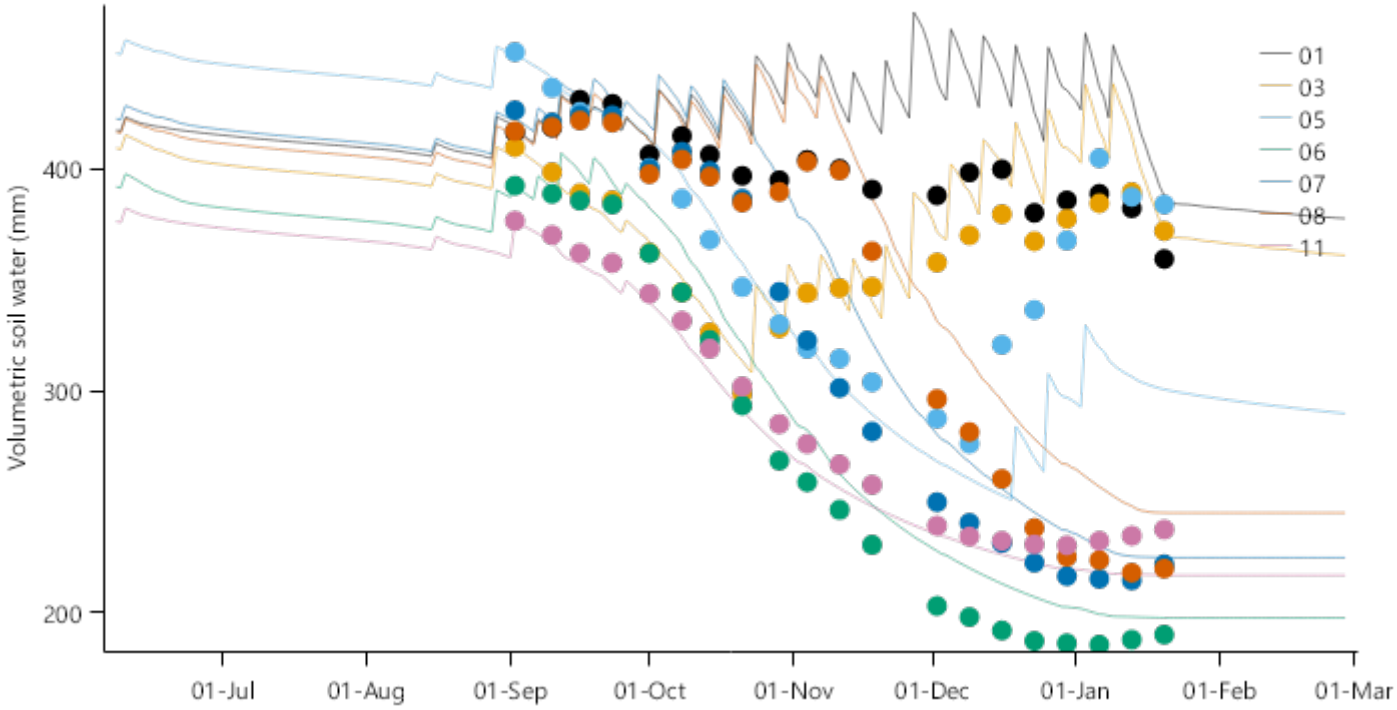
2.5.1 Lincoln9192

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:

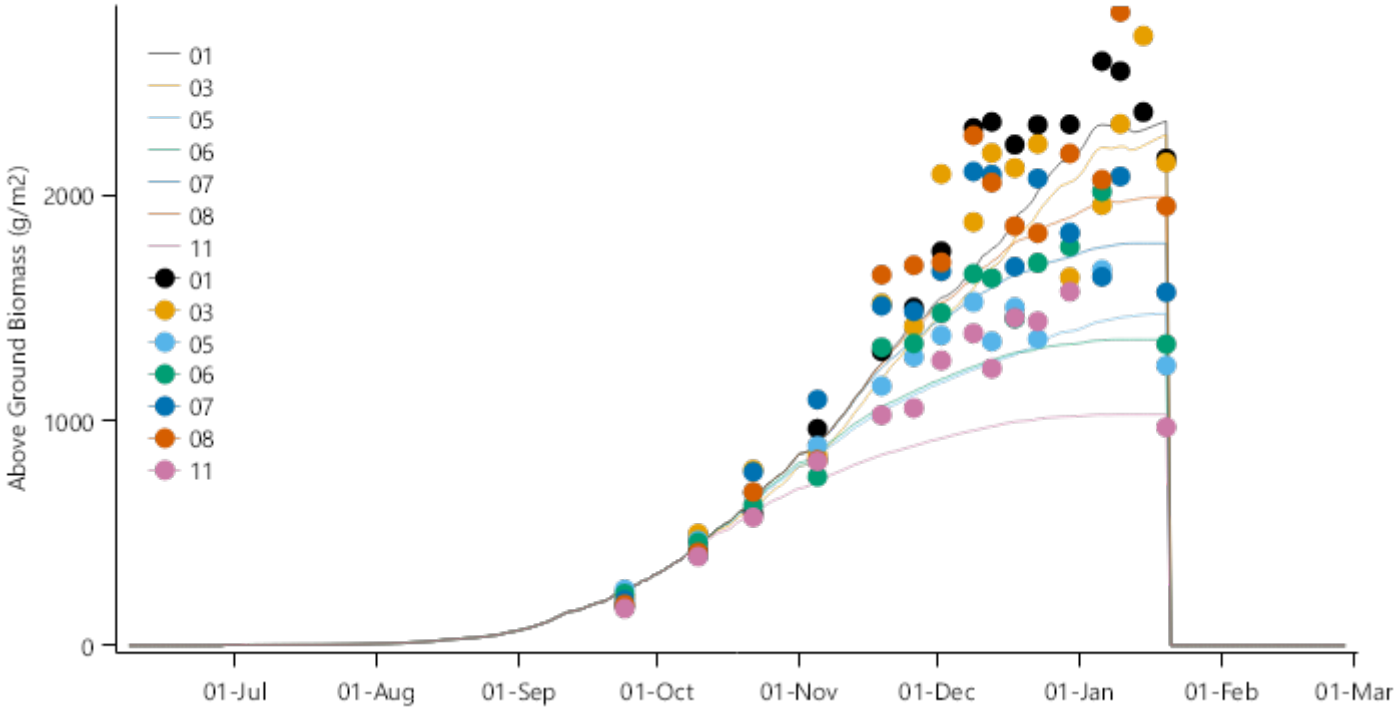
1. Full irrigation where measured ET was replaced weekly
2. Short Early Drought where irrigation was withheld from sowing until late October then full irrigation was applied
3. Long Early Drought where irrigation was withheld from sowing until mid December then full irrigation was applied
4. Long Late 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.

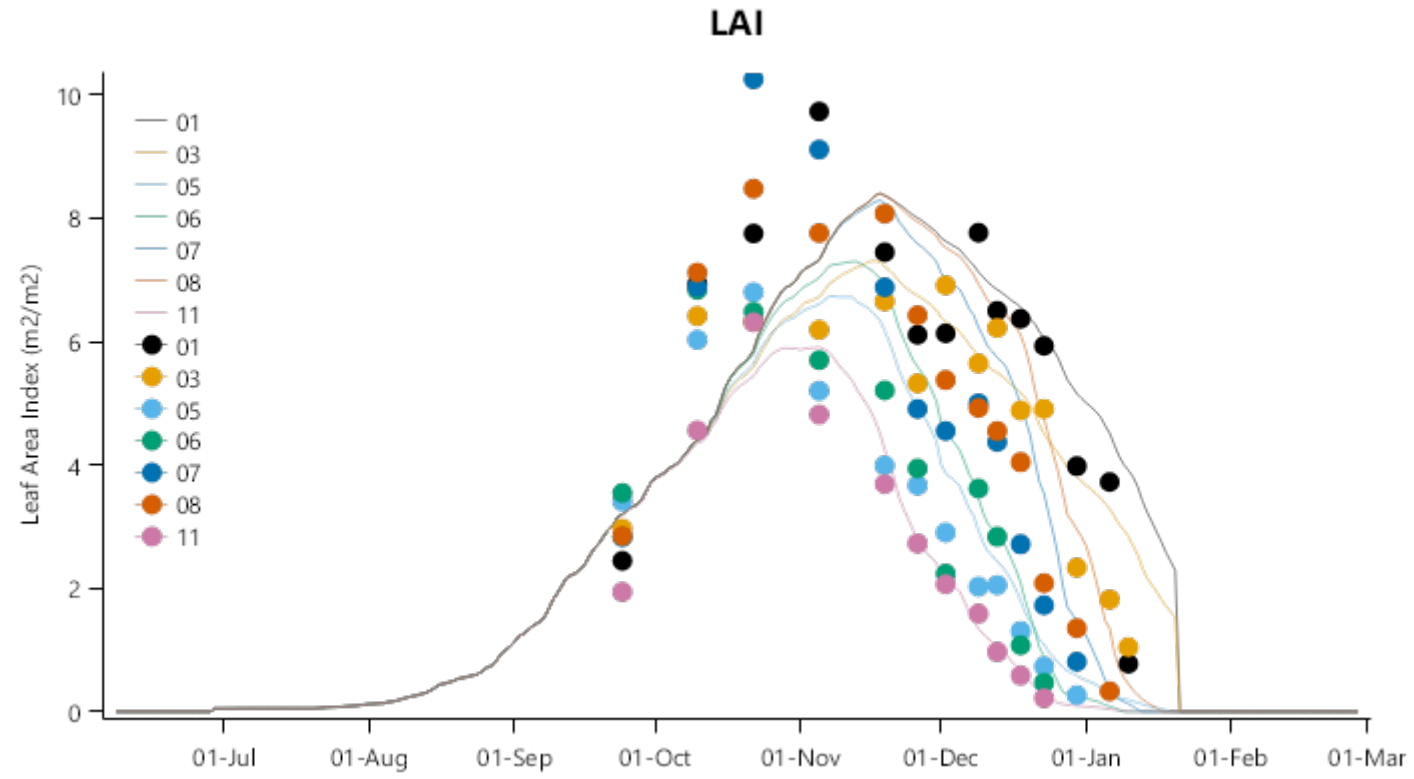
Irrigation was applied at weekly intervals through and assemply of low rate drip emitters on each plot. Soil water content was measured weekly with a neutron probe and biomass was measured at 10 - 14 day intervals. Samples throughtout the crop were from two 0.1m^2 quatrants and the final harvest sample 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.

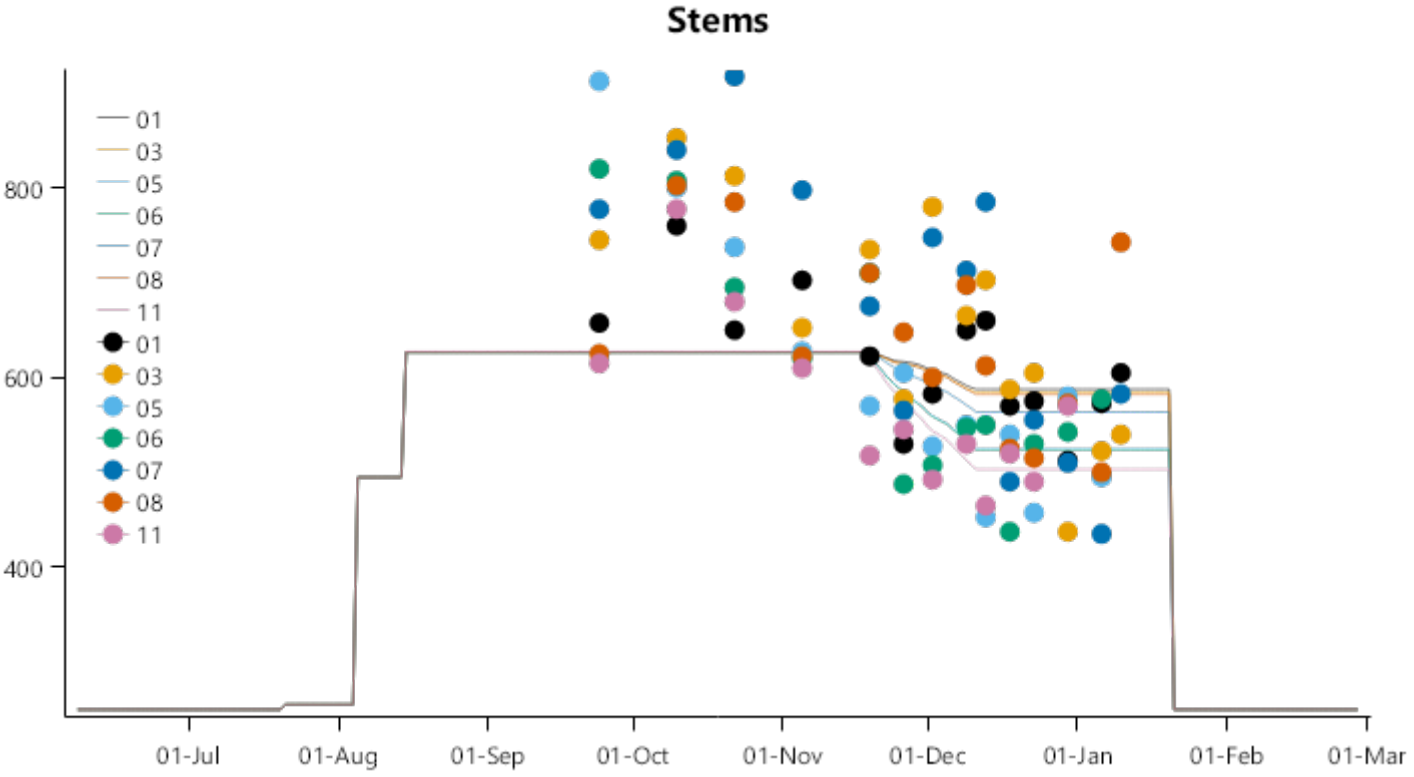
SoilWaterProfile

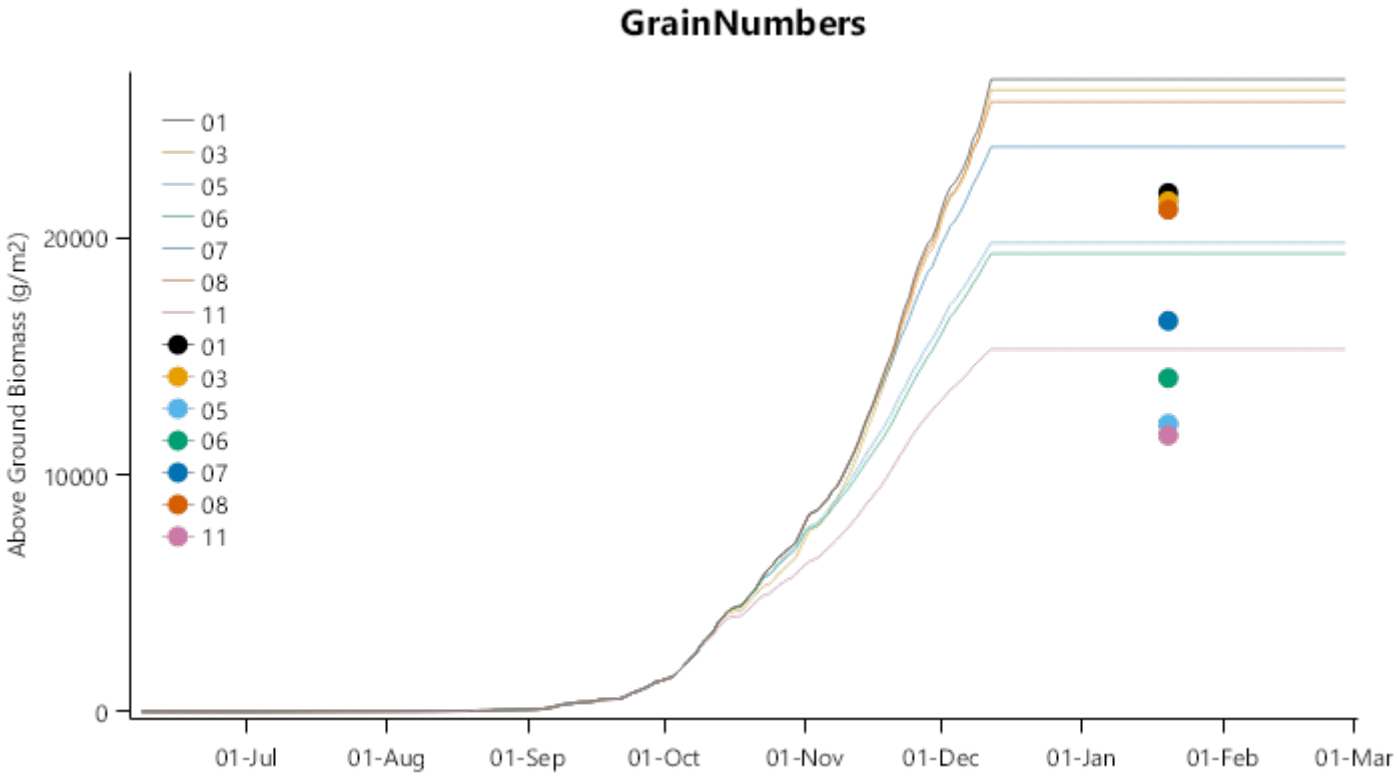


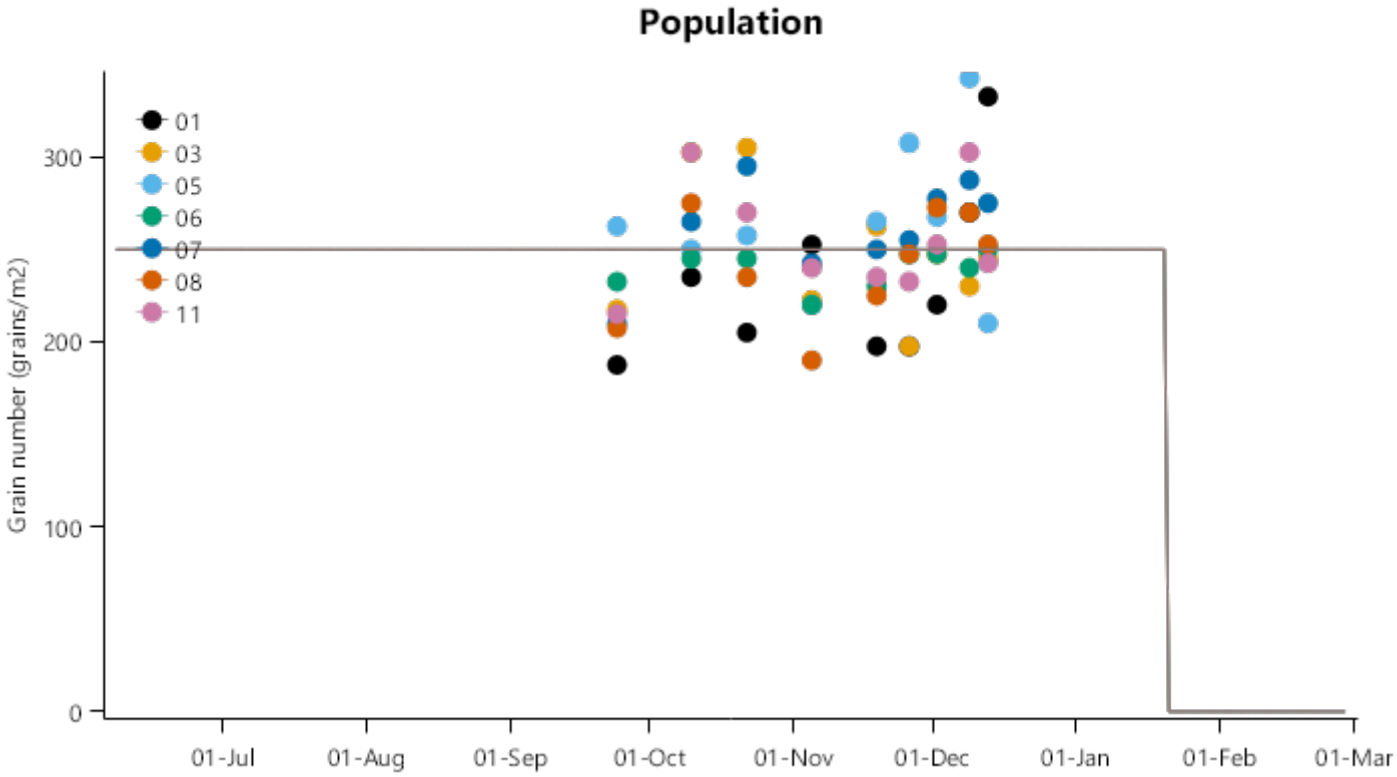
AboveGroundWt




LAI
Leaf Area Index (m2/m2)
0
2
4
6
8
10
01
03
05
06
07
08
11
01-Jul
01-Aug
01-Sep
01-Oct
01-Nov
01-Dec
01-Jan
01-Feb
01-Mar


Stems
400
600
800
01
03
05
06
07
08
11
01-Jul
01-Aug
01-Sep
01-Oct
01-Nov
01-Dec
01-Jan
01-Feb
01-Mar





2.5.2 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..

2.5.3 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.

2.5.4 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.

2.5.5 Lincoln2015

2.5.5.1 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.

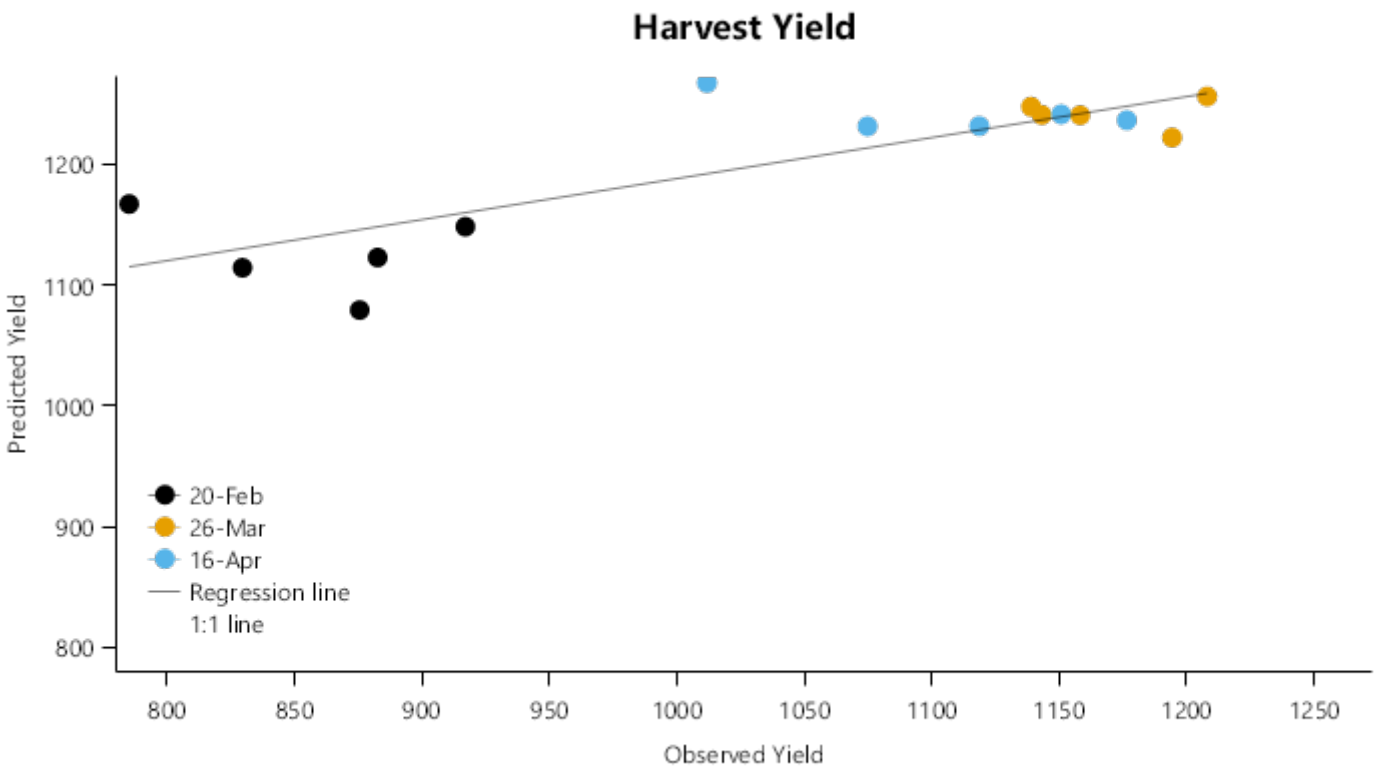
2.5.6 Leeston2013

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.



2.5.7 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.

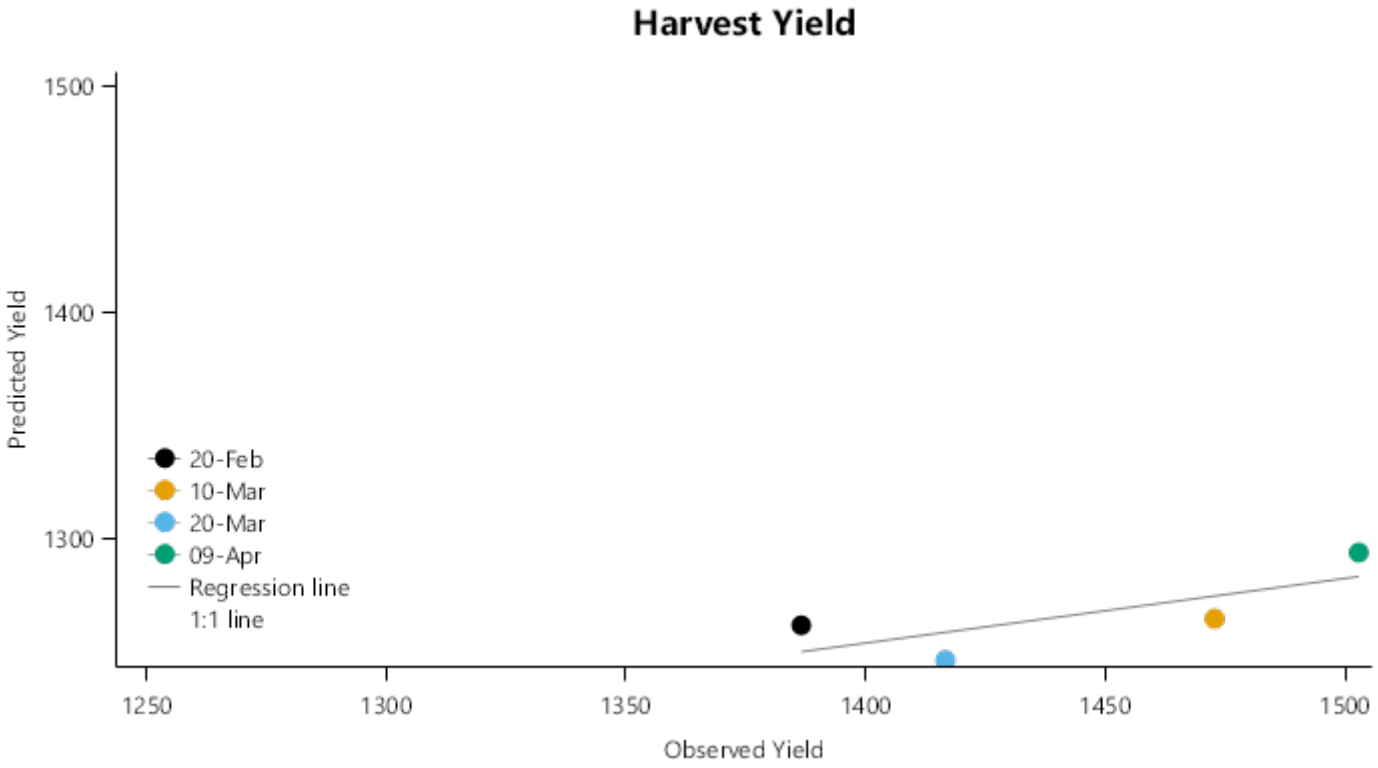
2.5.8 Wakanui2015

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.



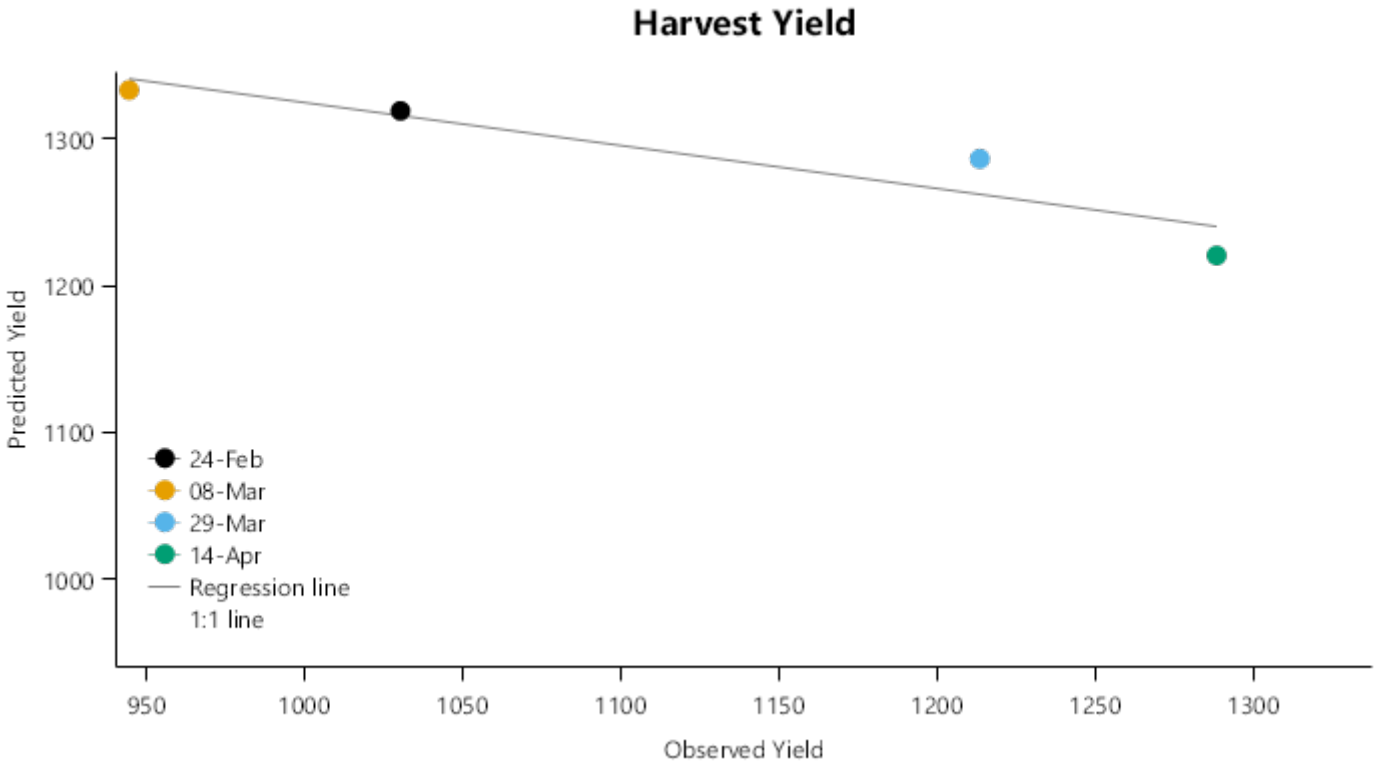
2.5.9 Wakanui2016

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.



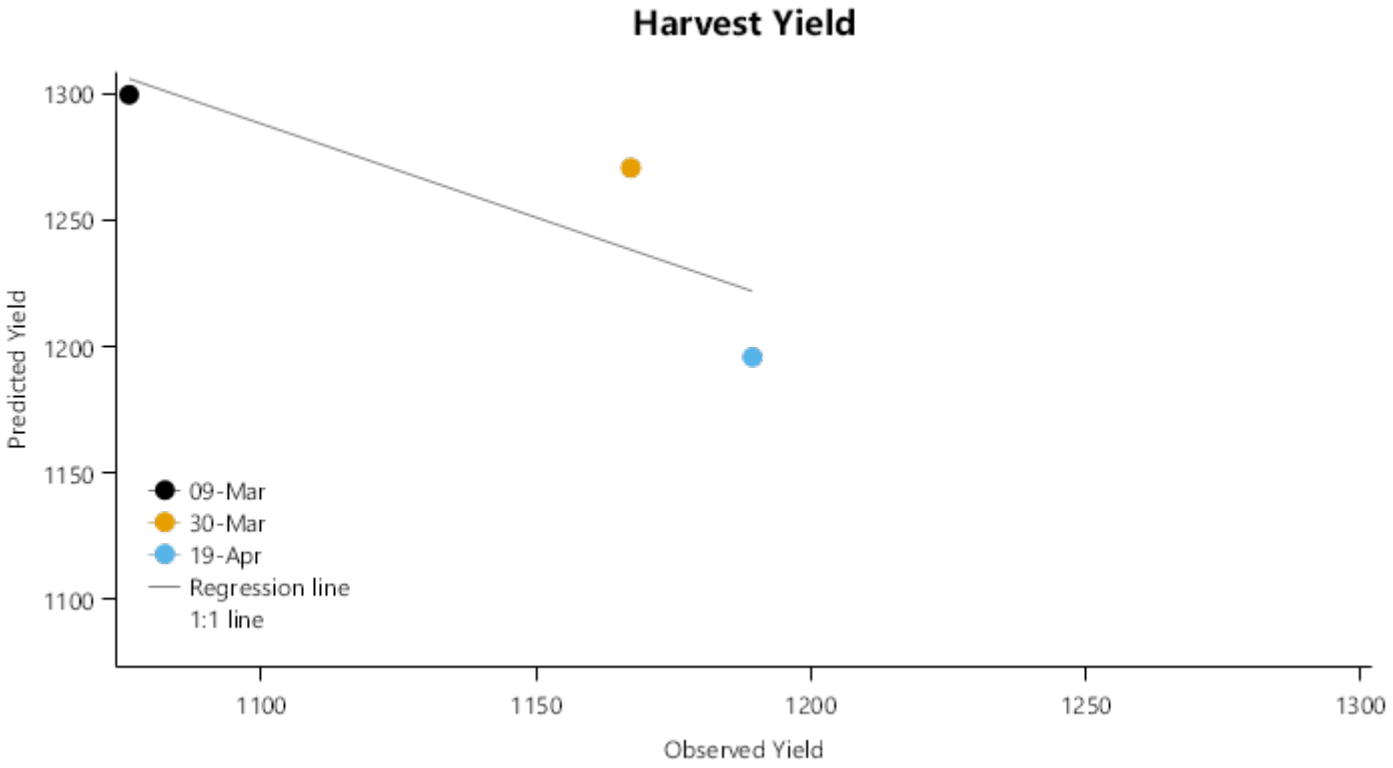
2.5.10 Wakanui2017

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.



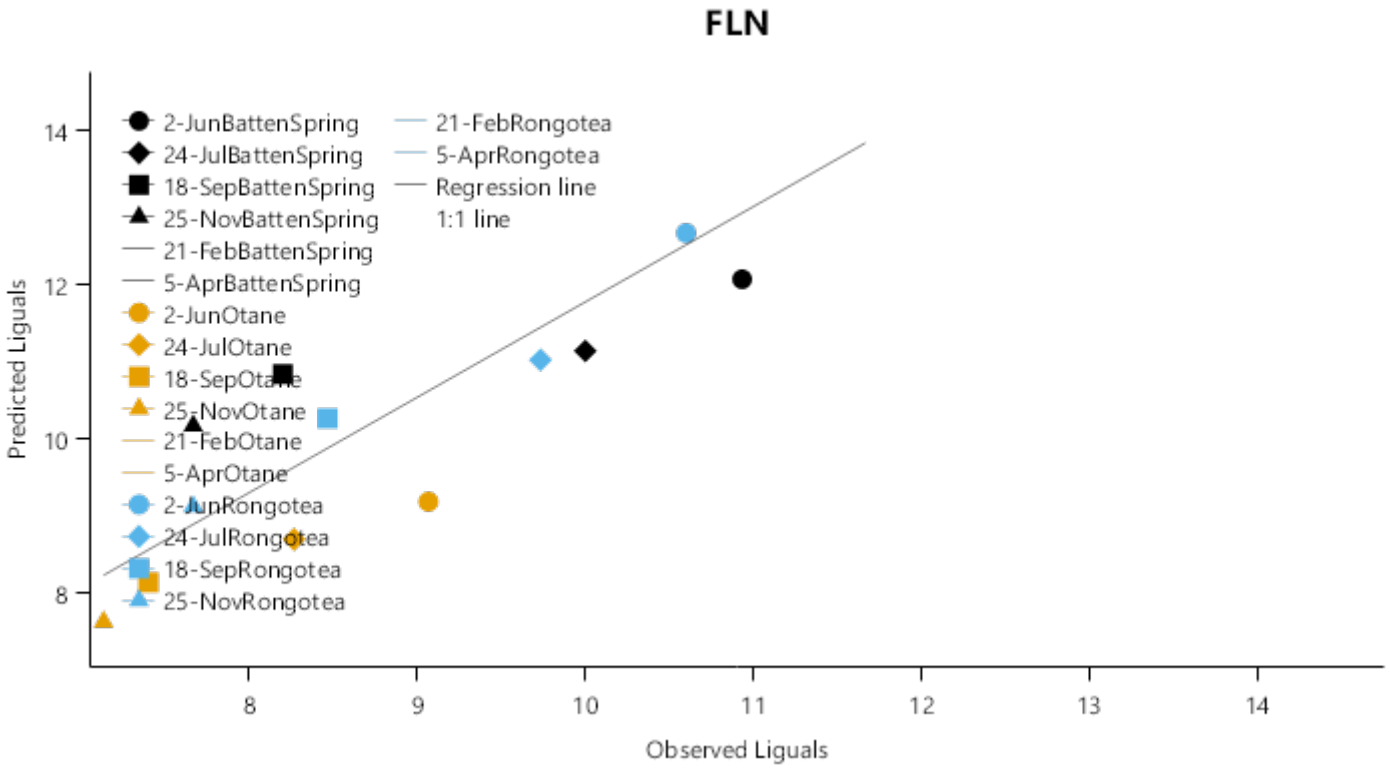
2.5.11 PalmerstonNorth1989

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.



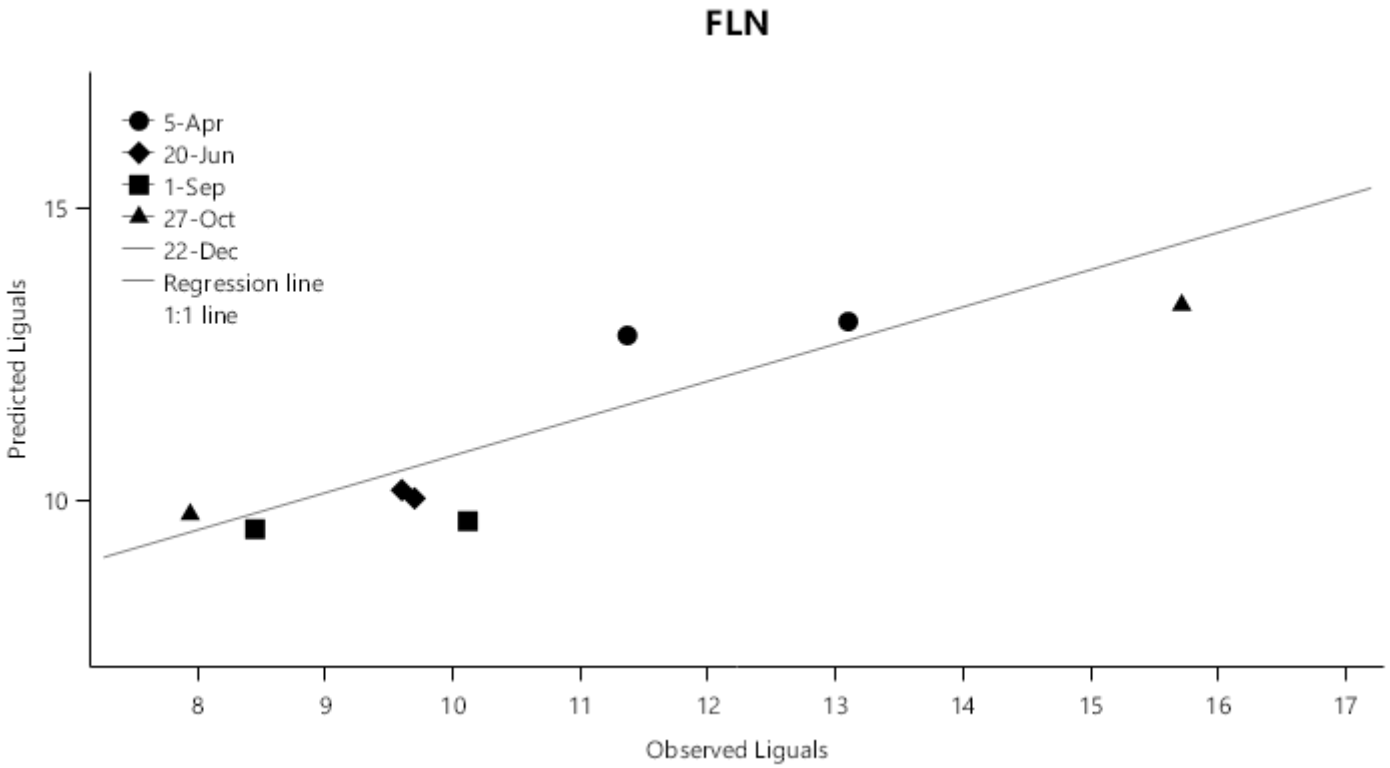
2.5.12 Lincoln1994

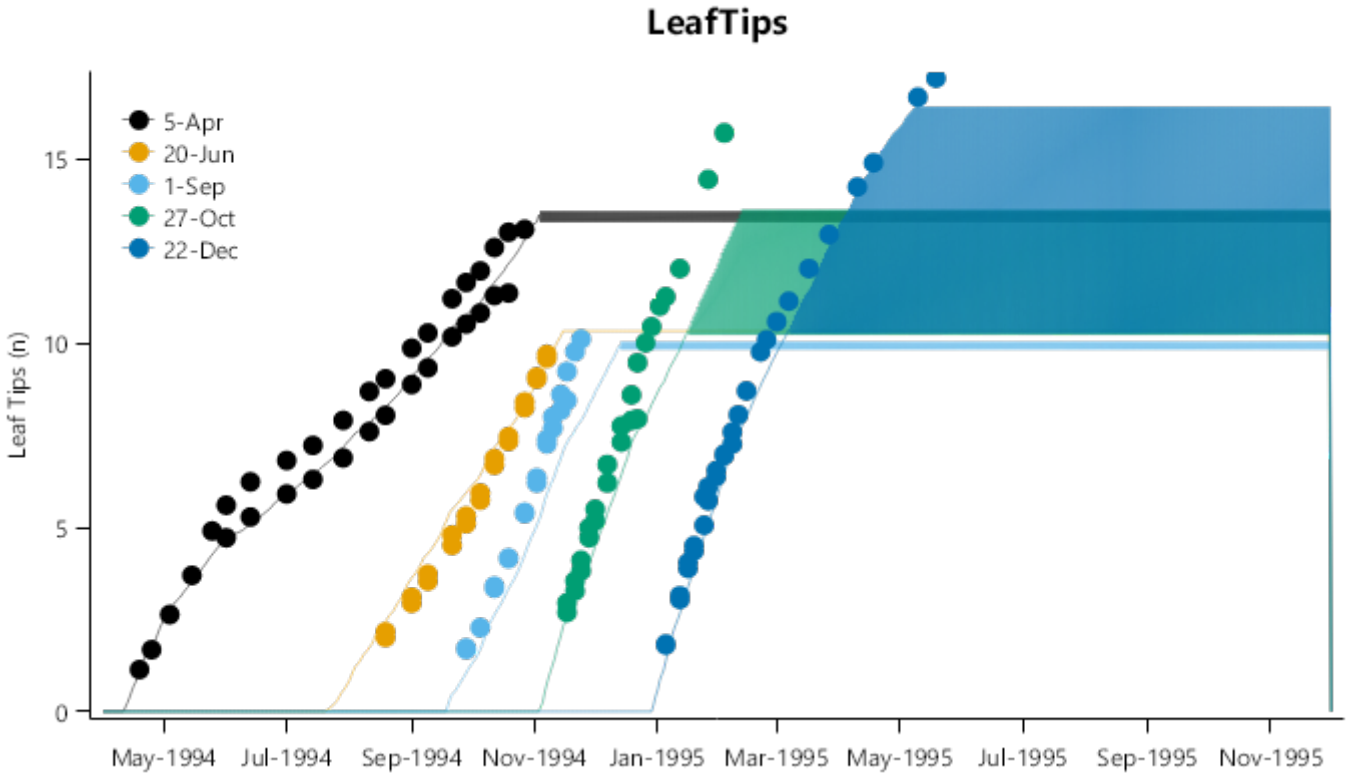
The design, management and yield results of this trial have been described in full by Craigie R.A., 2015. In brief, this trial was conducted to assess the impact of earlier sowing on potential yields of 'Wakanui' wheat grown at Wakanui (the cultivar was named after the area) in Mid Canterbury, New Zealand.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





2.5.13 CPTPhenology

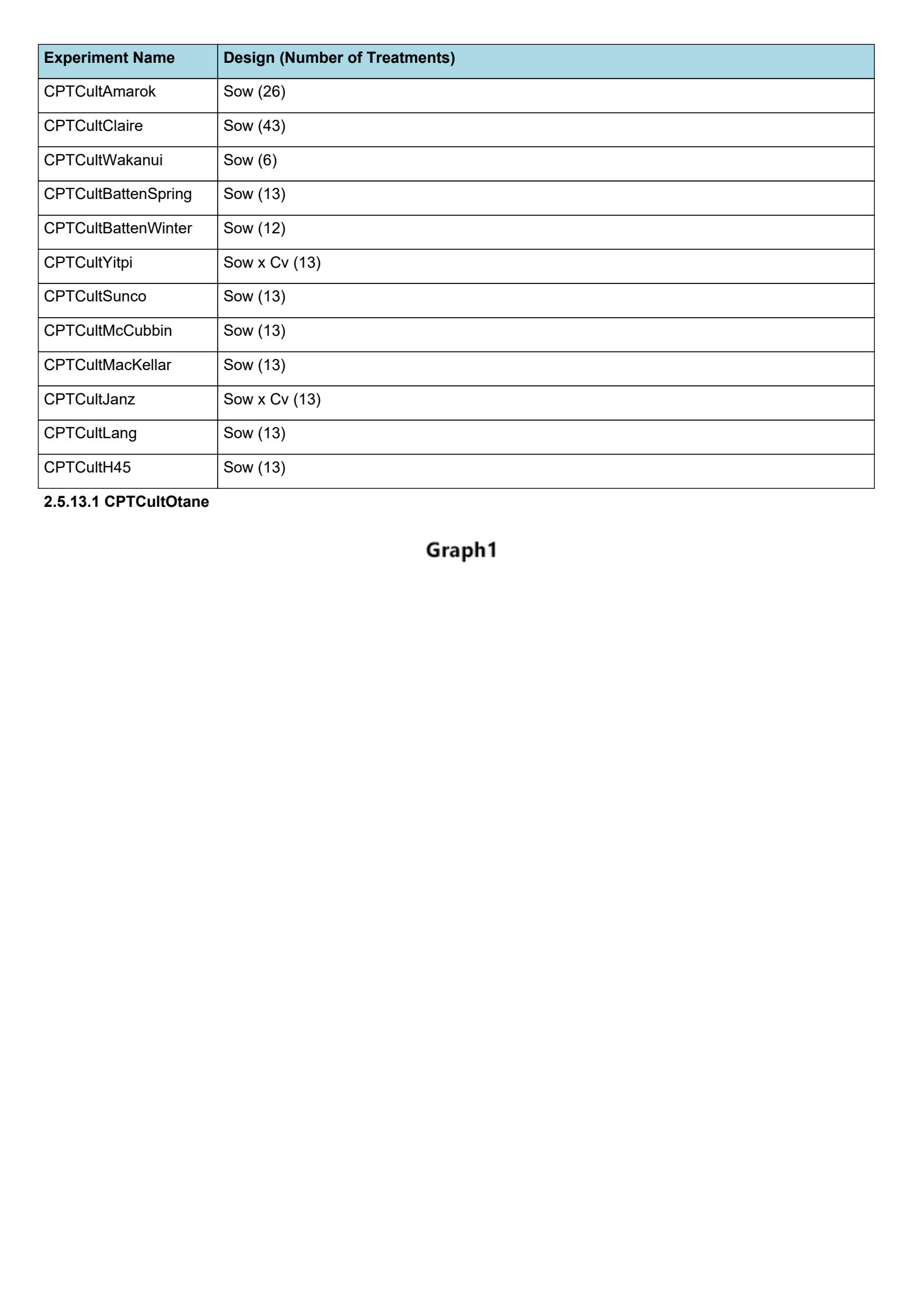
A range of soon to be released cultivars have their phenology assesed each year at Plant and Food Research in Lincoln, New Zealand. Each cultivar is planted on 4 sowing dates representing Autumn, Winter, Early Spring and Late Spring sowings. (approx April, June, Aug, Nov). Each cultivar is observed for 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.

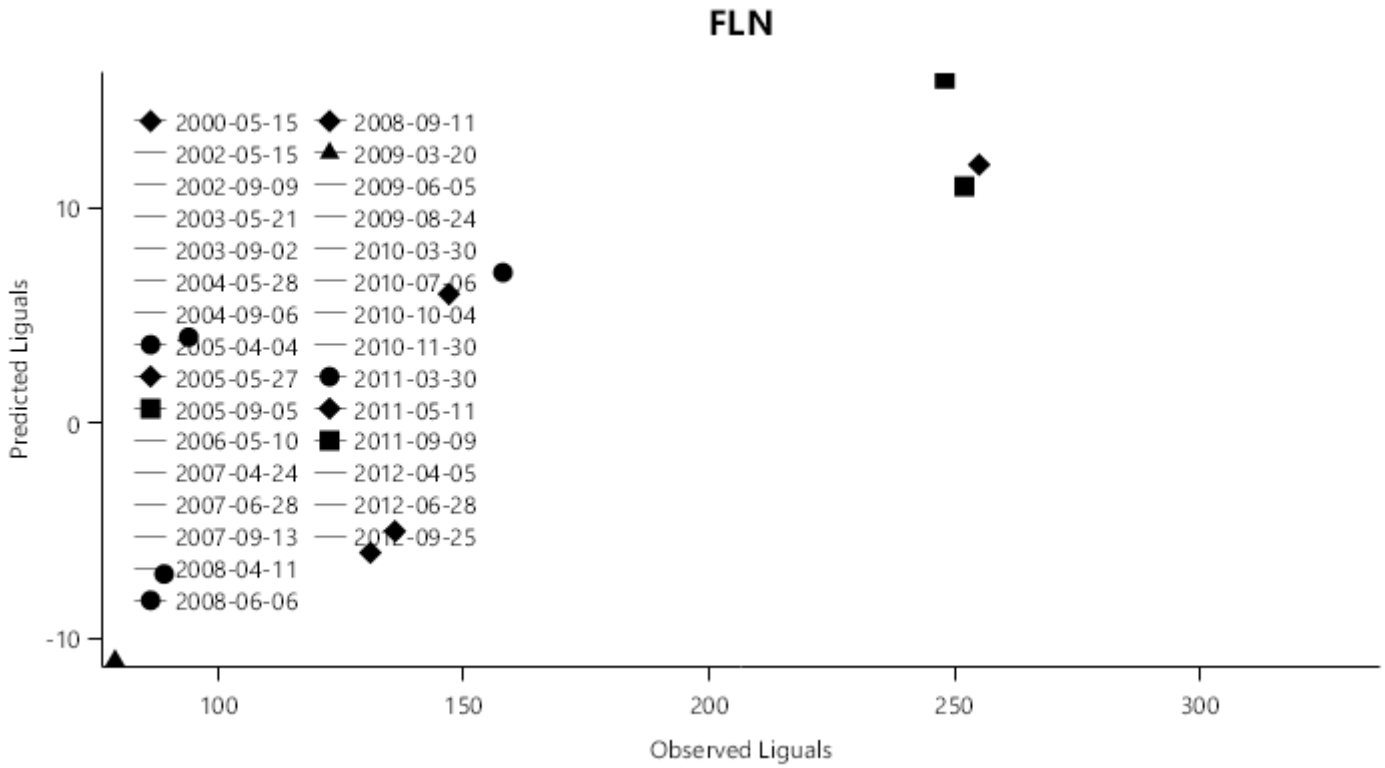
List of experiments.

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

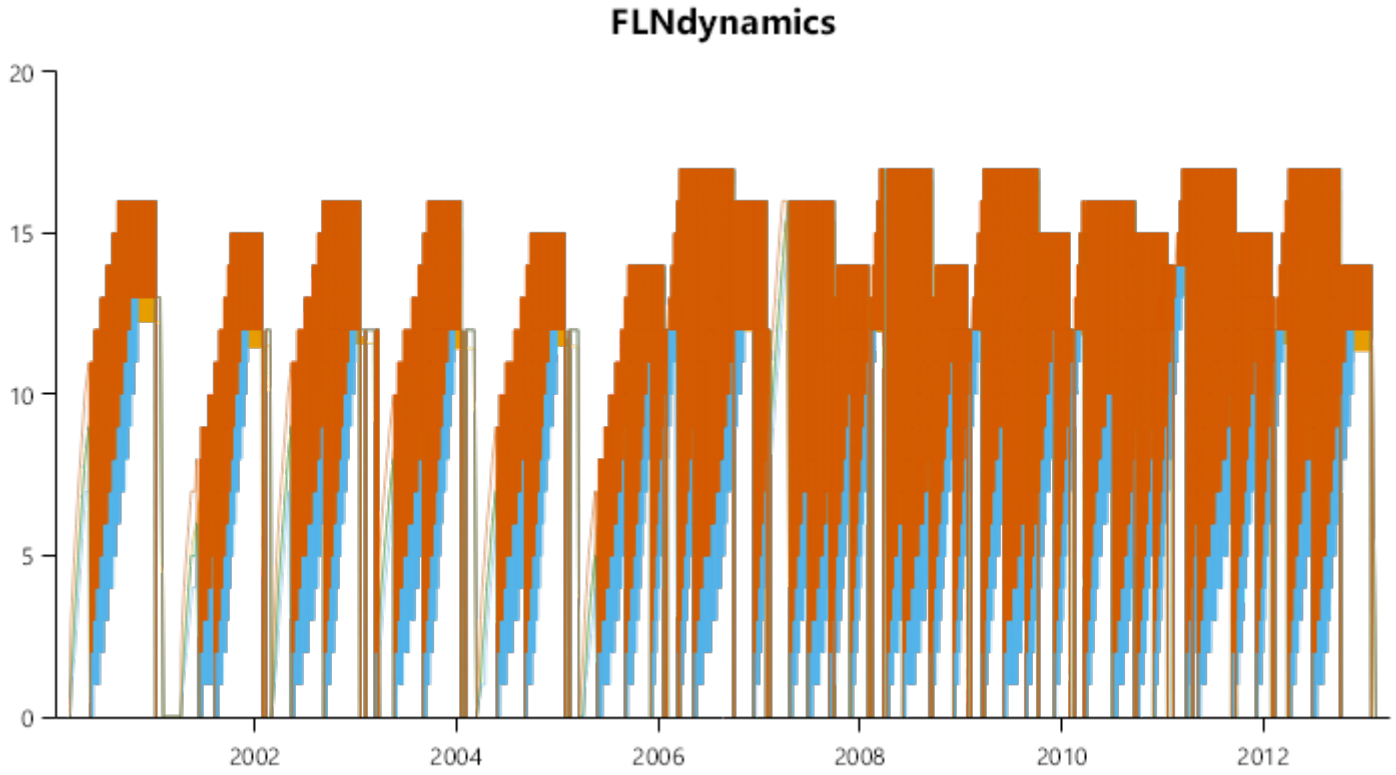
Experiment Name	Design (Number of Treatments)
CPTCultAmarok	Sow (26)
CPTCultClaire	Sow (43)
CPTCultWakanui	Sow (6)
CPTCultBattenSpring	Sow (13)
CPTCultBattenWinter	Sow (12)
CPTCultYitpi	Sow x Cv (13)
CPTCultSunco	Sow (13)
CPTCultMcCubbin	Sow (13)
CPTCultMacKellar	Sow (13)
CPTCultJanz	Sow x Cv (13)
CPTCultLang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

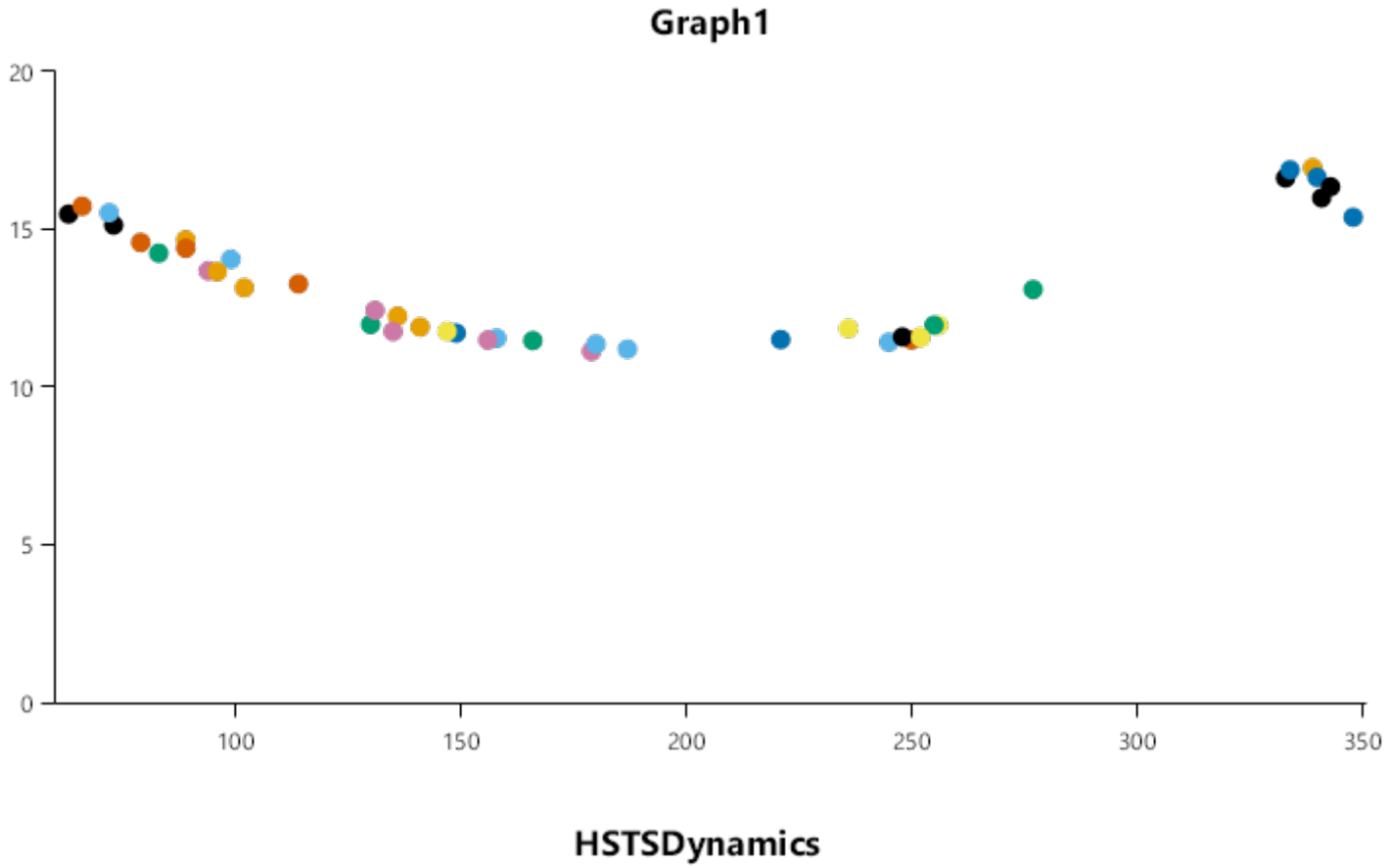
2.5.13.1 CPTCultOtane





2.5.13.2 CPTCultClaire



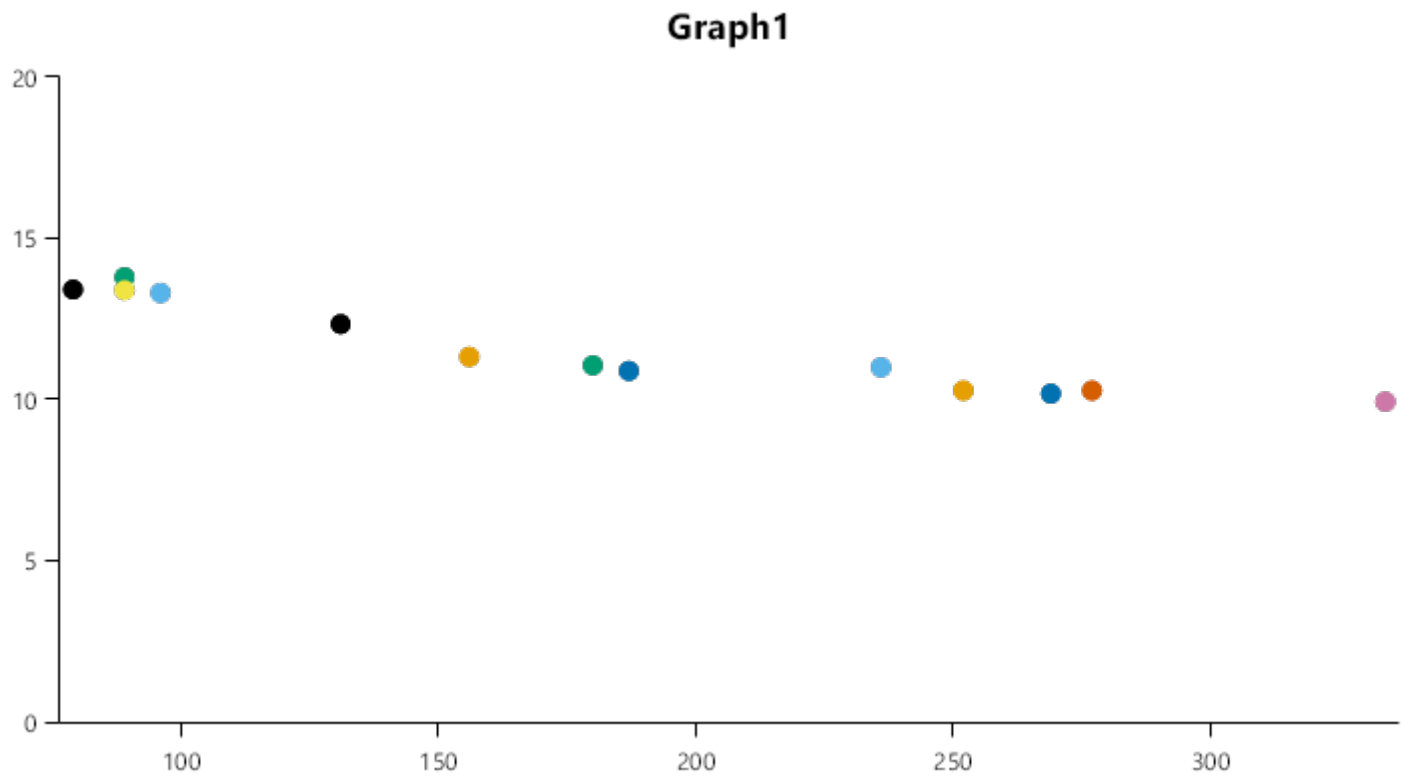

Graph1
20
15
10
5
0
100
150
200
250
300
350
HSTSDynamics

FLNdynamics1

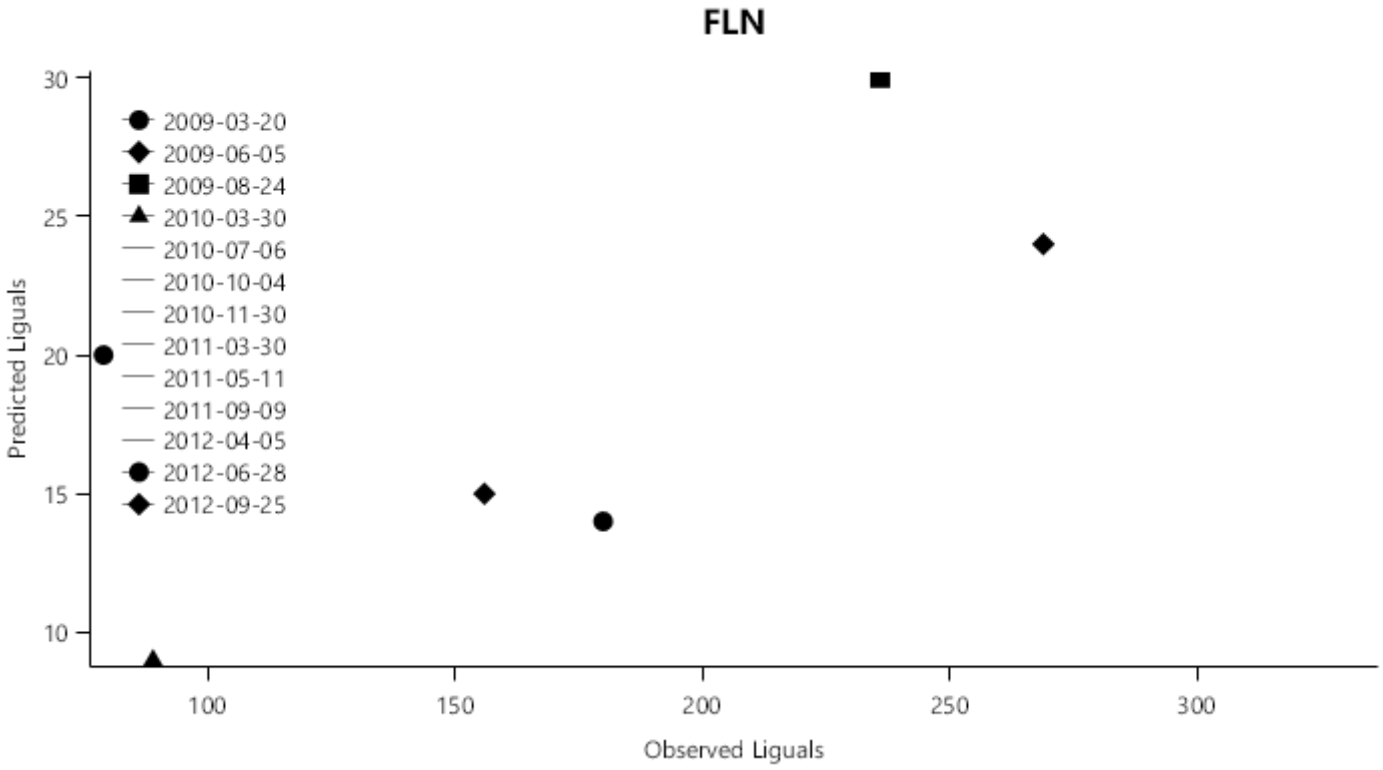
Graph11

Graph111

2.5.13.3 CPTCultBattenSpring



FLNdynamics1

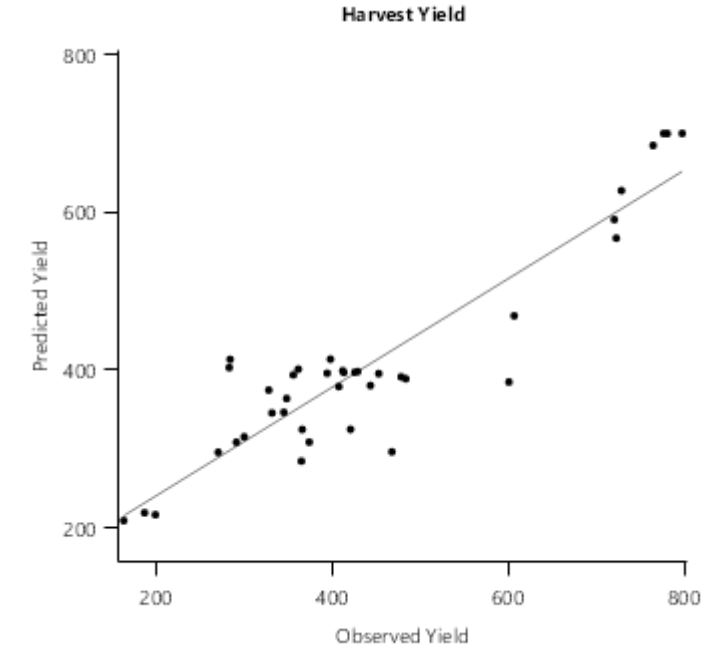


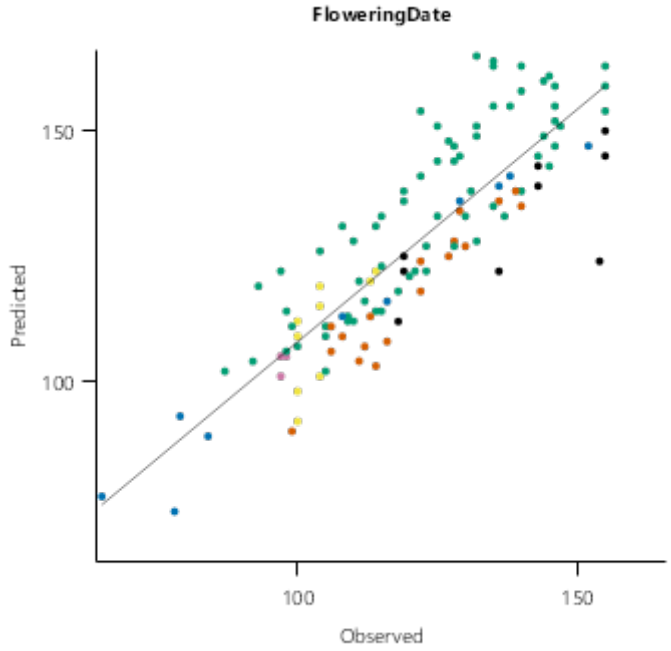
2.6 Southern Australia

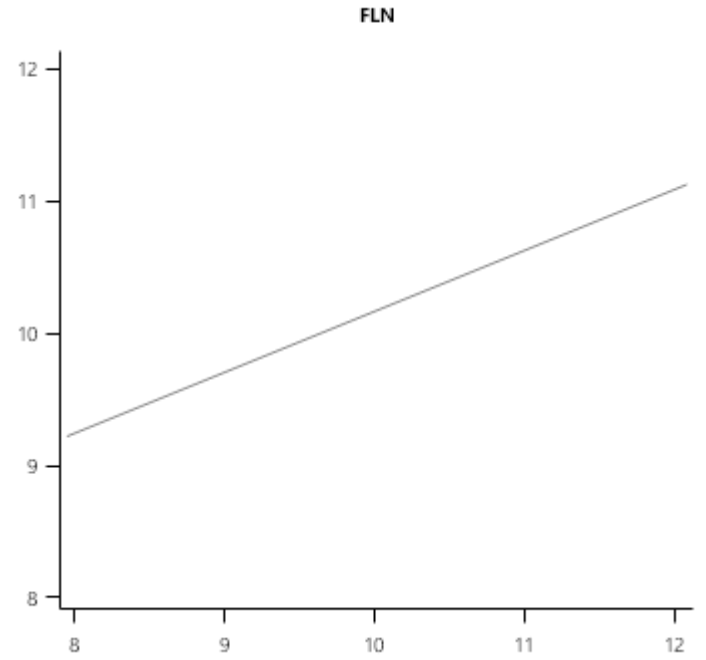
List of experiments.

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)

Experiment Name	Design (Number of Treatments)
Temora2012	Cv x TOS (9)
Birchip2011	TOS x Cv (16)
Tarlee2011	TOS x Cv (16)
Tamworth1992	Cv x TOS (75)

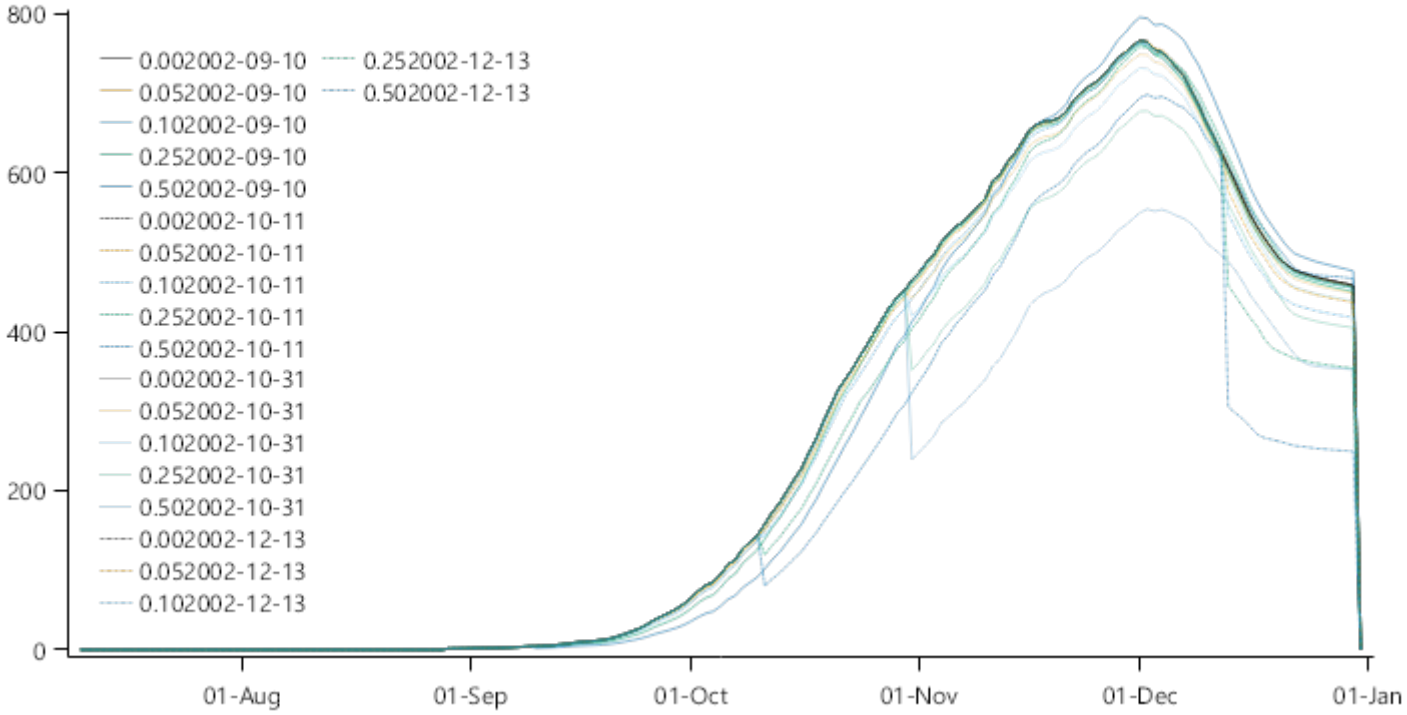




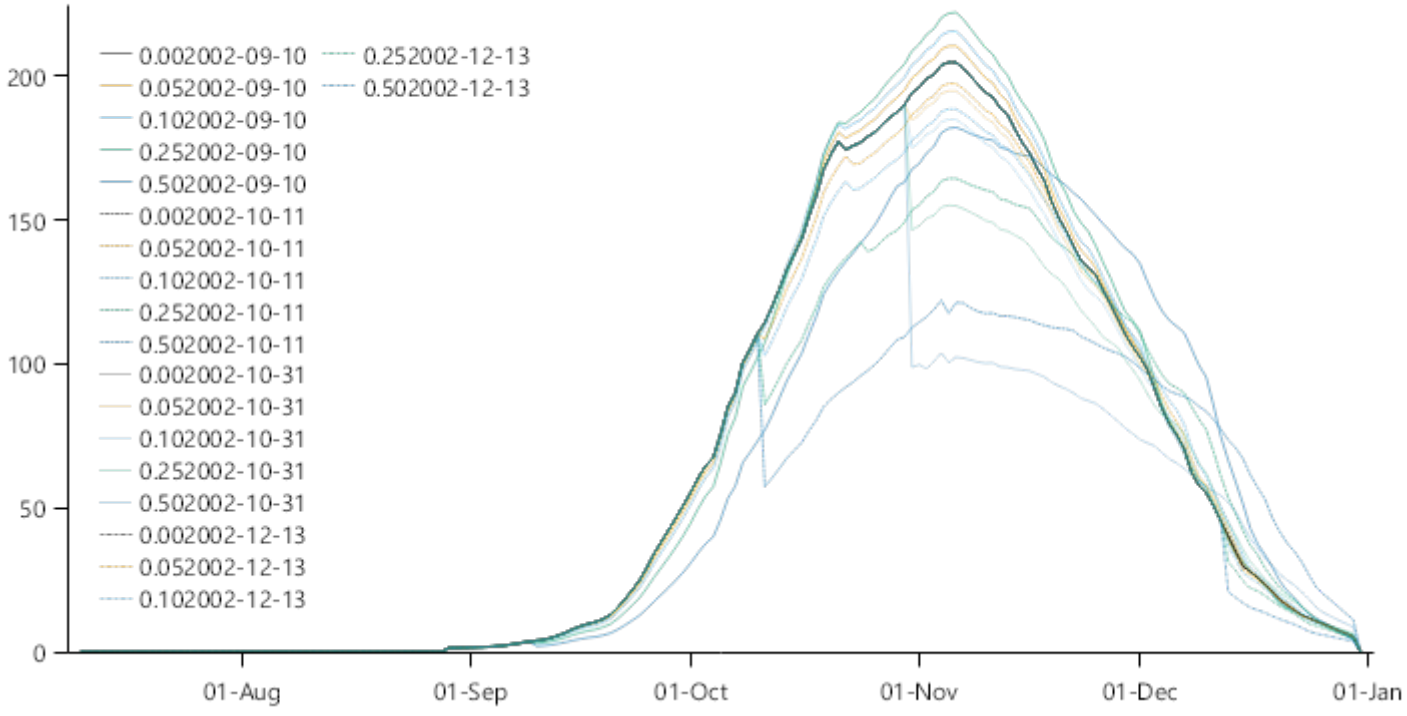


2.6.1 Mouse

Biomass

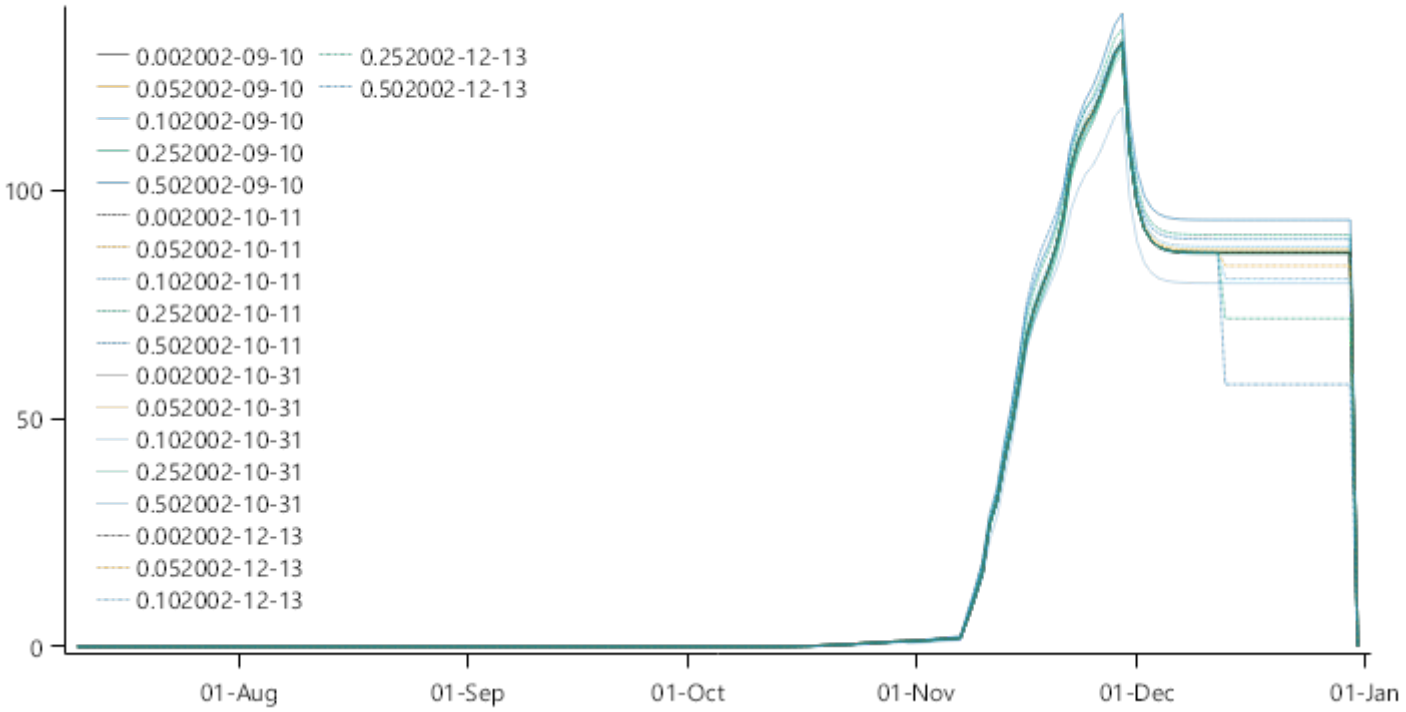


Leaf



Stem

Spike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0.102002-09-10
0.252002-09-10
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0.102002-10-11
0.252002-10-11
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0.002002-10-31
0.052002-10-31
0.102002-10-31
0.252002-10-31
0.502002-10-31
0.002002-12-13
0.052002-12-13
0.102002-12-13
0.252002-12-13
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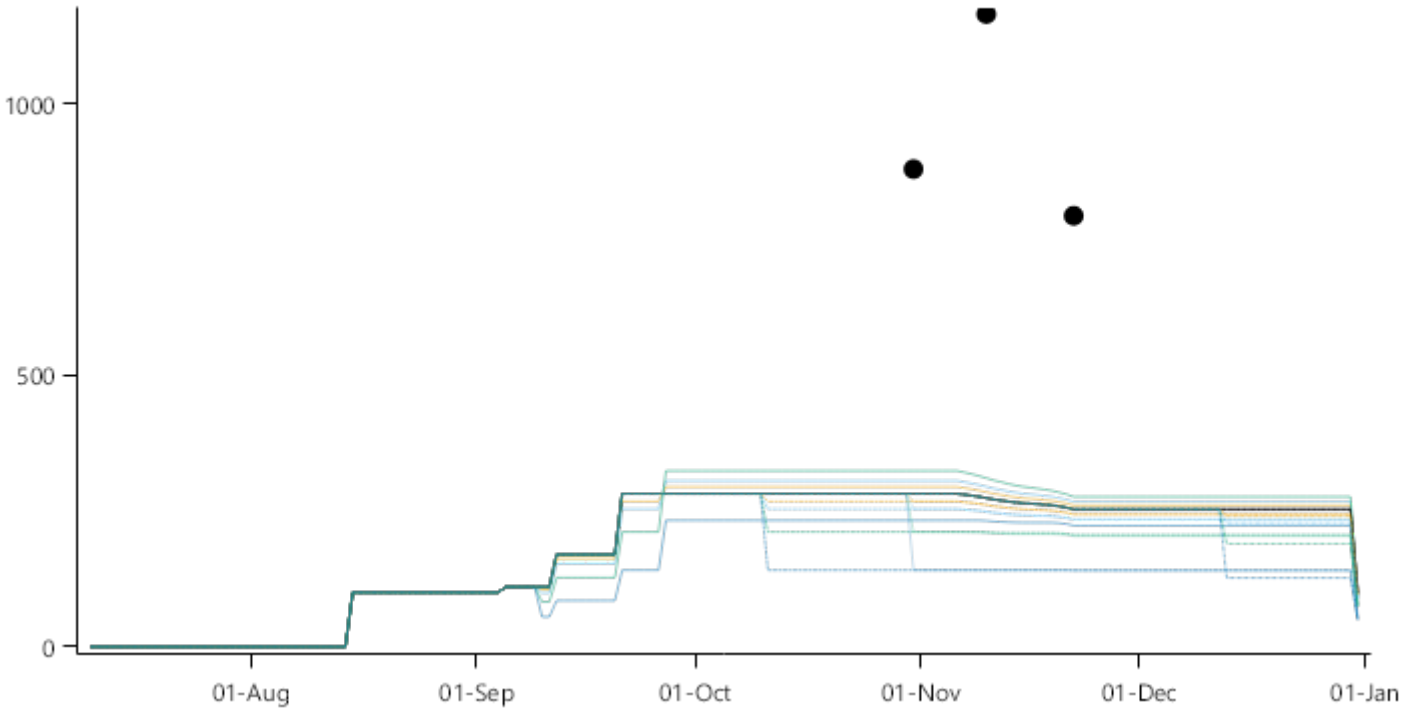
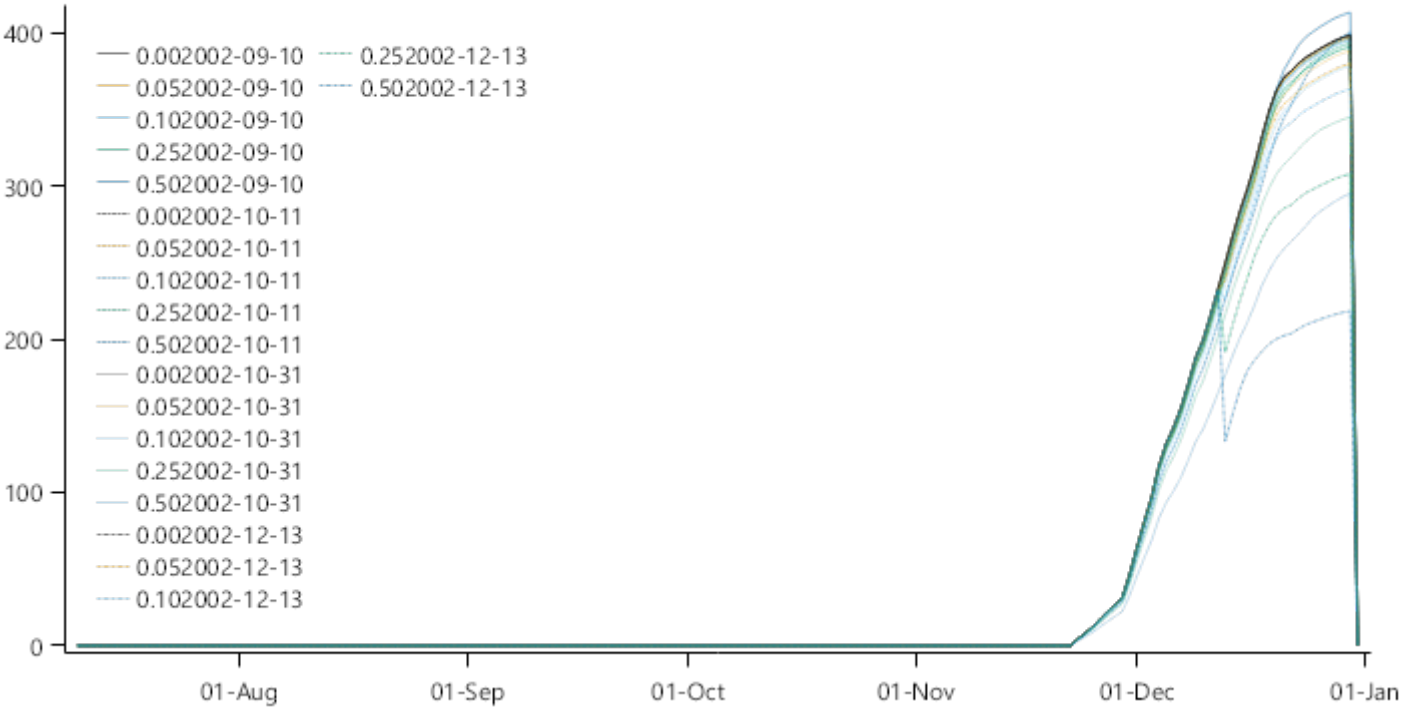
01-Aug
01-Sep
01-Oct
01-Nov
01-Dec
01-Jan

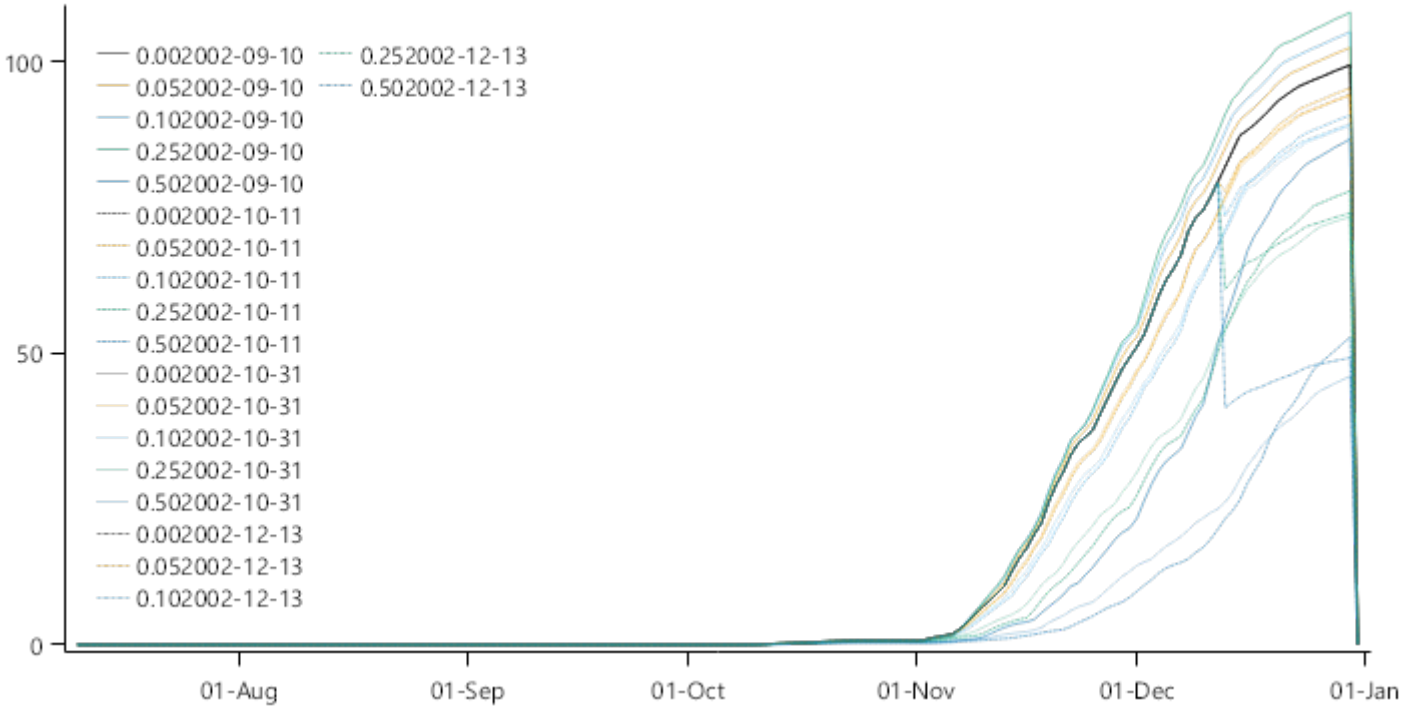
StemPopn



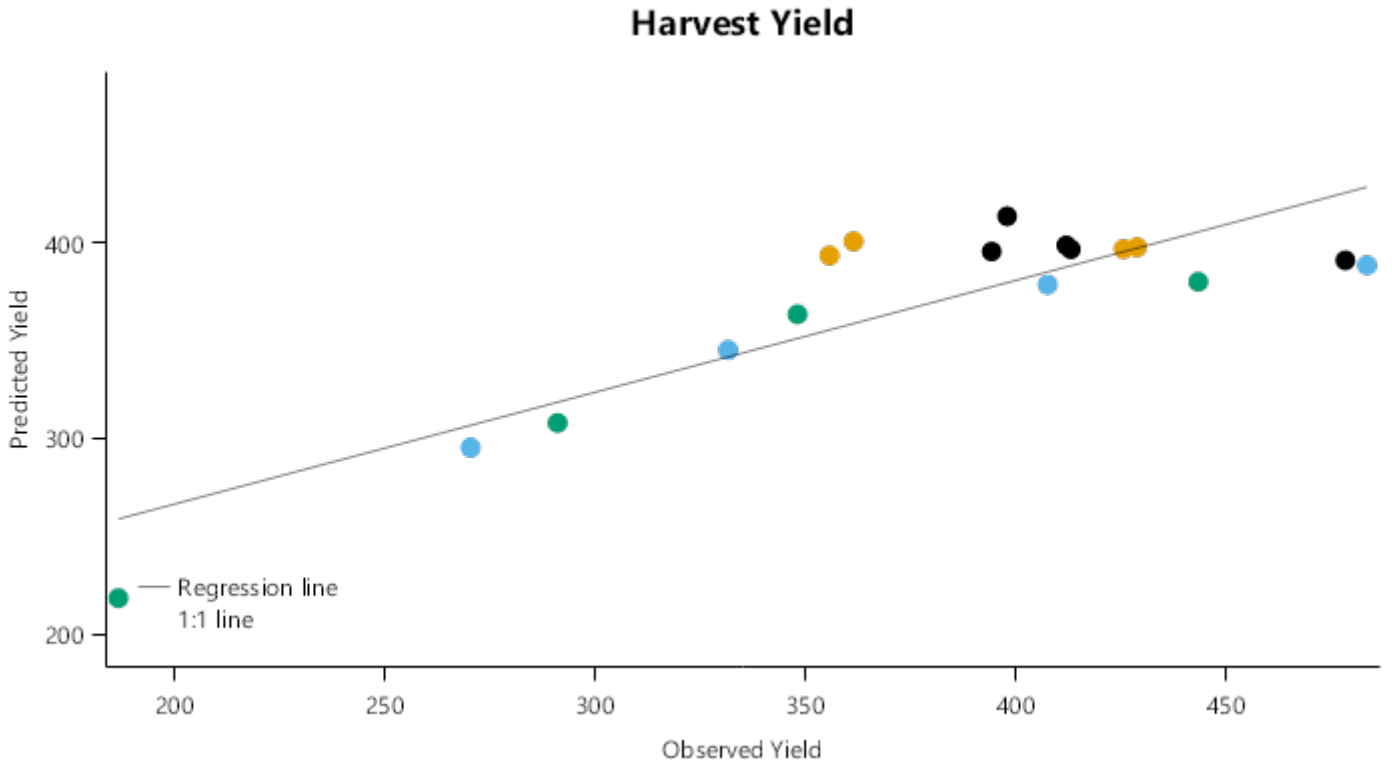
Grain

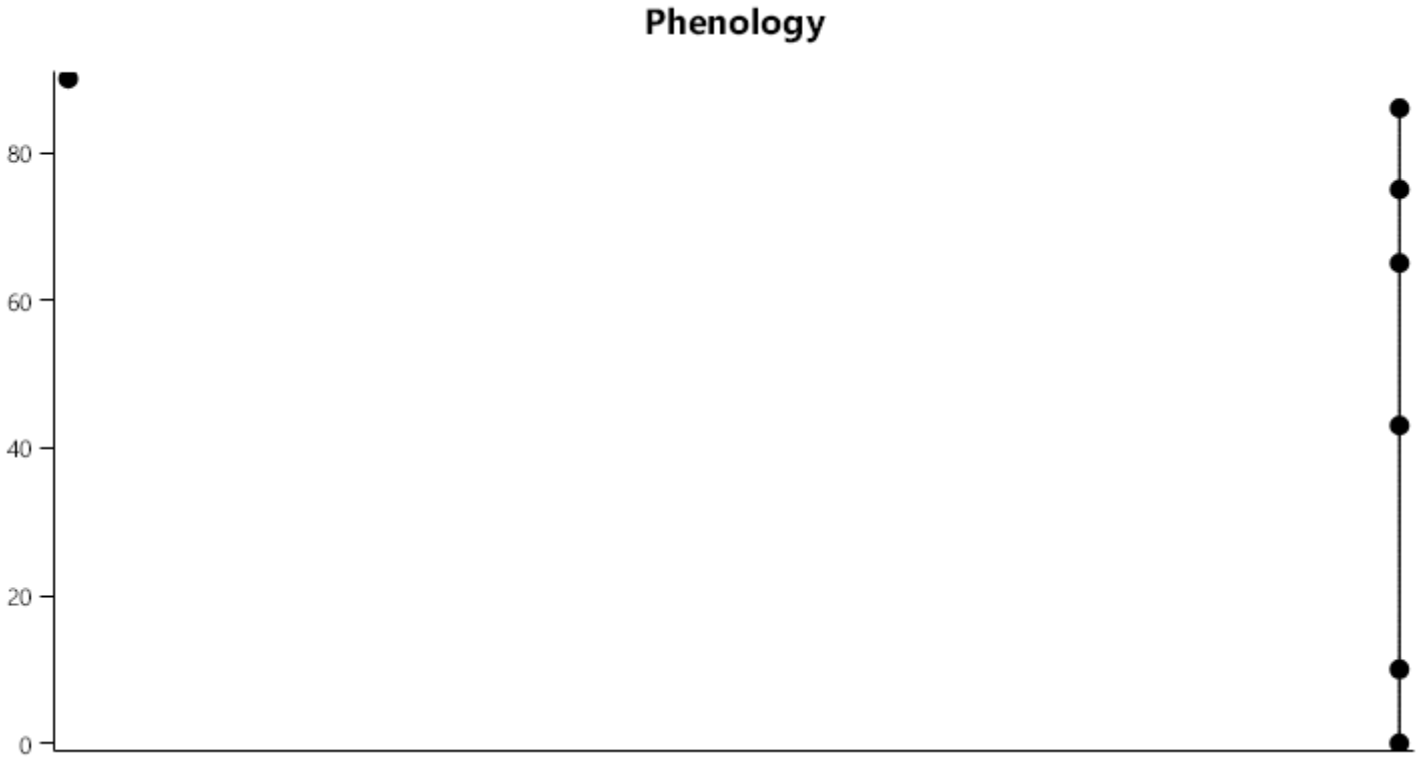


DeadLeaf



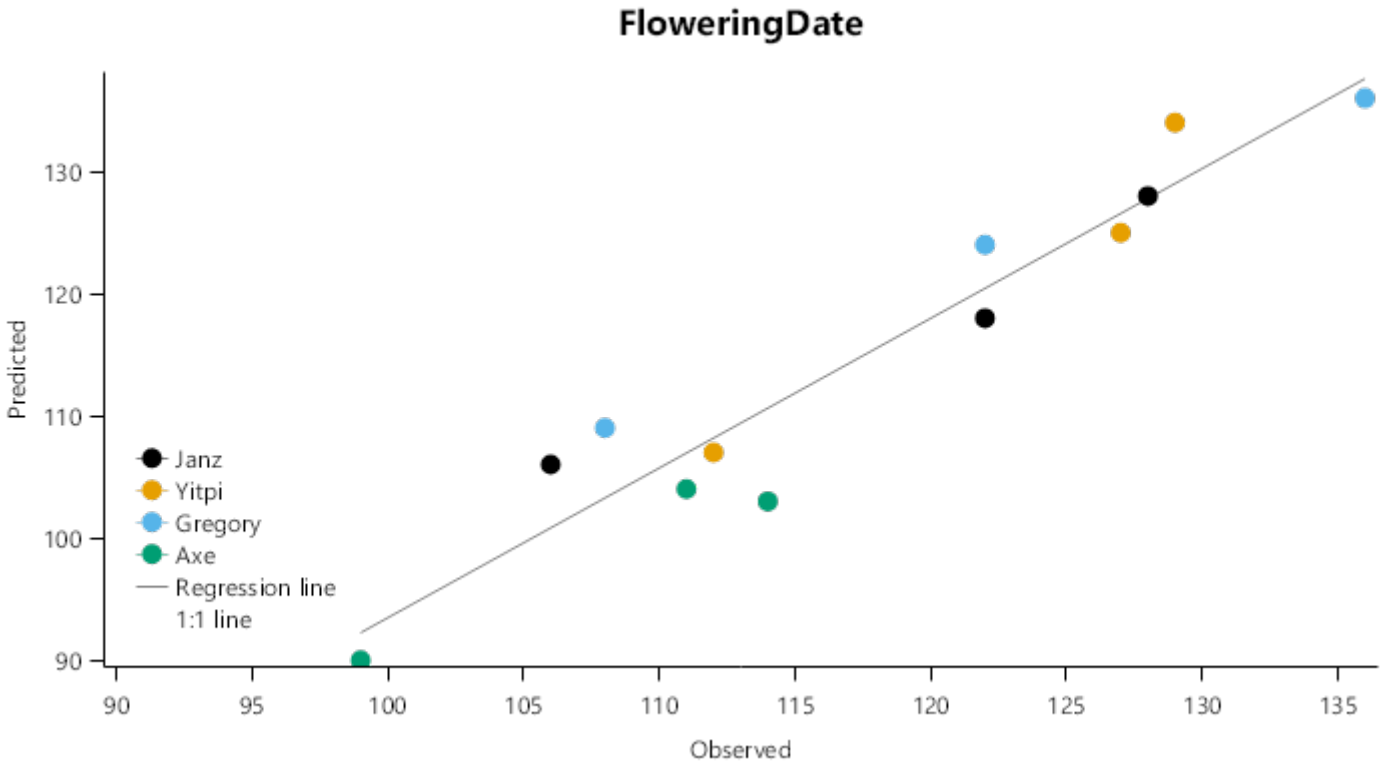
SurfaceOM





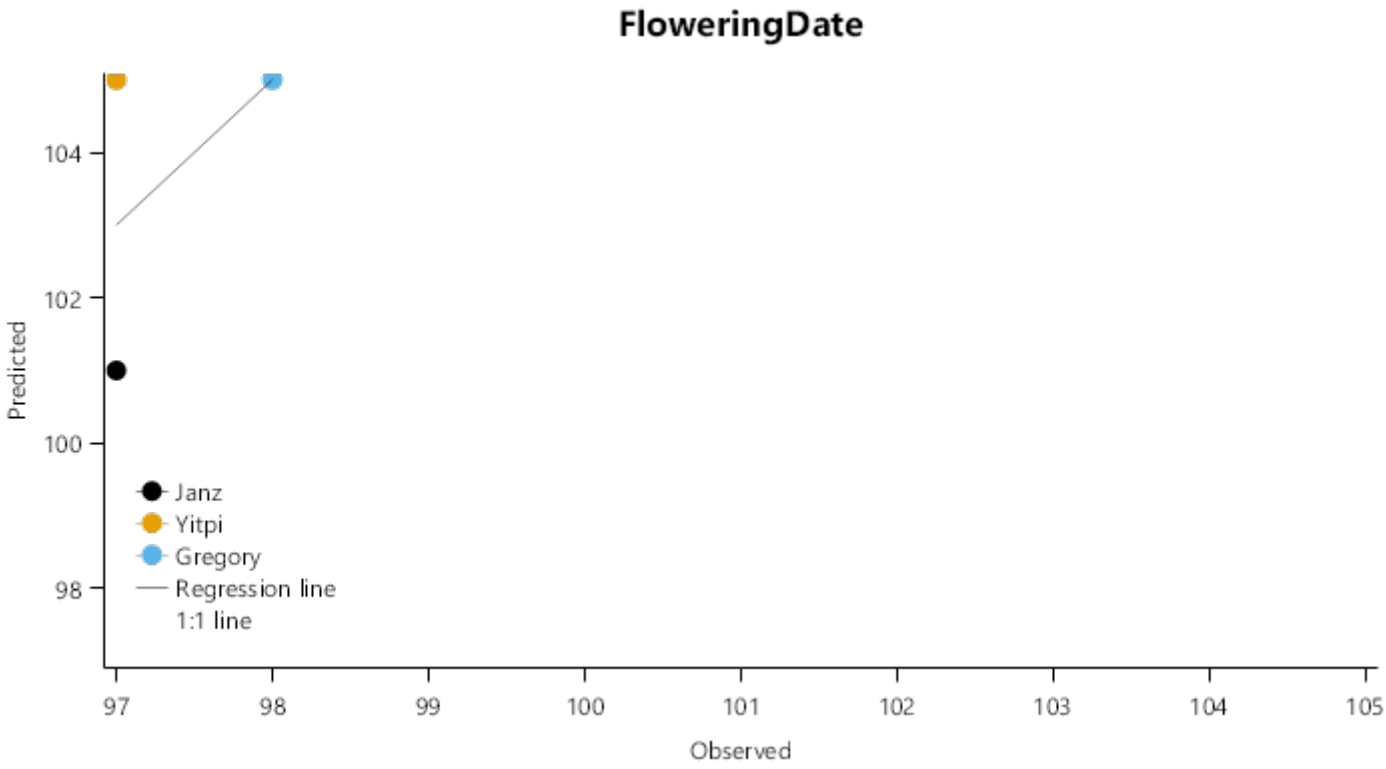
2.6.2 Walpeup2011

INSERT TEXT HERE



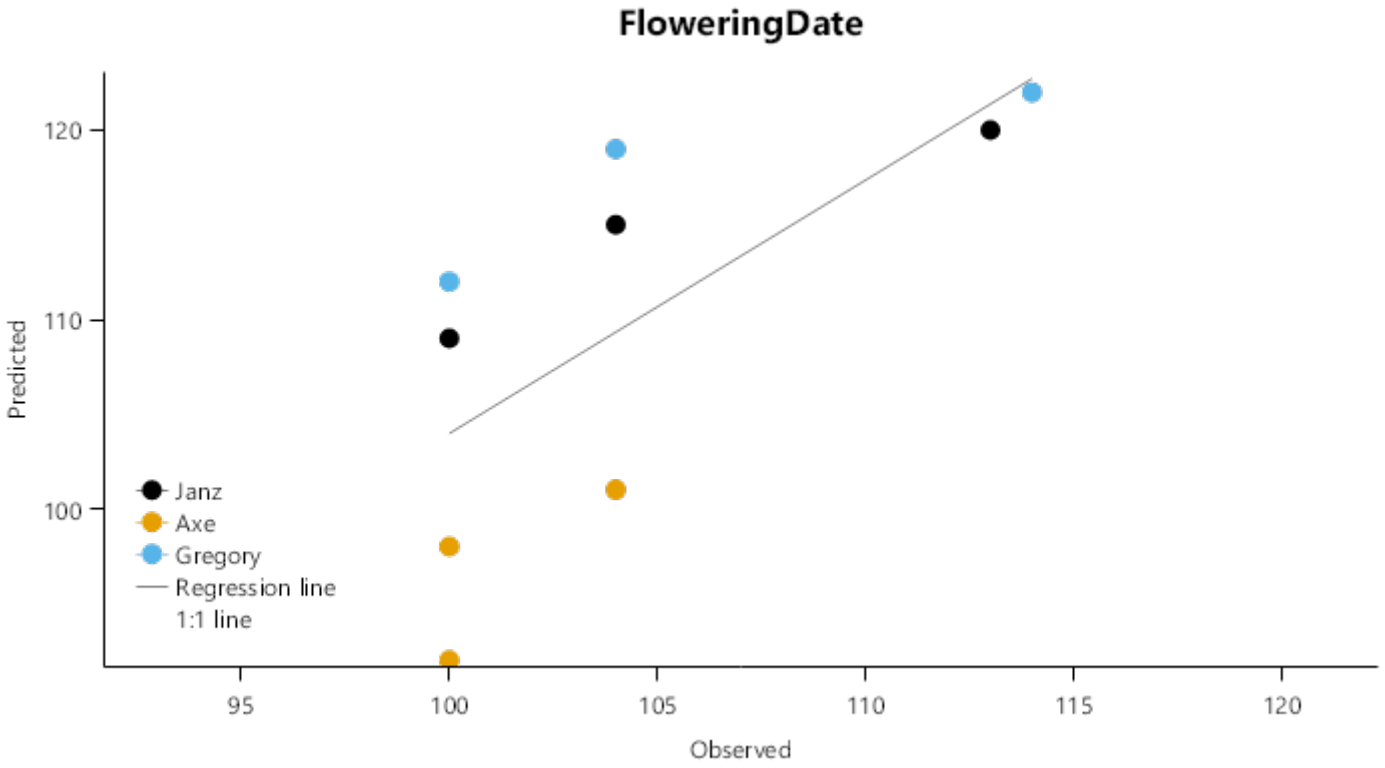
2.6.3 Walpeup2012

INSERT TEXT HERE



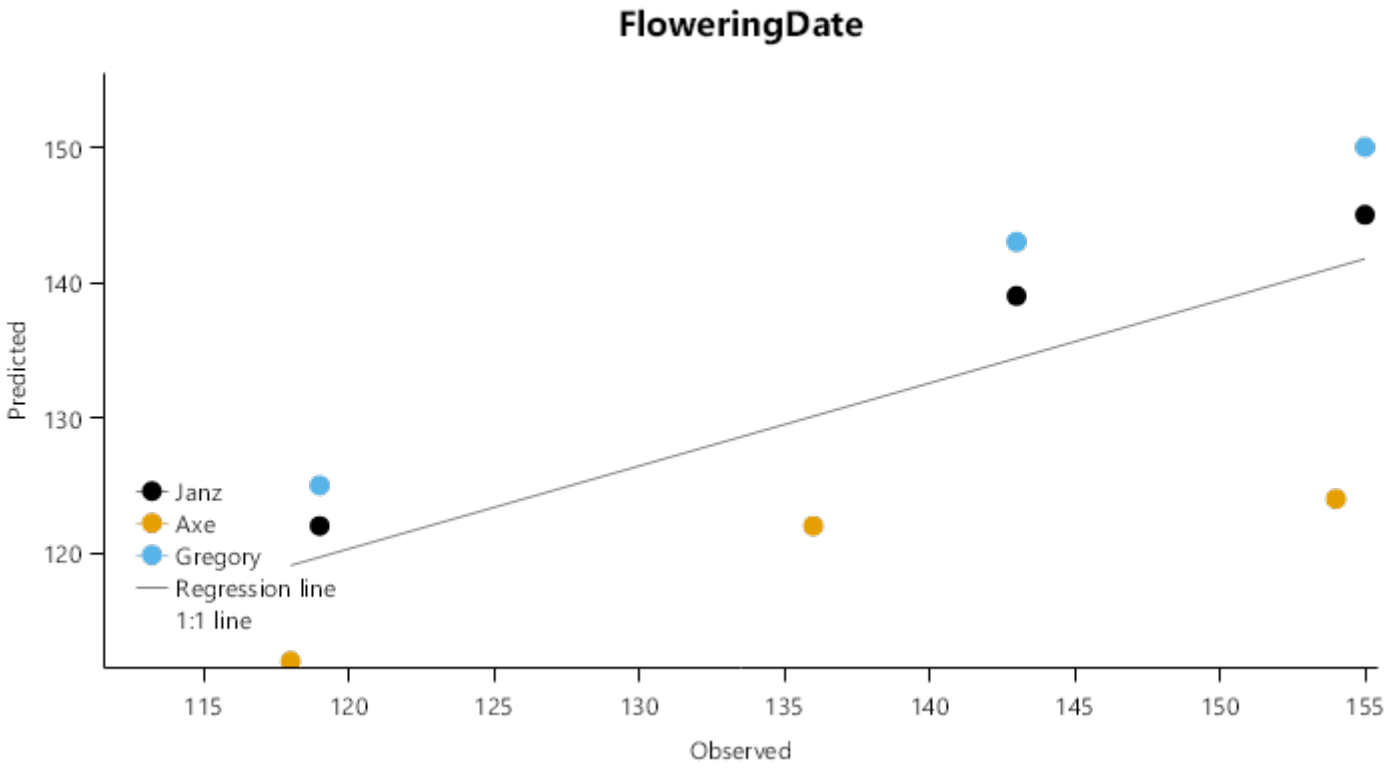
2.6.4 Minnipa2012

INSERT TEXT HERE

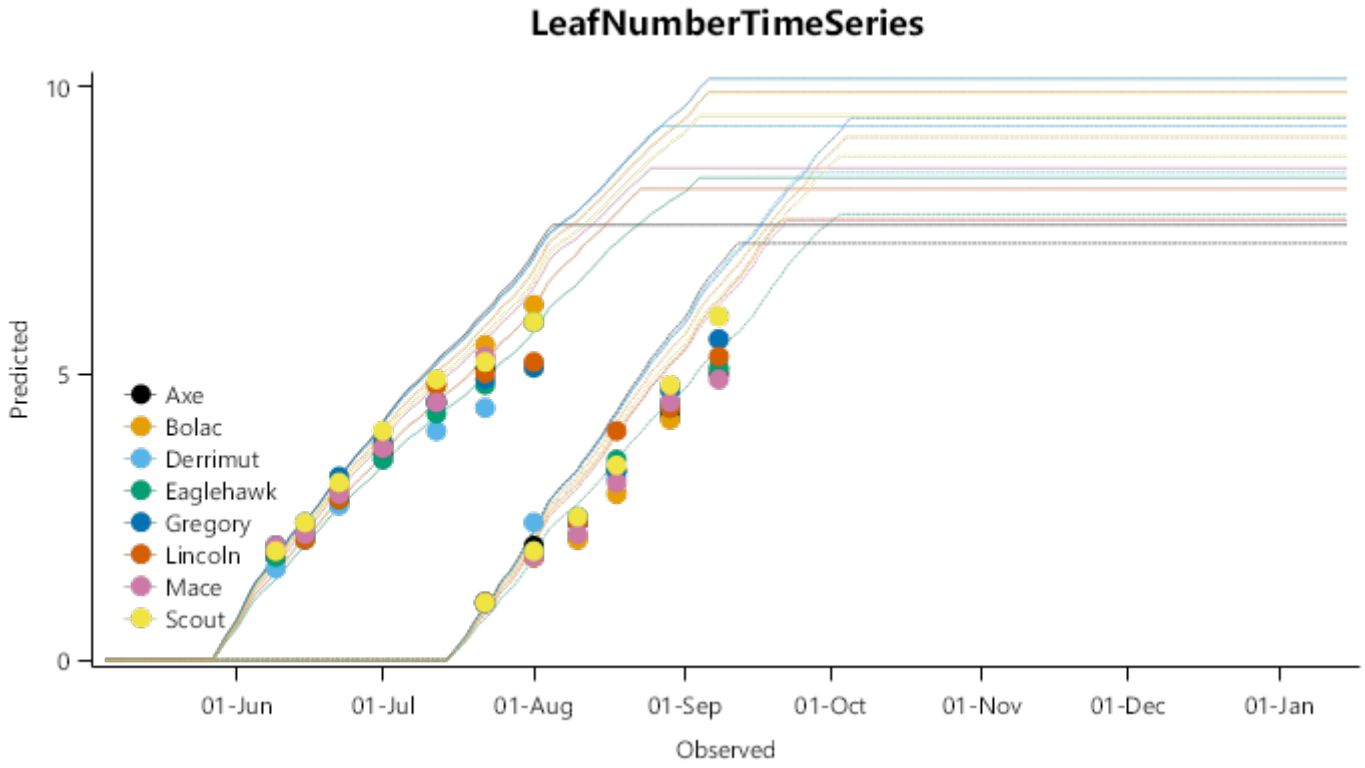


2.6.5 Temora2012

INSERT TEXT HERE



2.6.6 Birchip2011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Predicted
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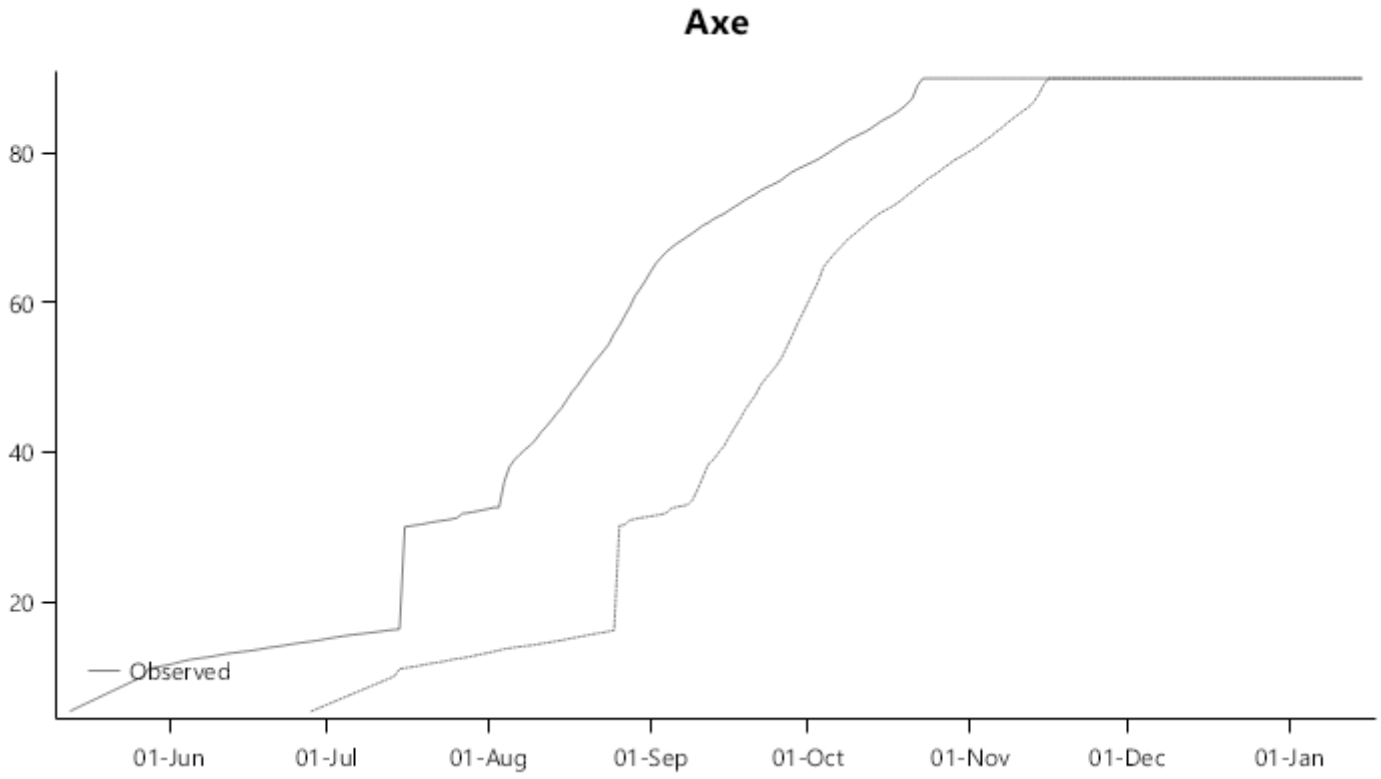
5
0
Axe
Bolac
Derrimut
Eaglehawk
Gregory
Lincoln
Mace
Scout
01-Jun
01-Jul
01-Aug
01-Sep
01-Oct
01-Nov
01-Dec
01-Jan
Observed


Axe
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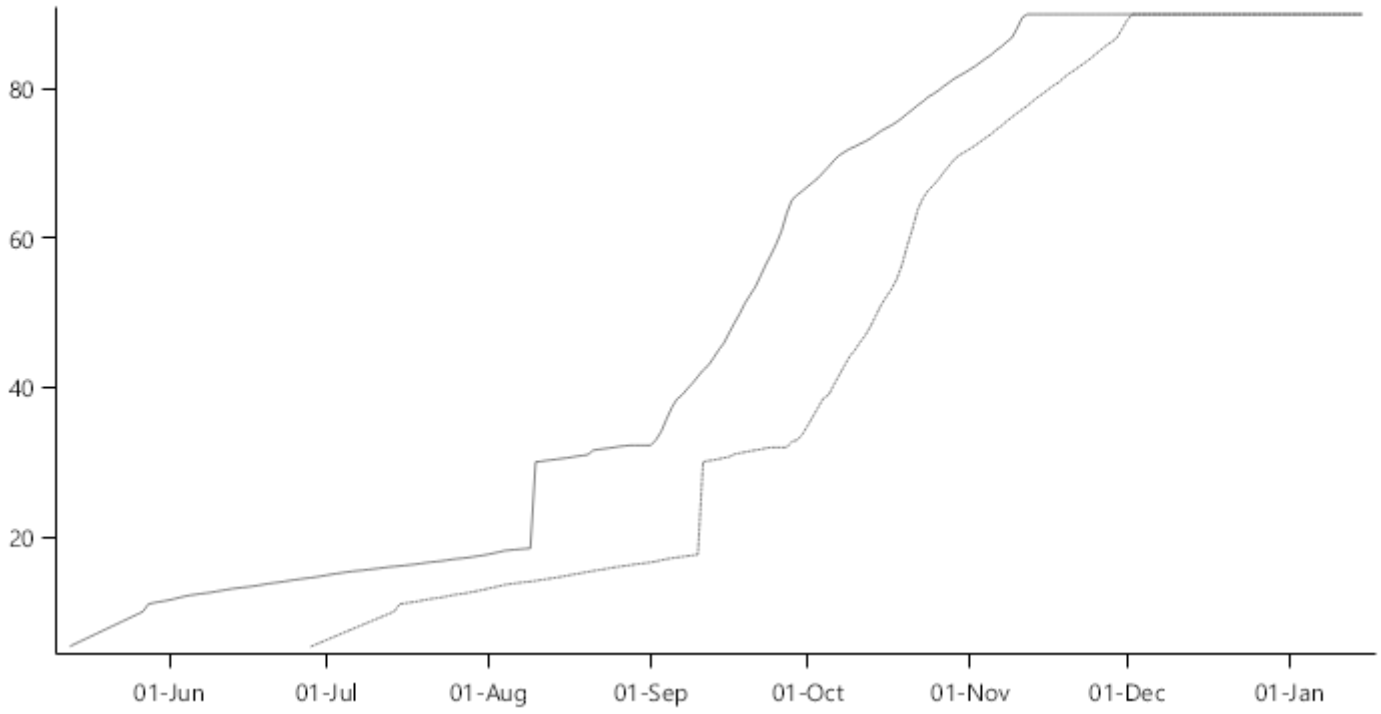
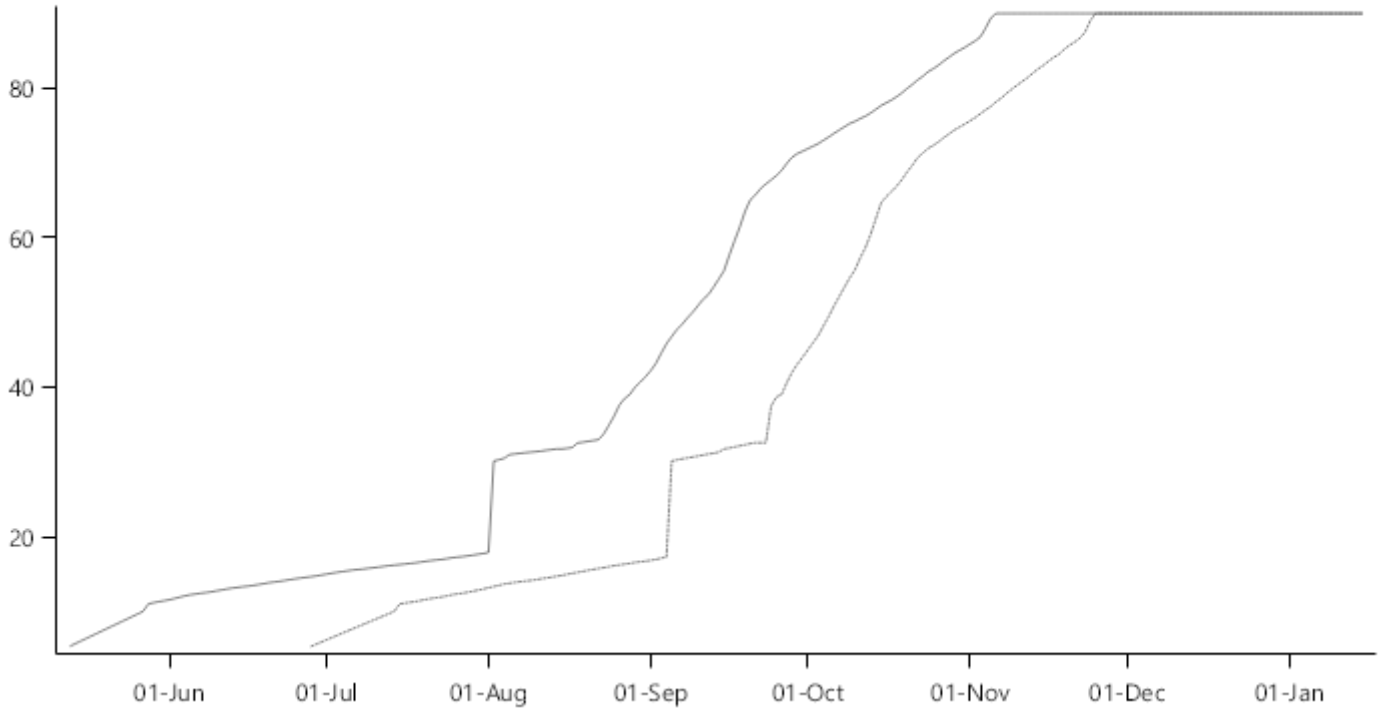
60
40
20
Observed
01-Jun
01-Jul
01-Aug
01-Sep
01-Oct
01-Nov
01-Dec
01-Jan

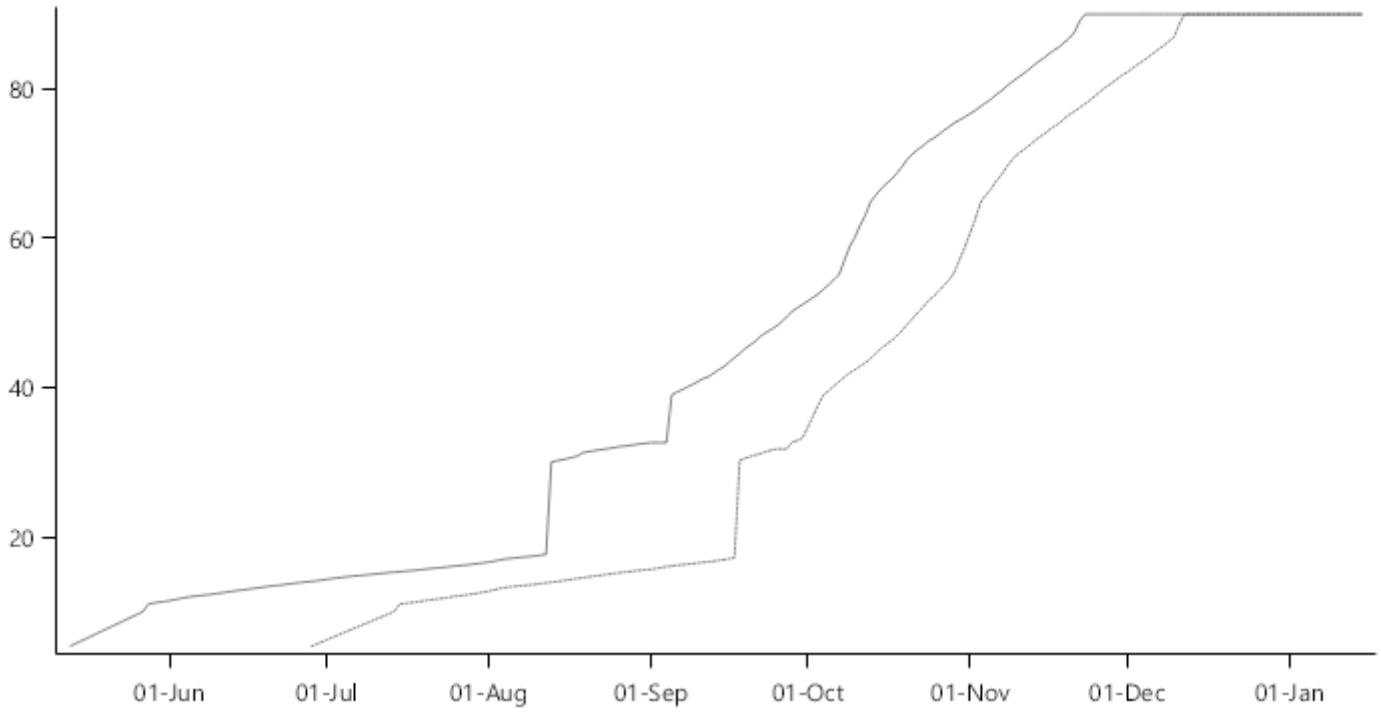
Bolac



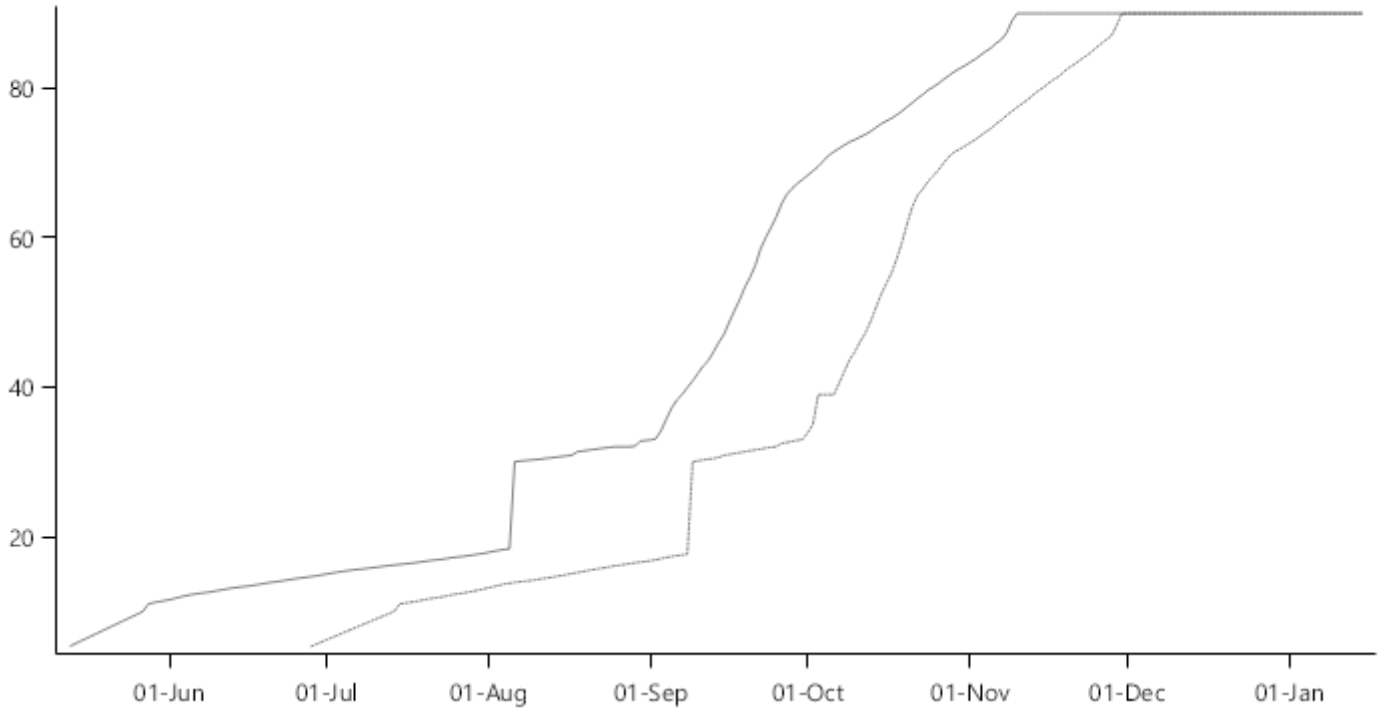
Derrimut



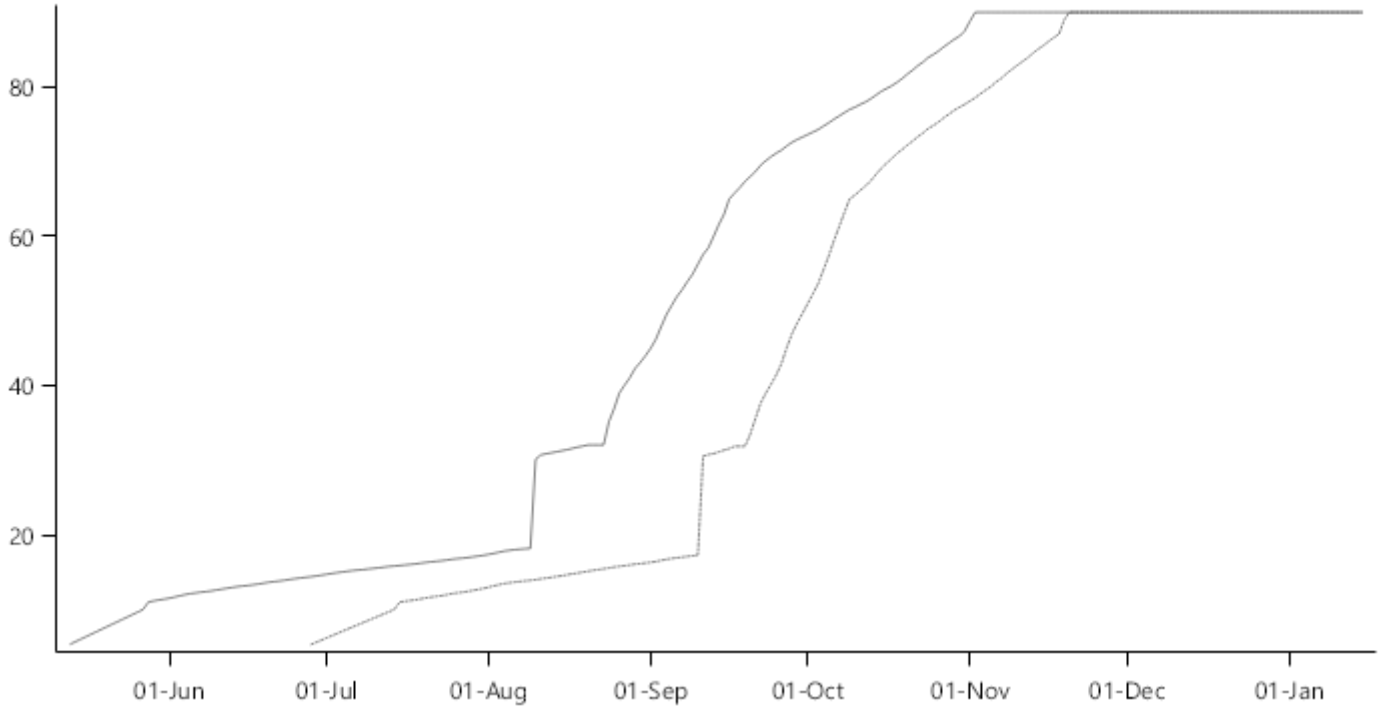
EagleHawk



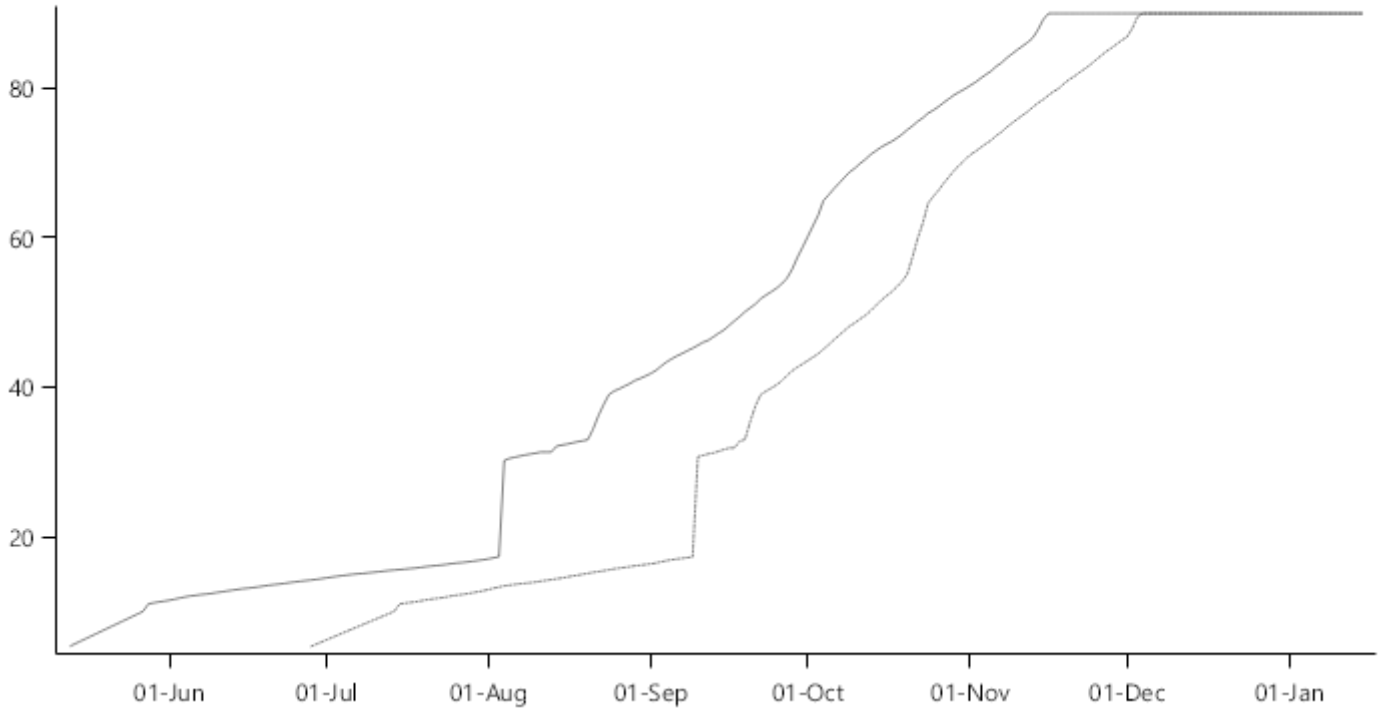
Gregory

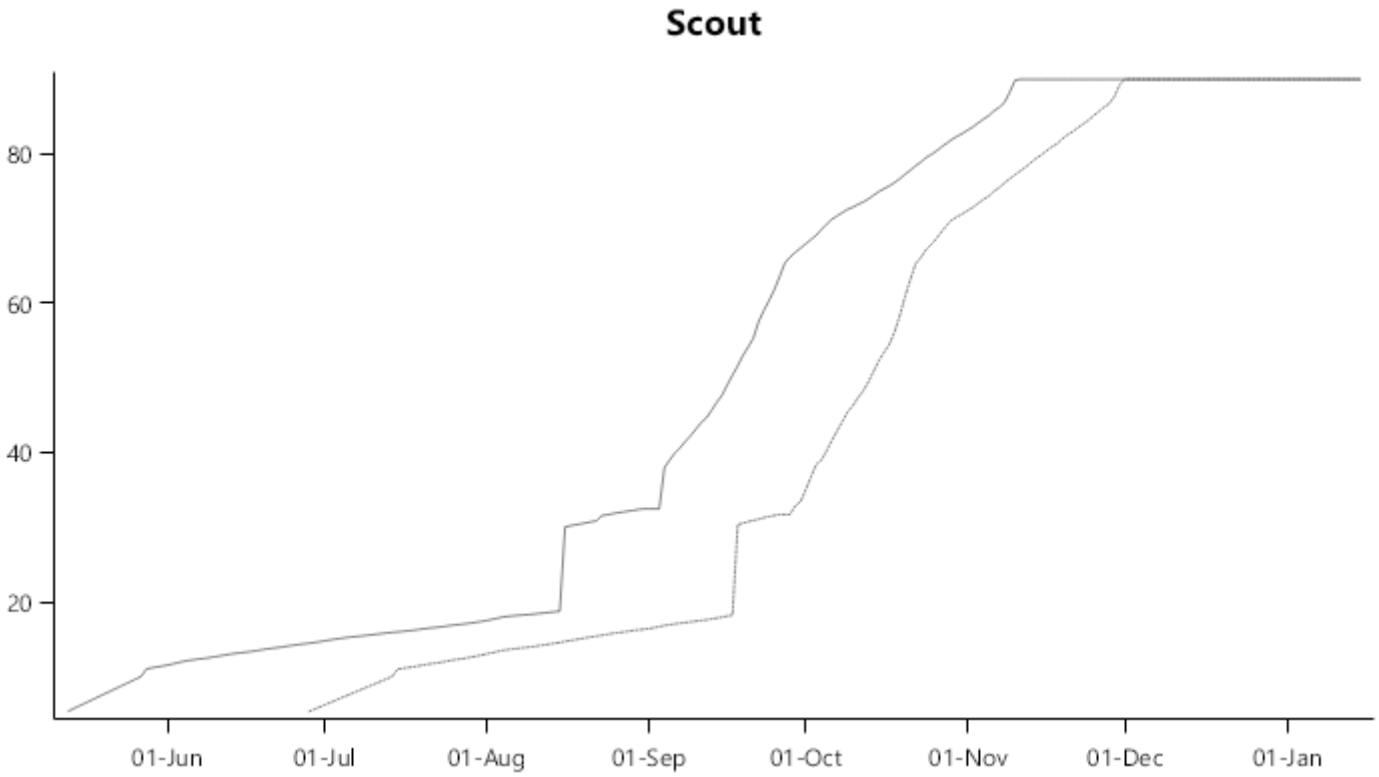


Mace

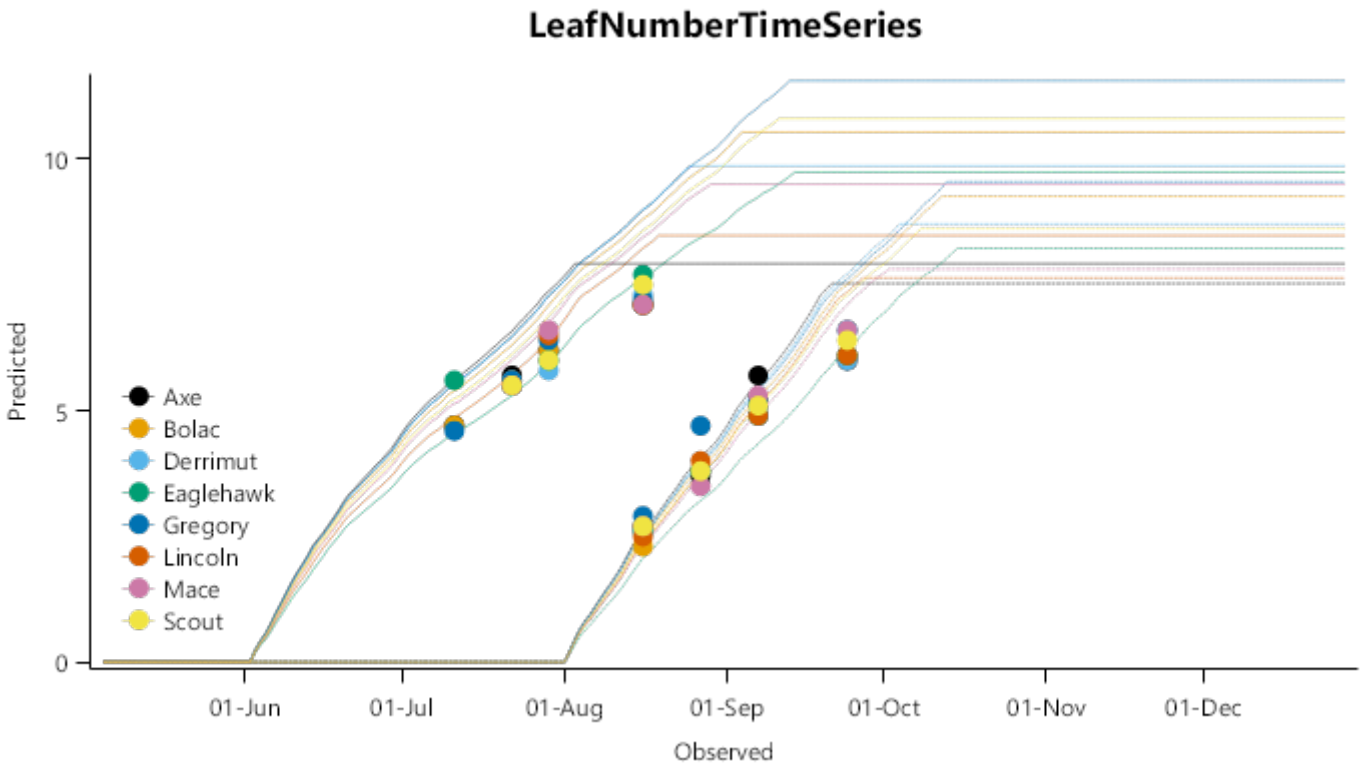


Lincoln

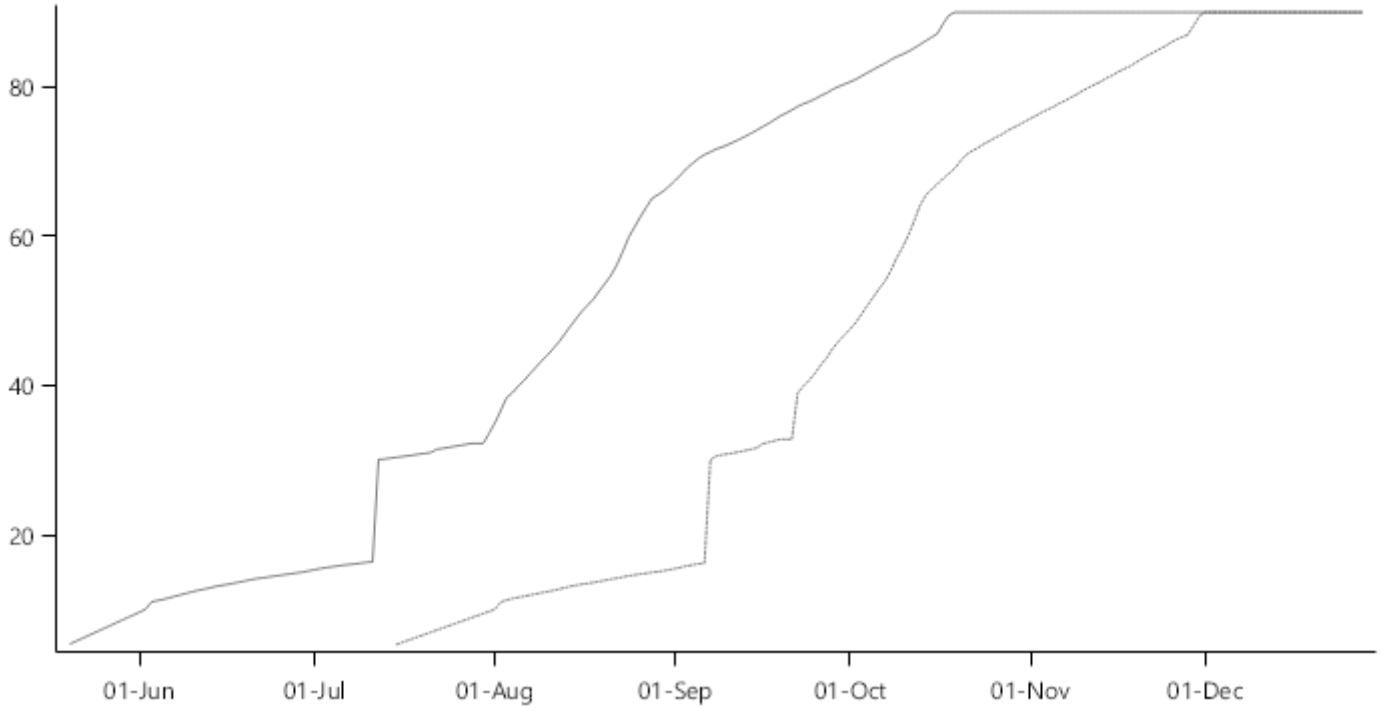




2.6.7 Tarlee2011



Axe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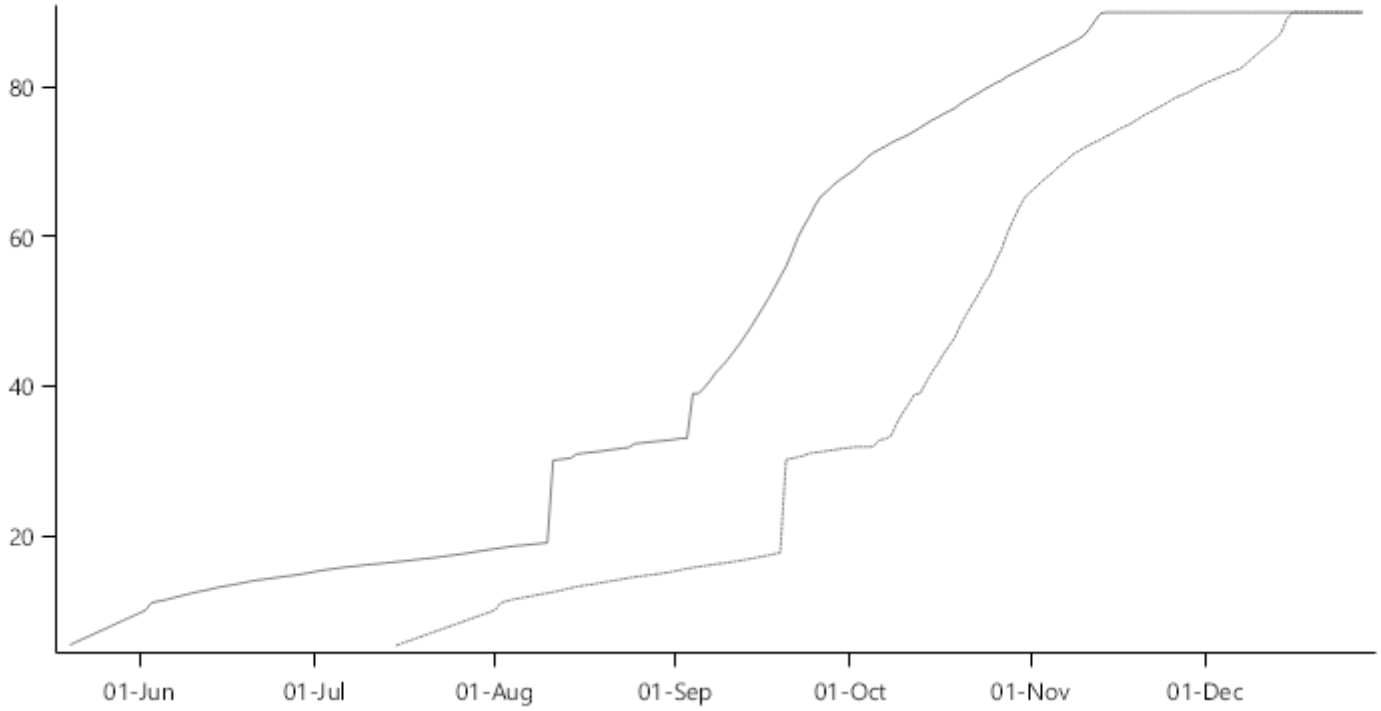
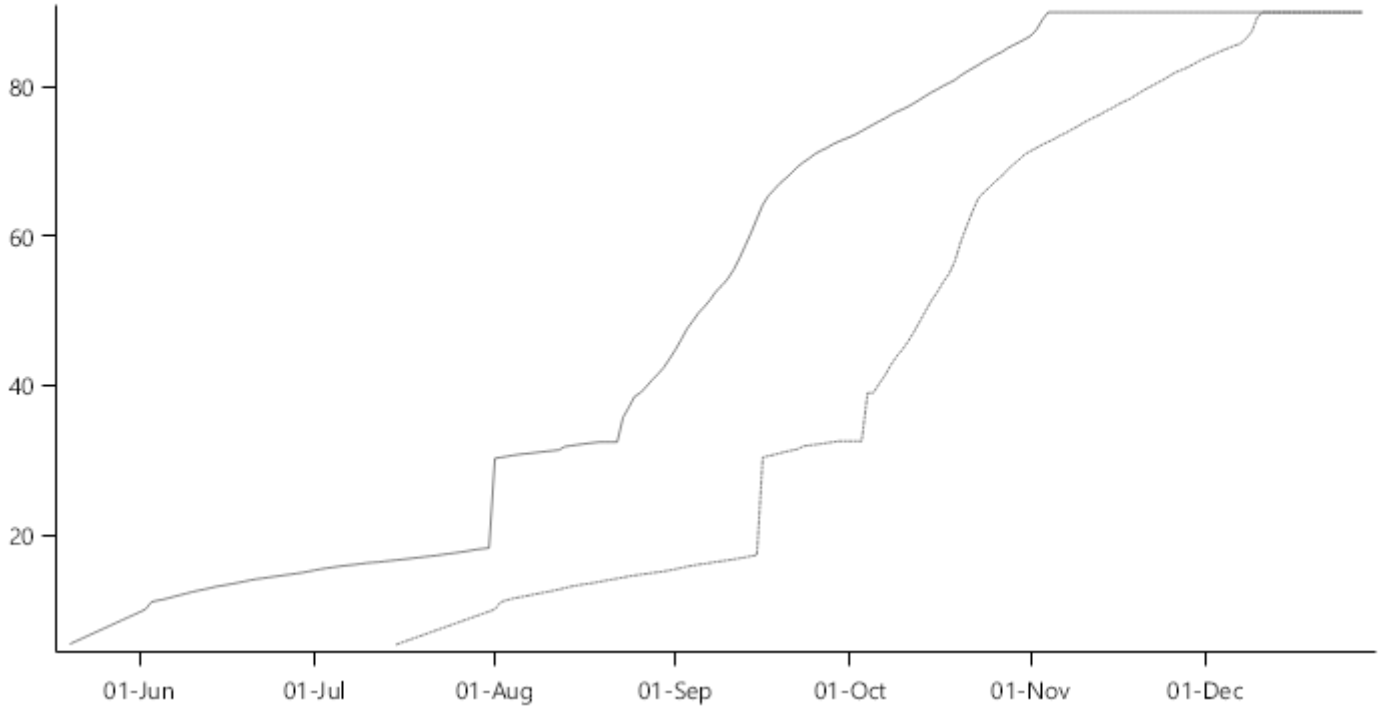
01-Jun
01-Jul
01-Aug
01-Sep
01-Oct
01-Nov
01-Dec

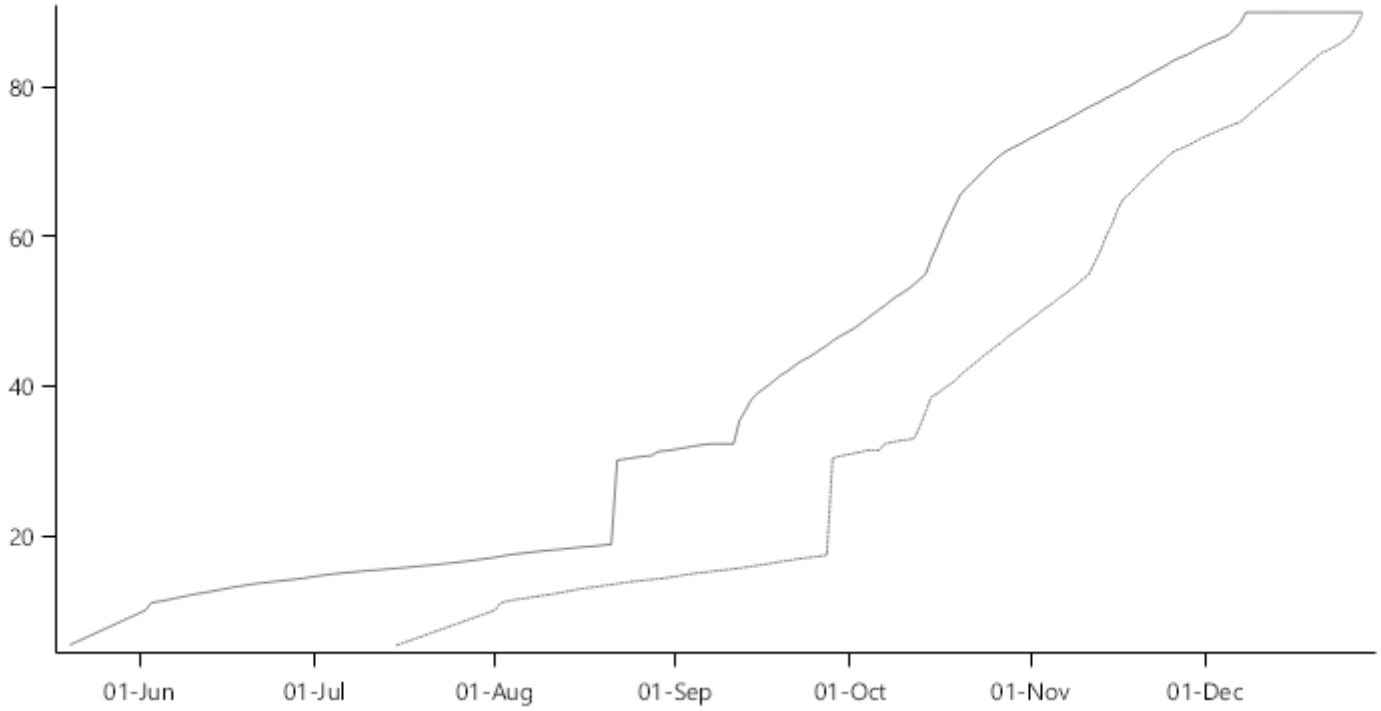
Bolac


80
60
40
20
01-Jun
01-Jul
01-Aug
01-Sep
01-Oct
01-Nov
01-Dec

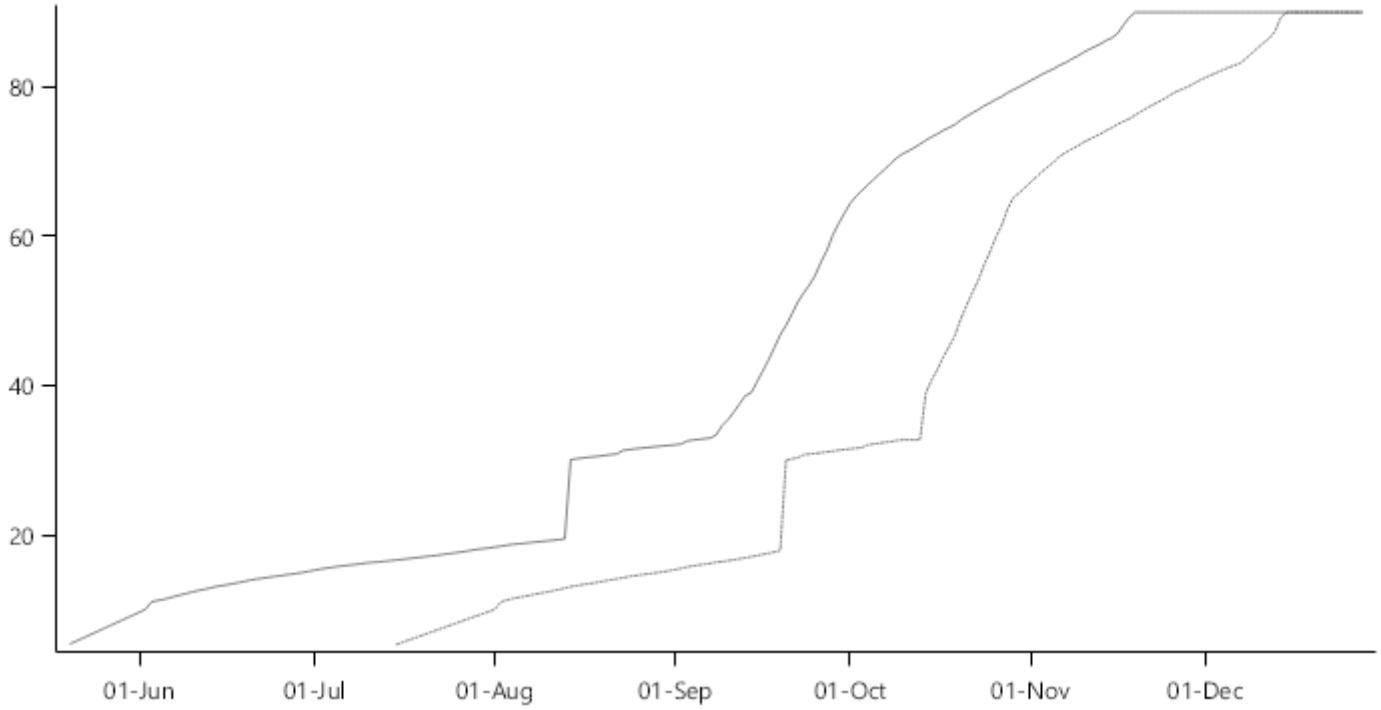
Derrimut



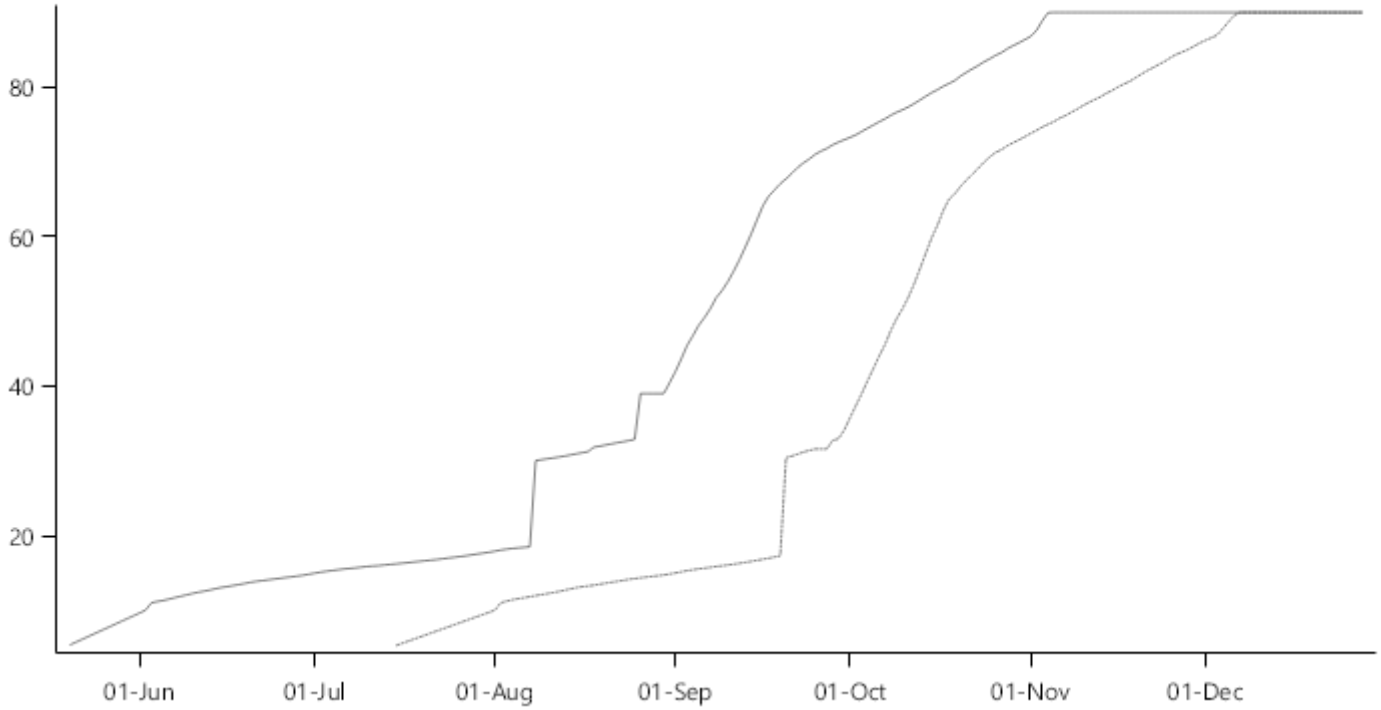
EagleHawk

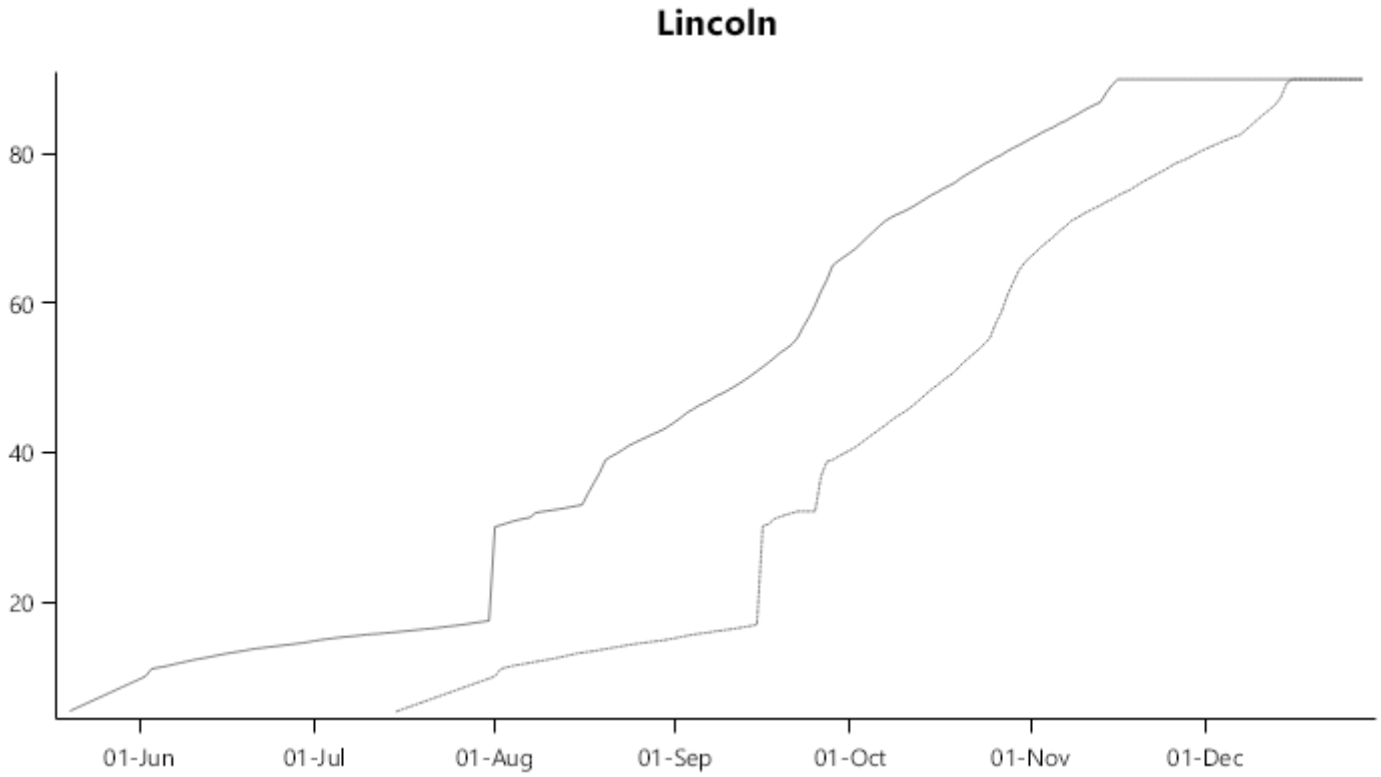


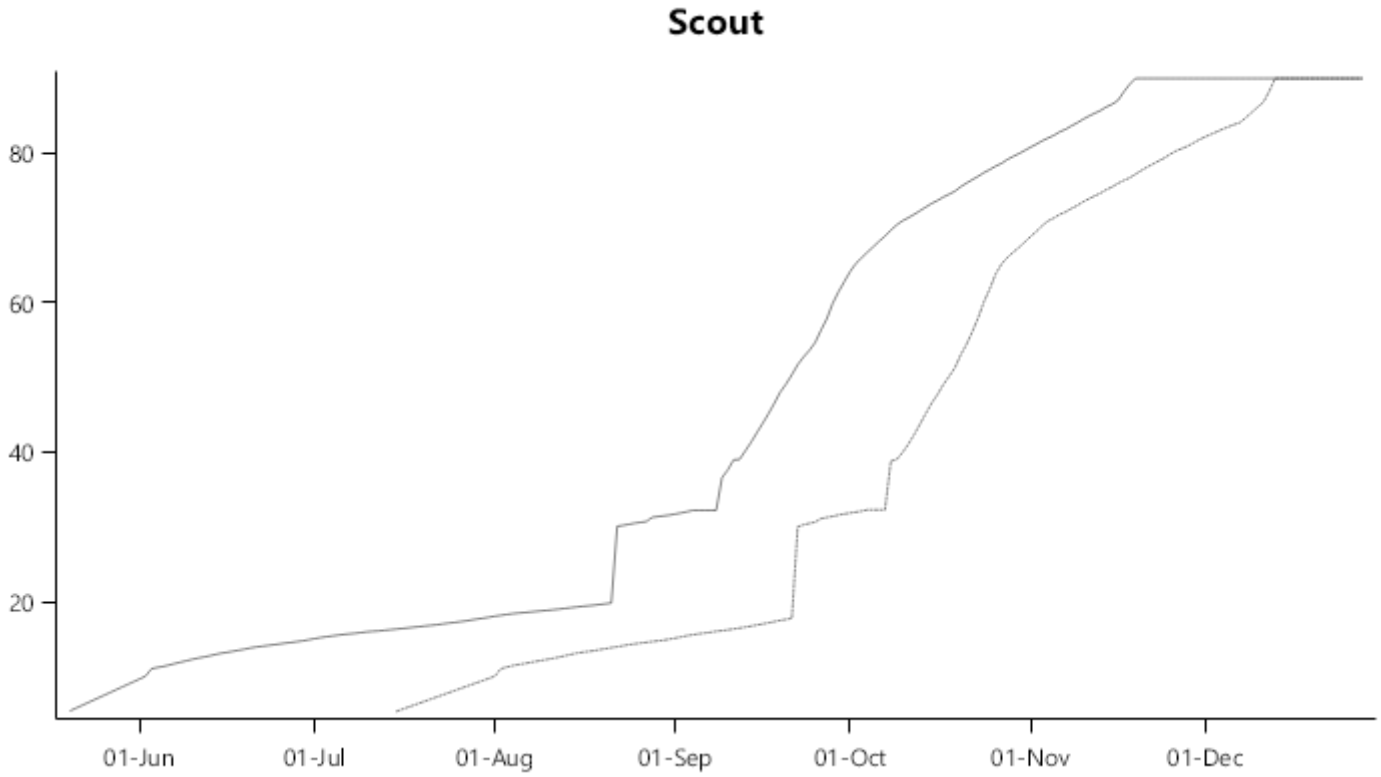
Gregory



Mace

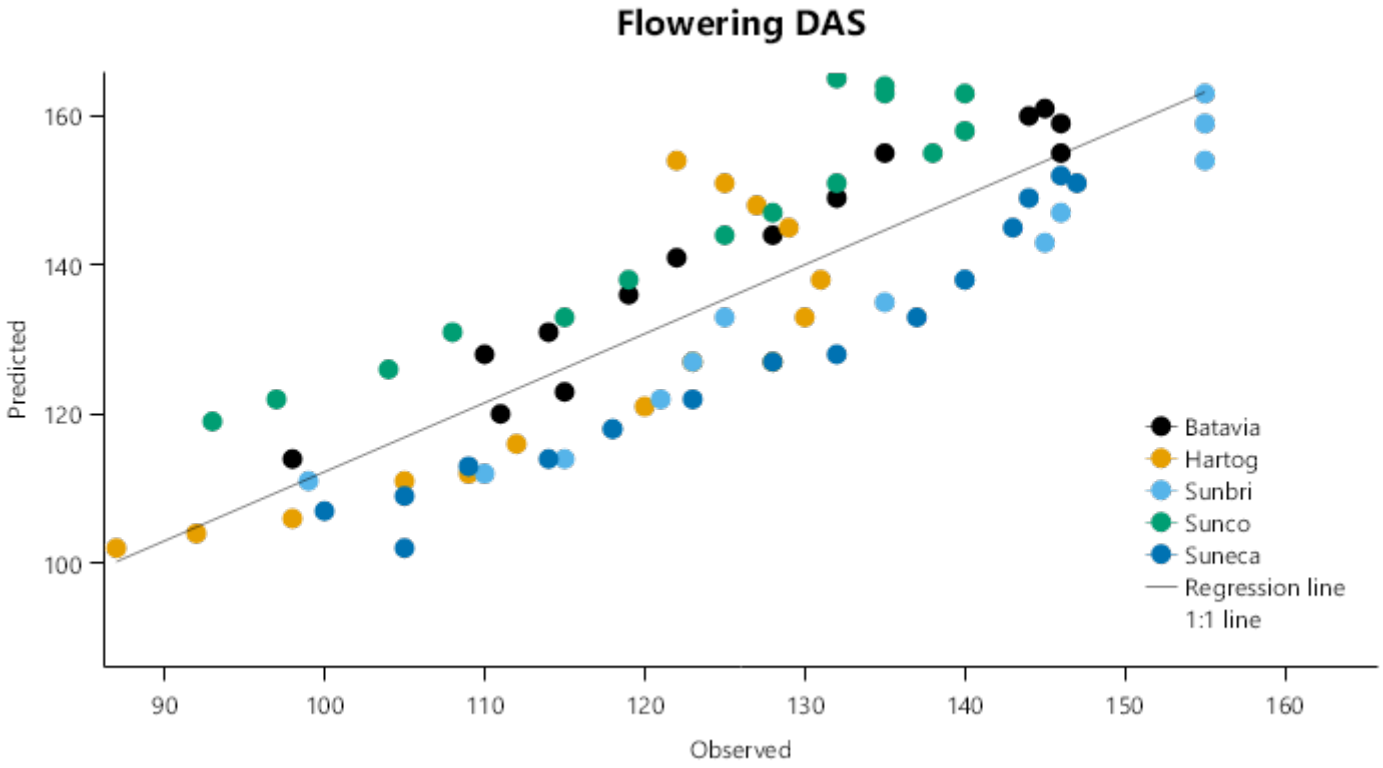


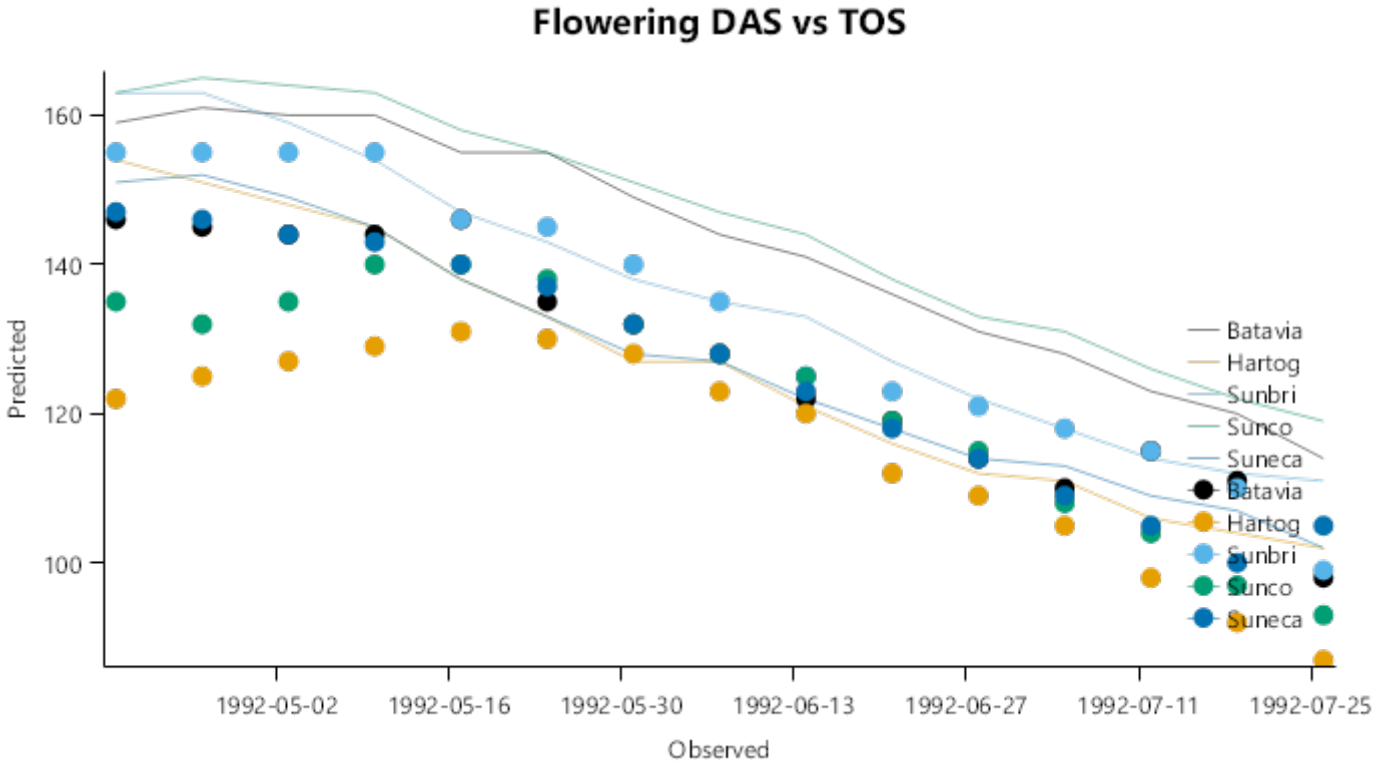




2.6.8 Tamworth1992

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





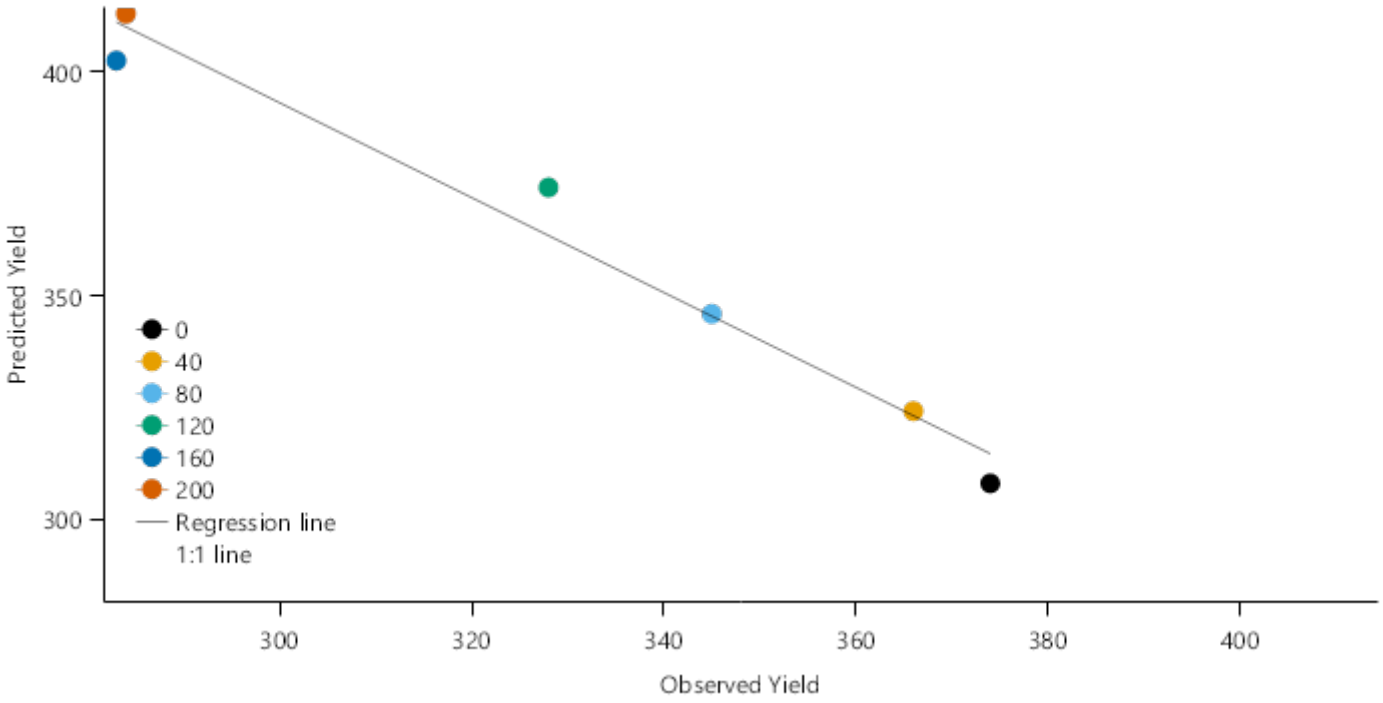
2.6.9 van Herwaarden et al 1998

List of experiments.

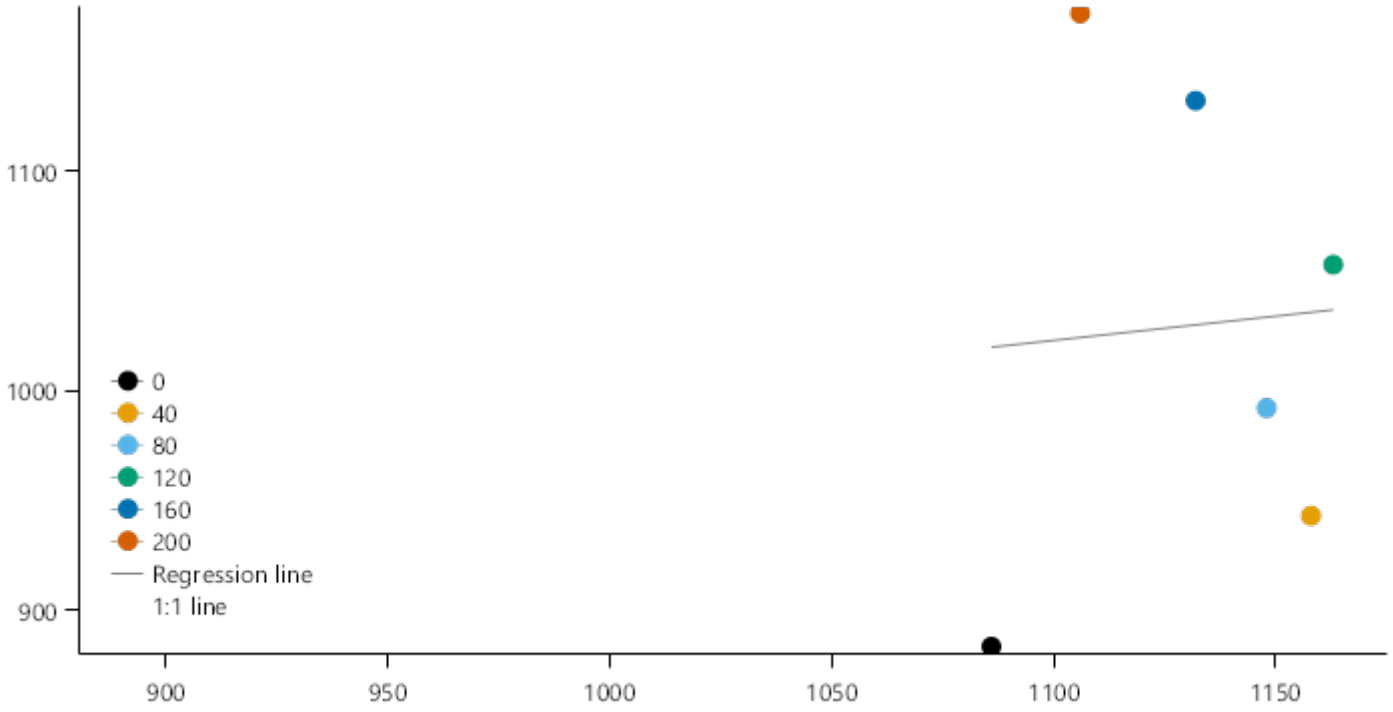
Experiment Name	Design (Number of Treatments)
Wagga1991	N (6)
Ginninderra1991	N x Cv (7)

2.6.9.1 Wagga1991

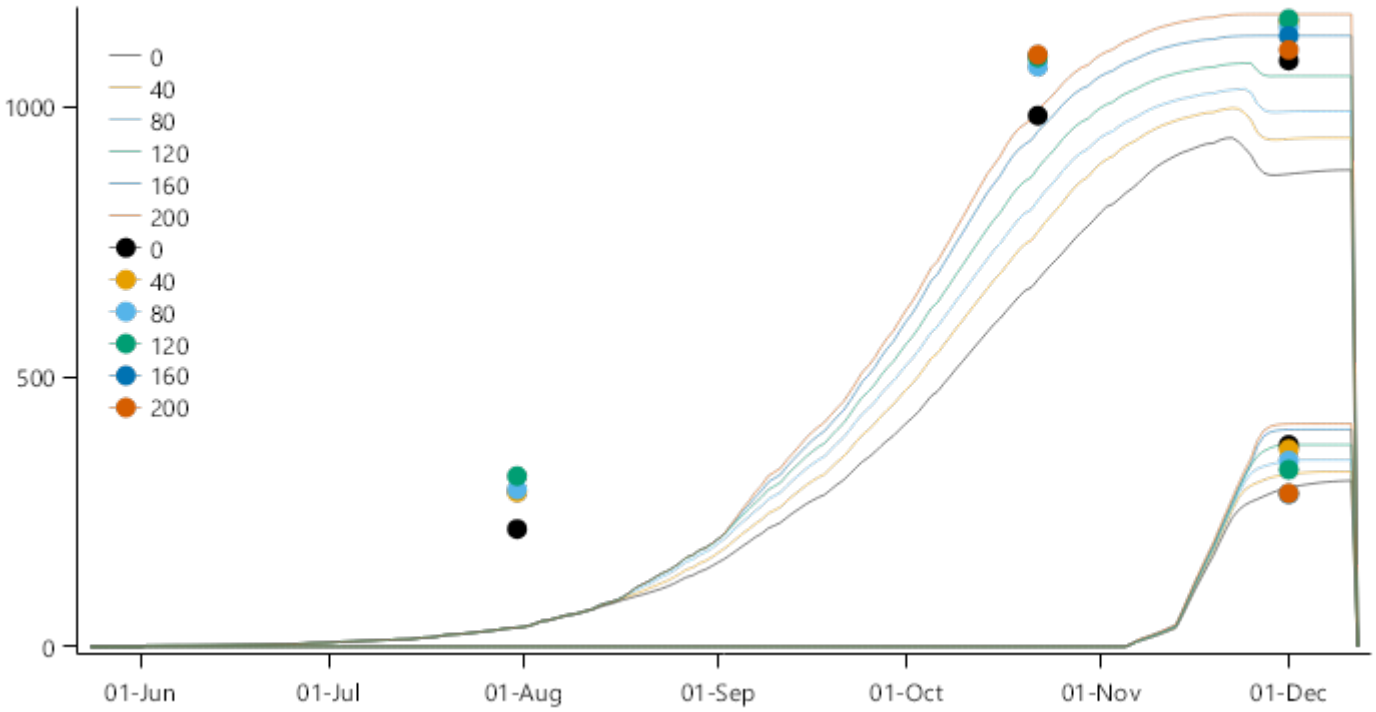
Yield



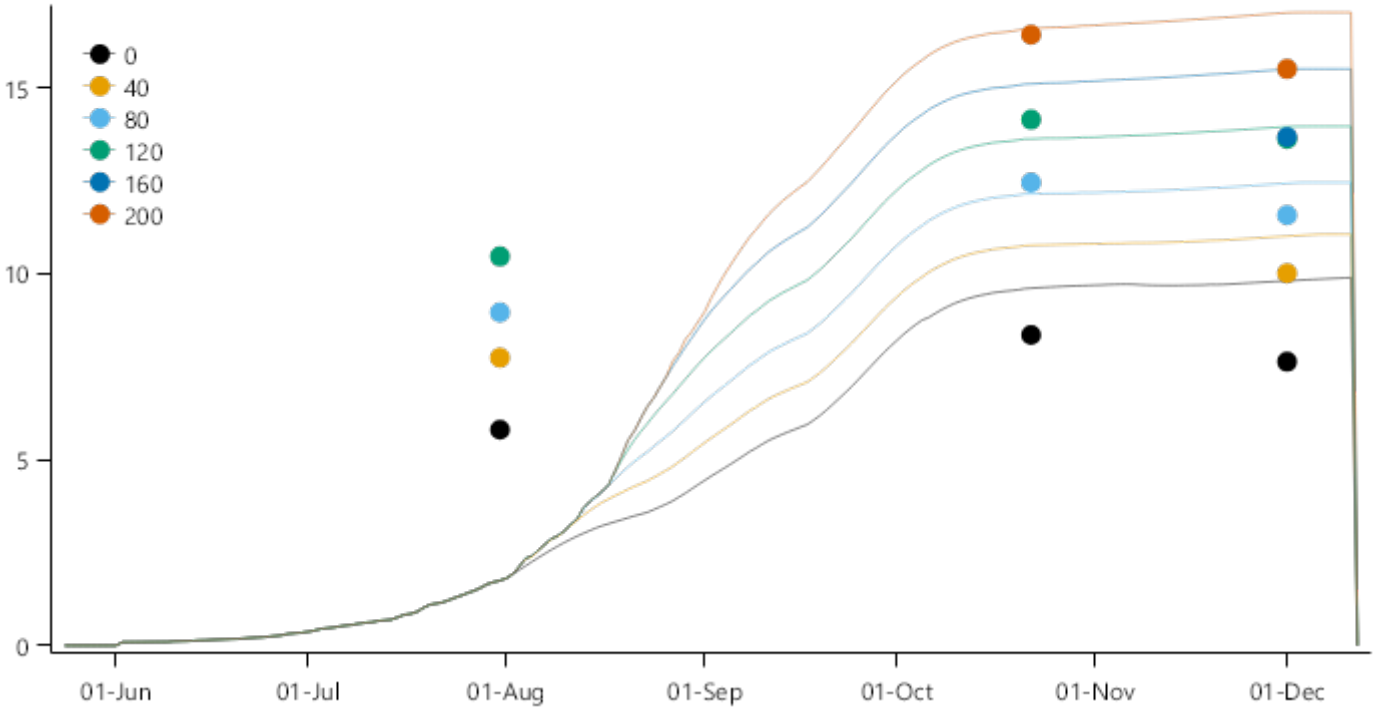
Biomass



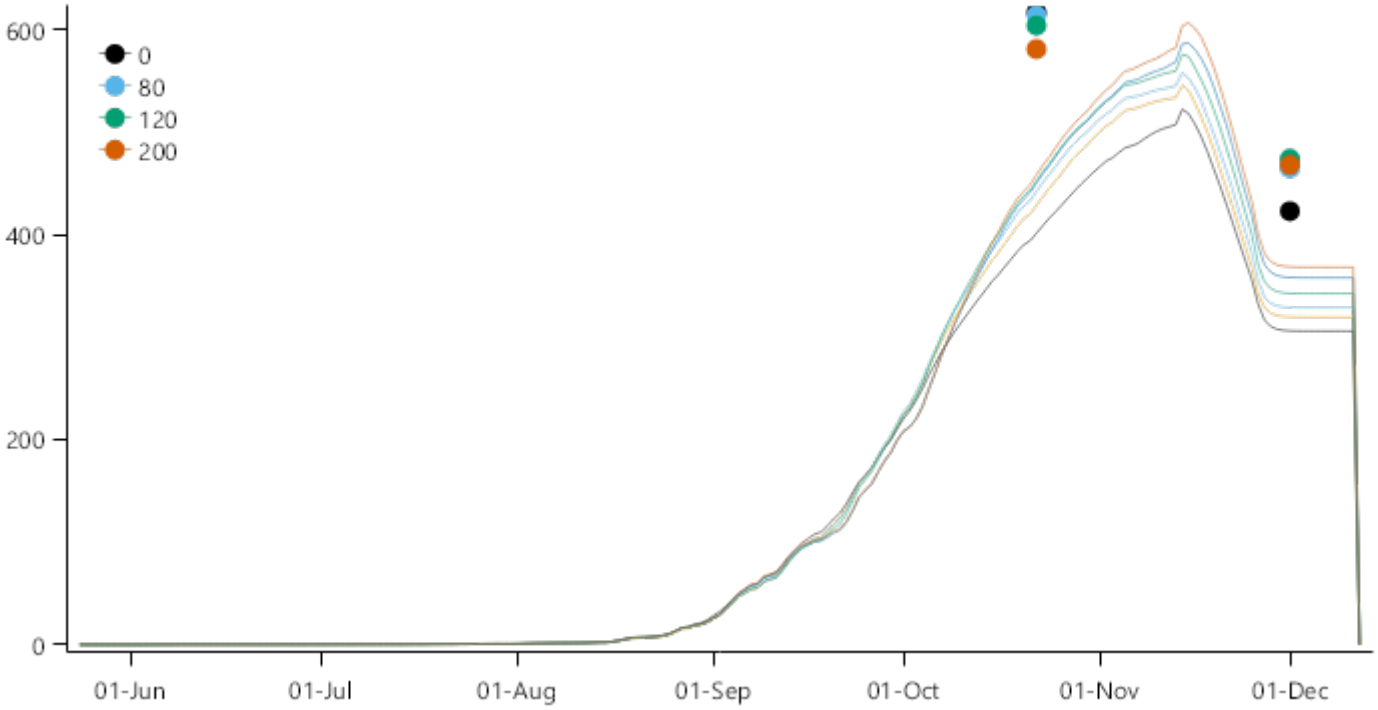
Biomass Timeseries



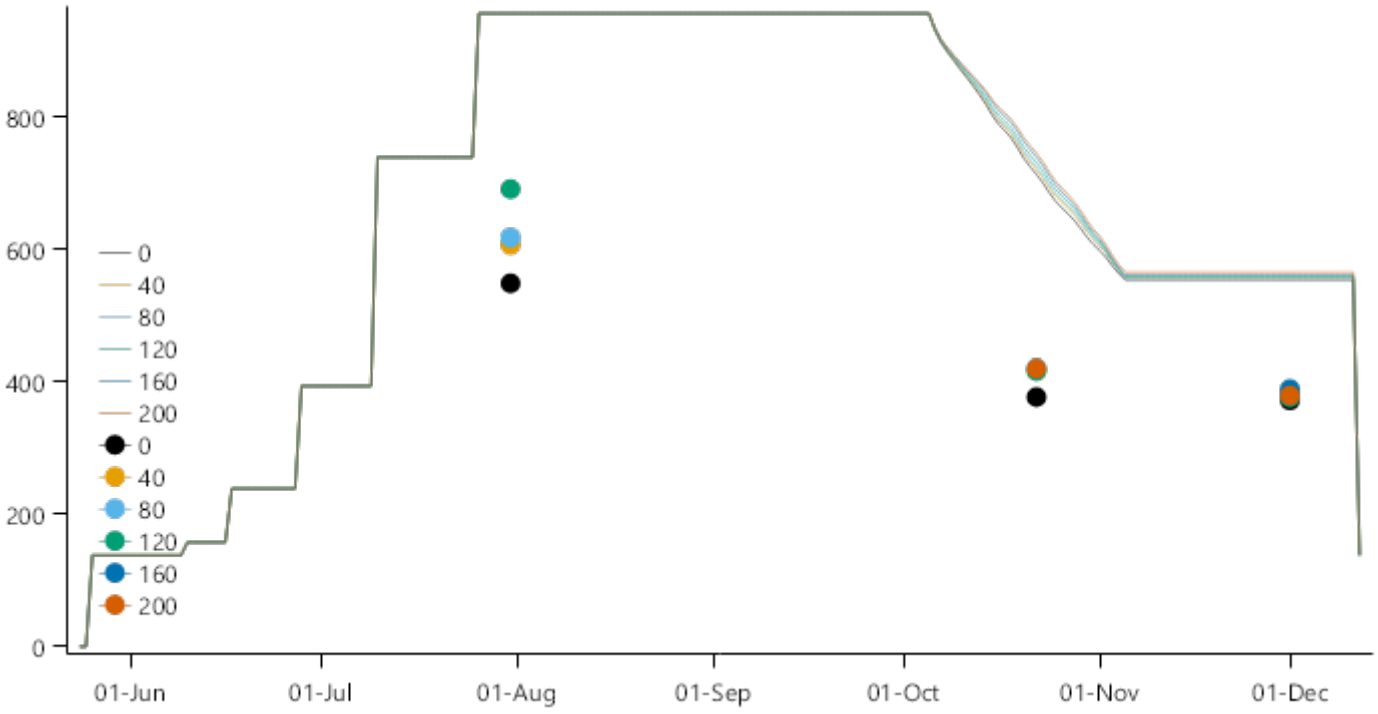
N Uptake Timeseries



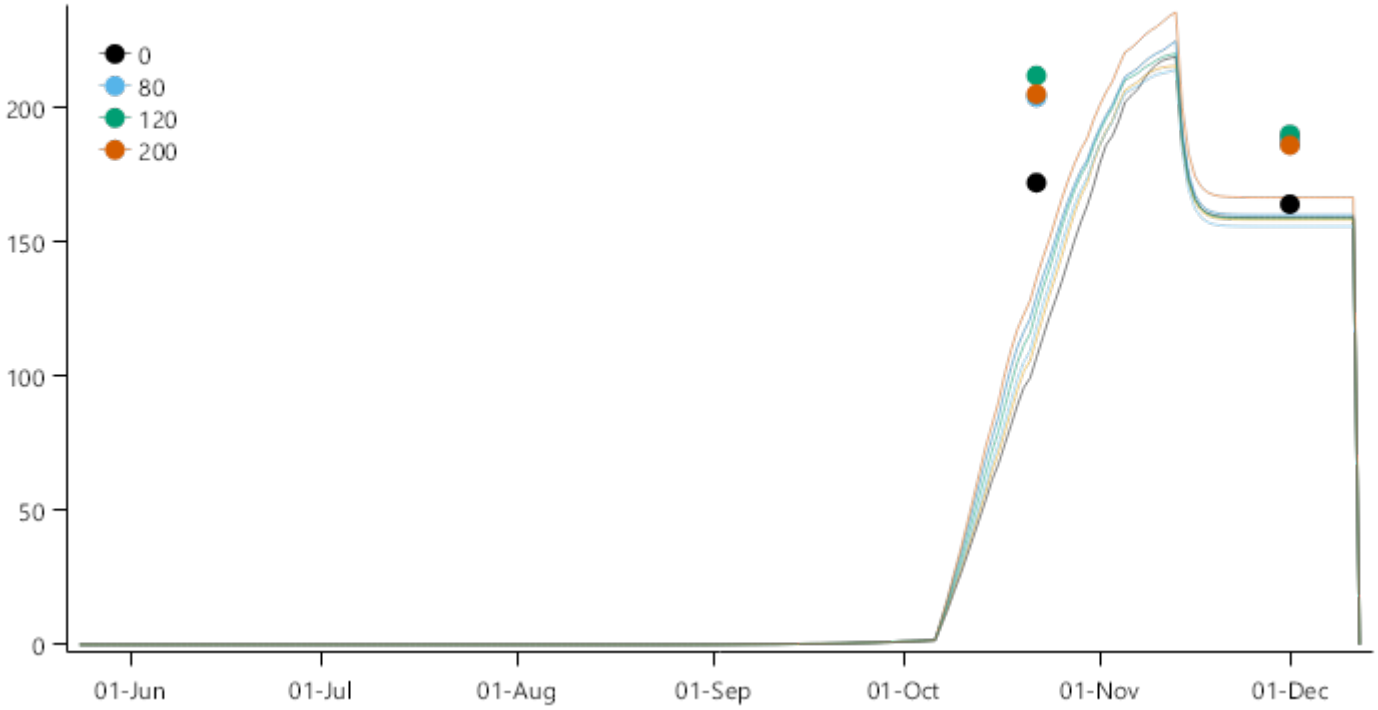
StemWt Timeseries



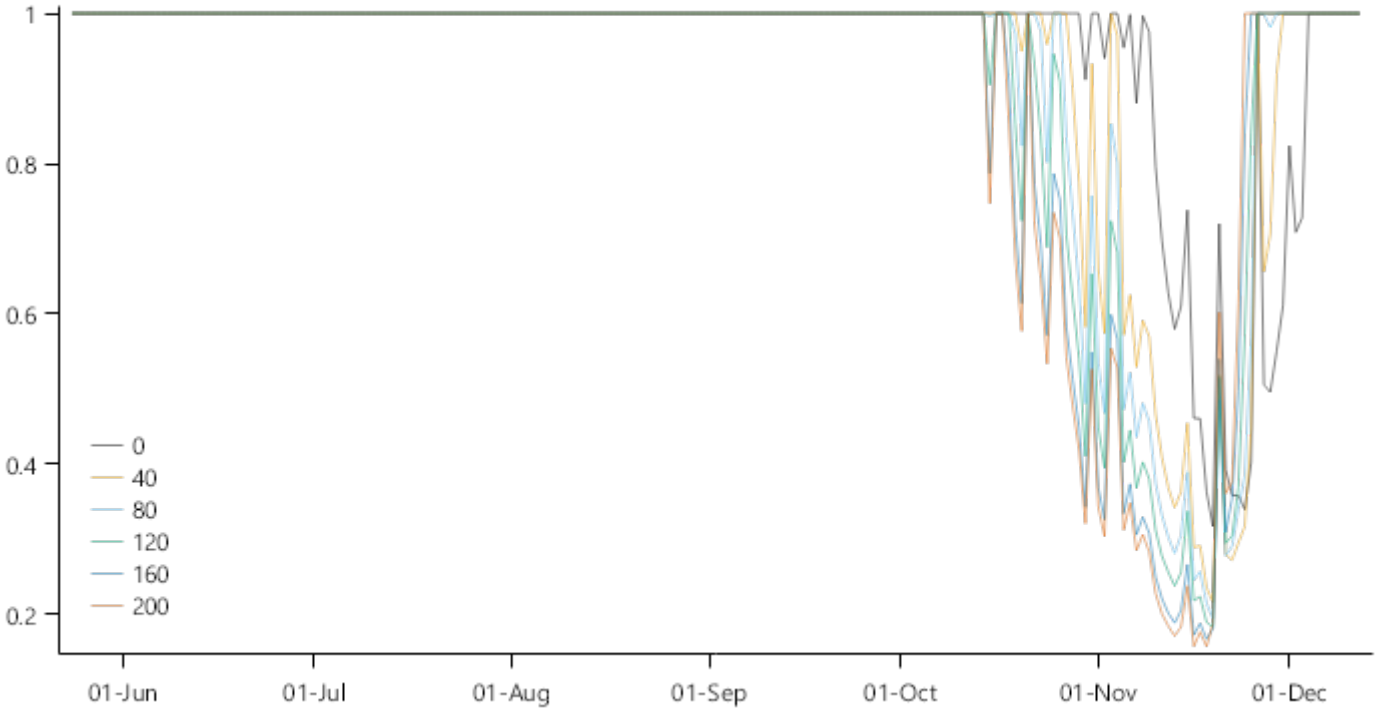
Stem Number Timeseries



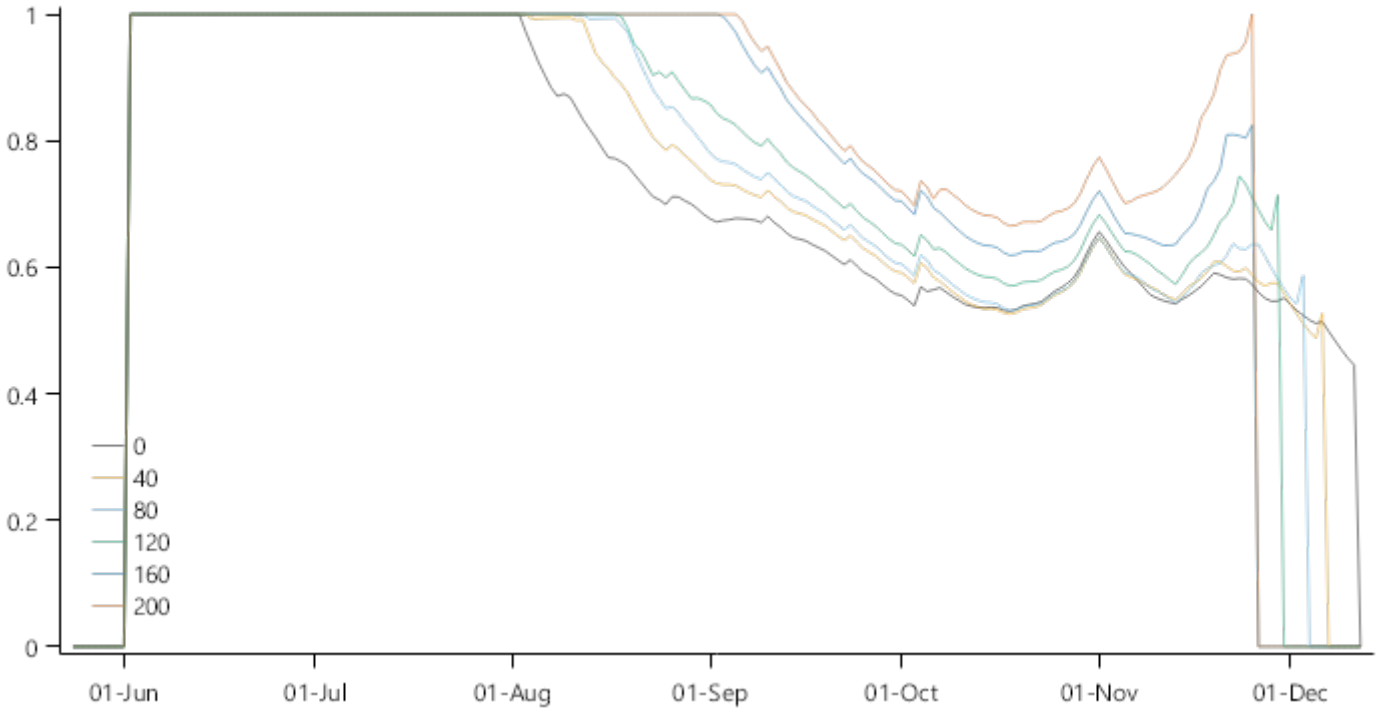
SpikeWt Timeseries



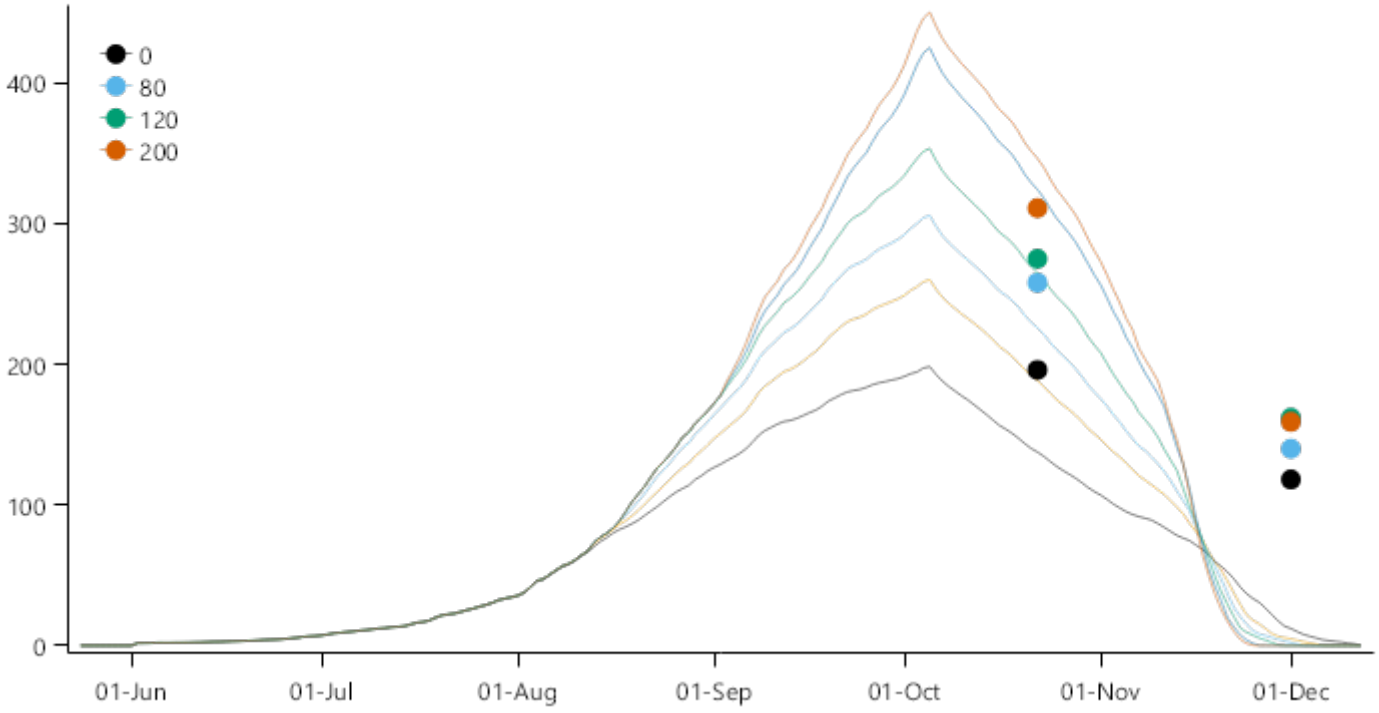
Water Stress

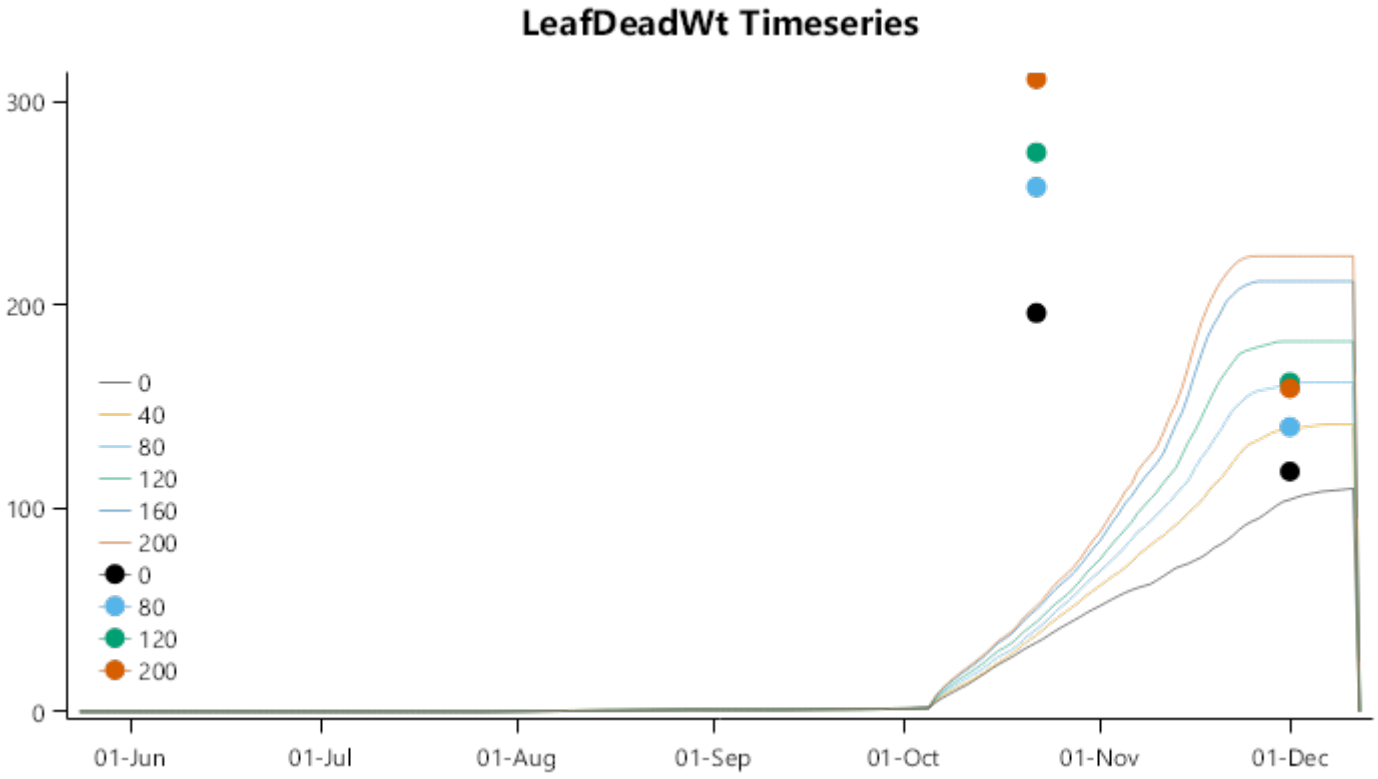


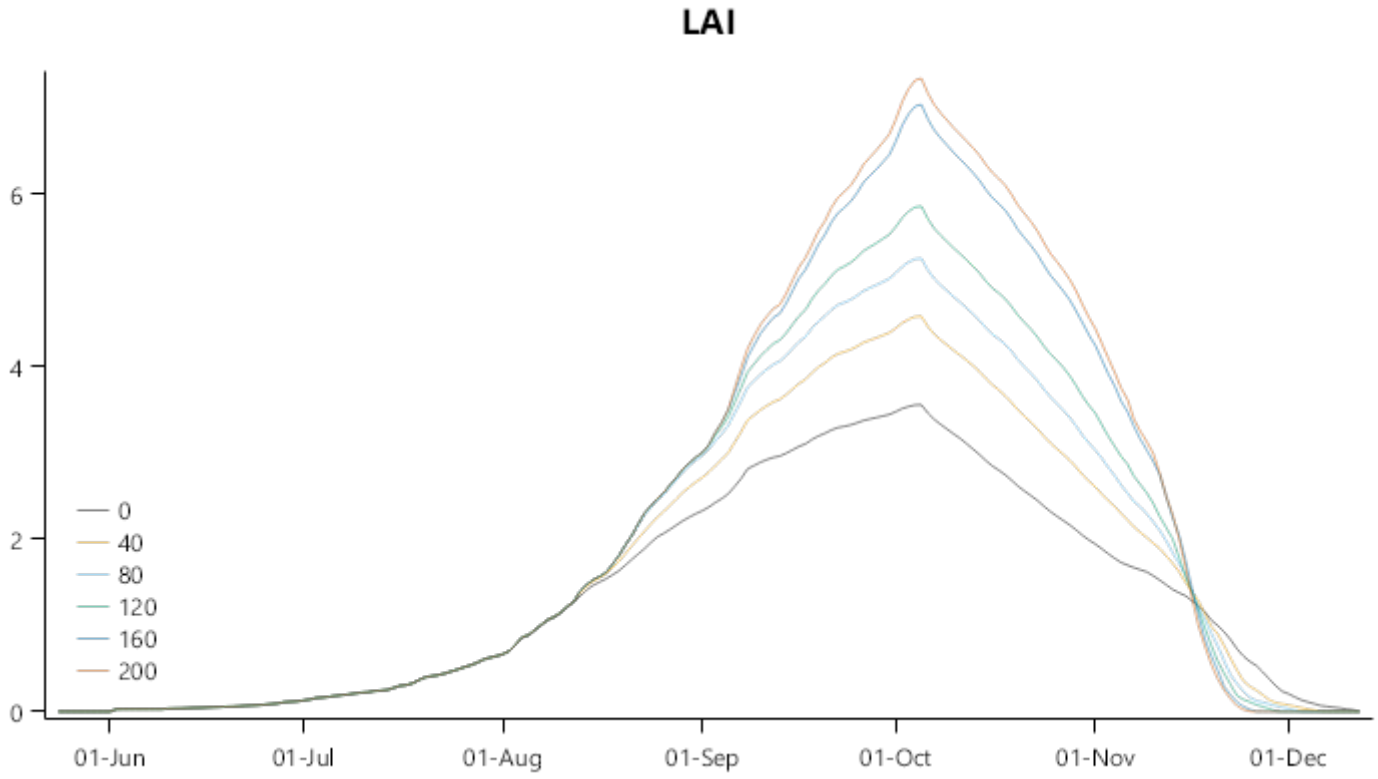
N Stress



LeafWt Timeseries

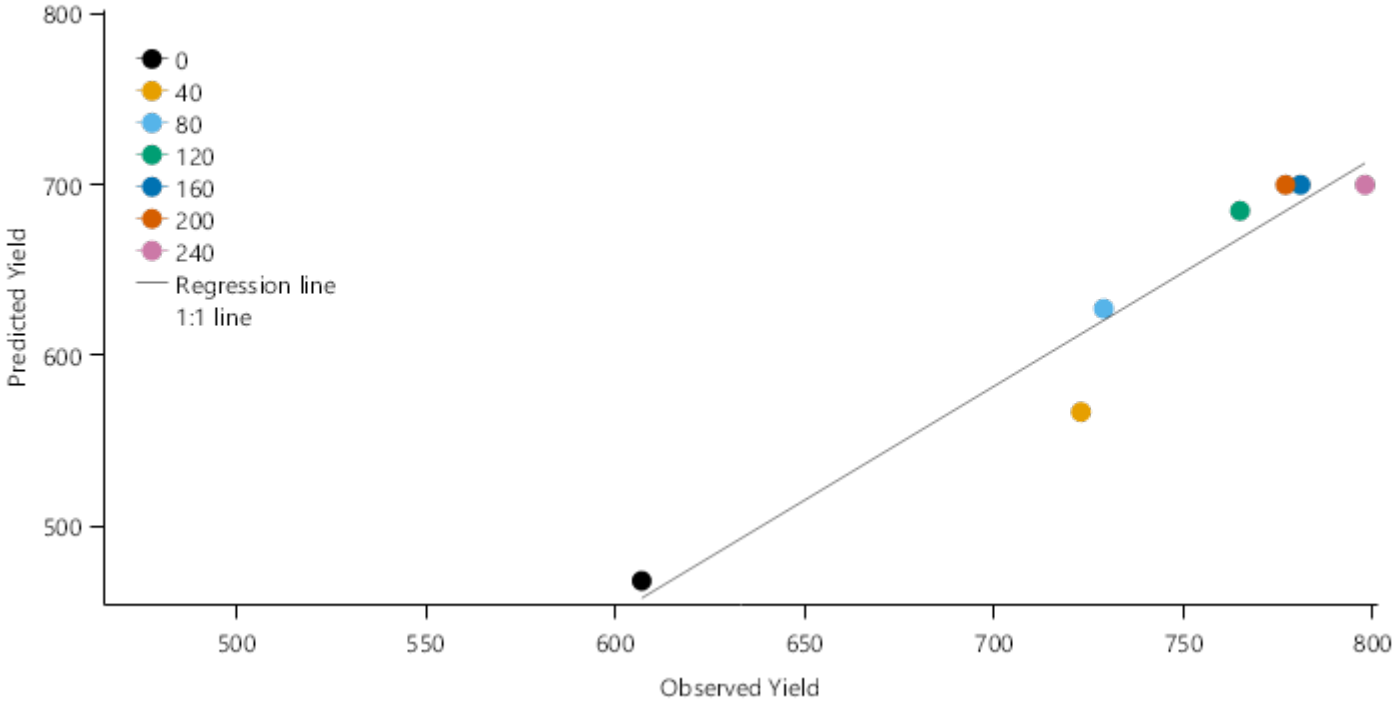




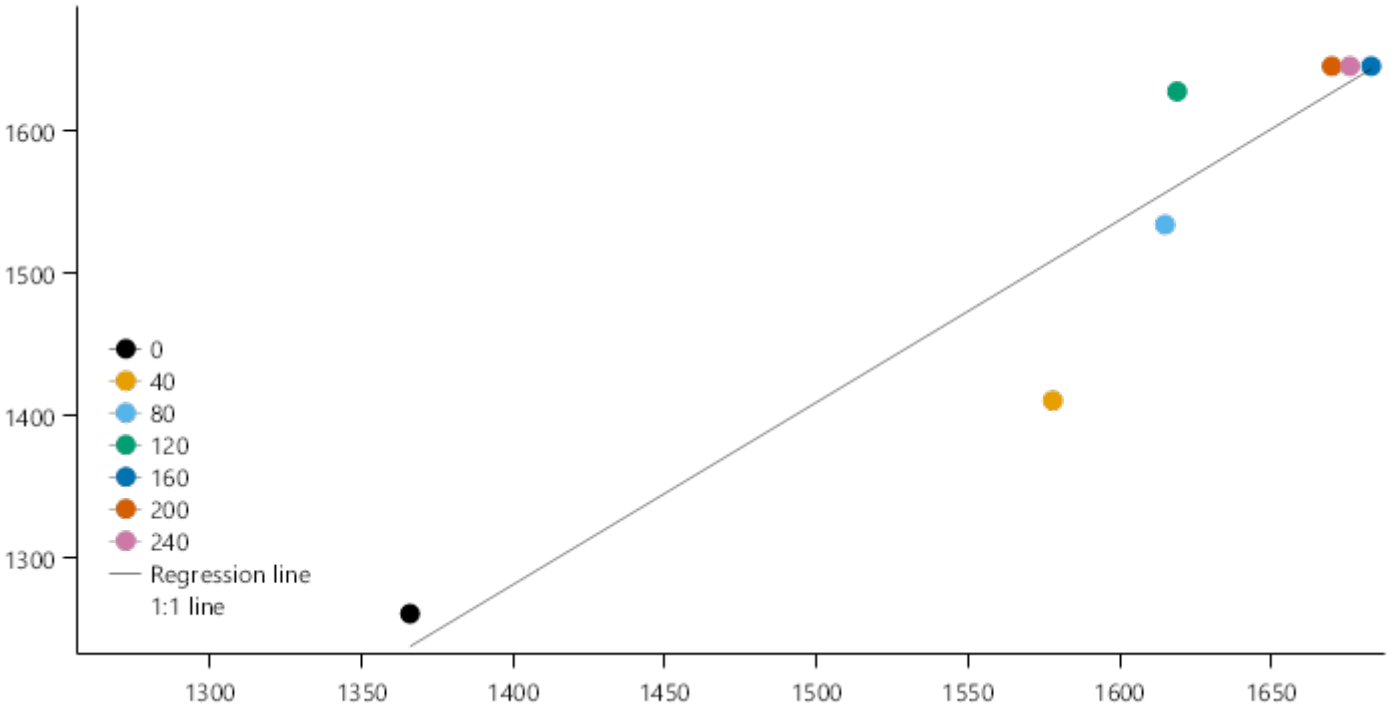


2.6.9.2 Ginninderra1991

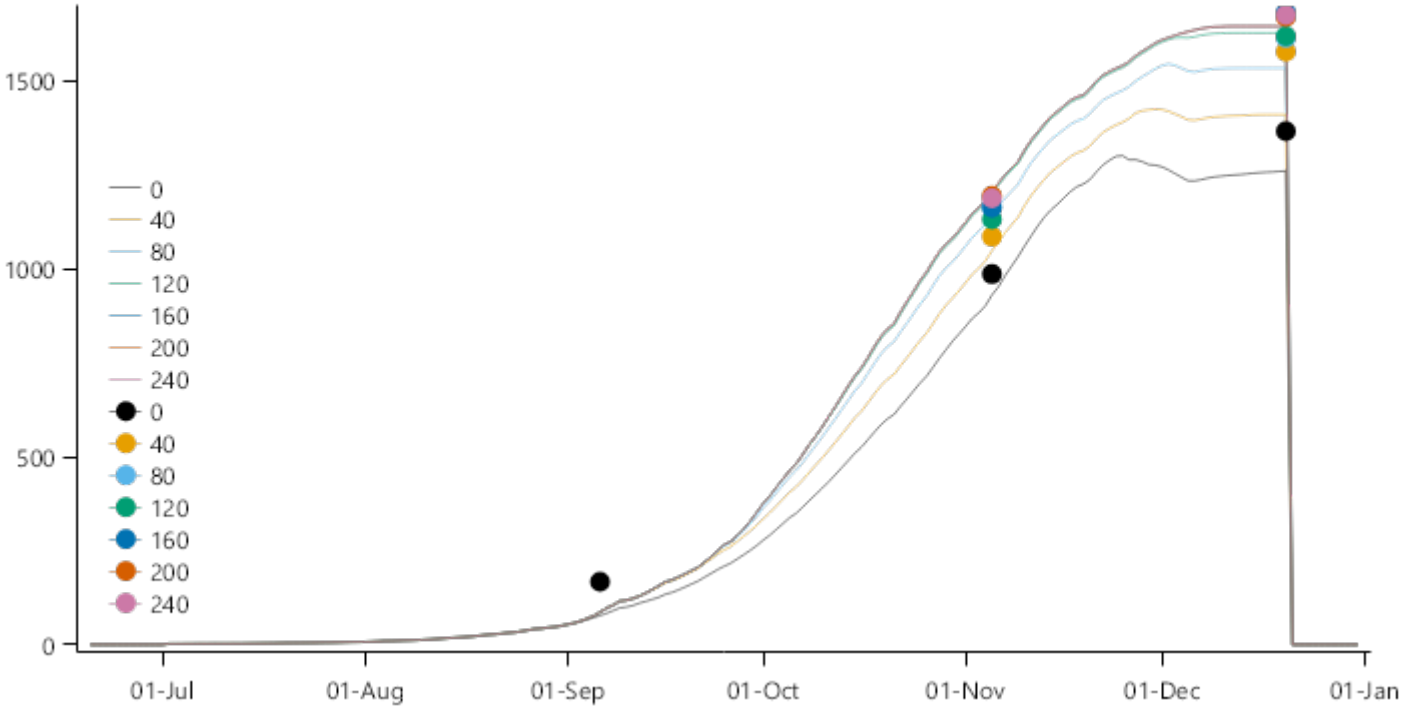
Yield



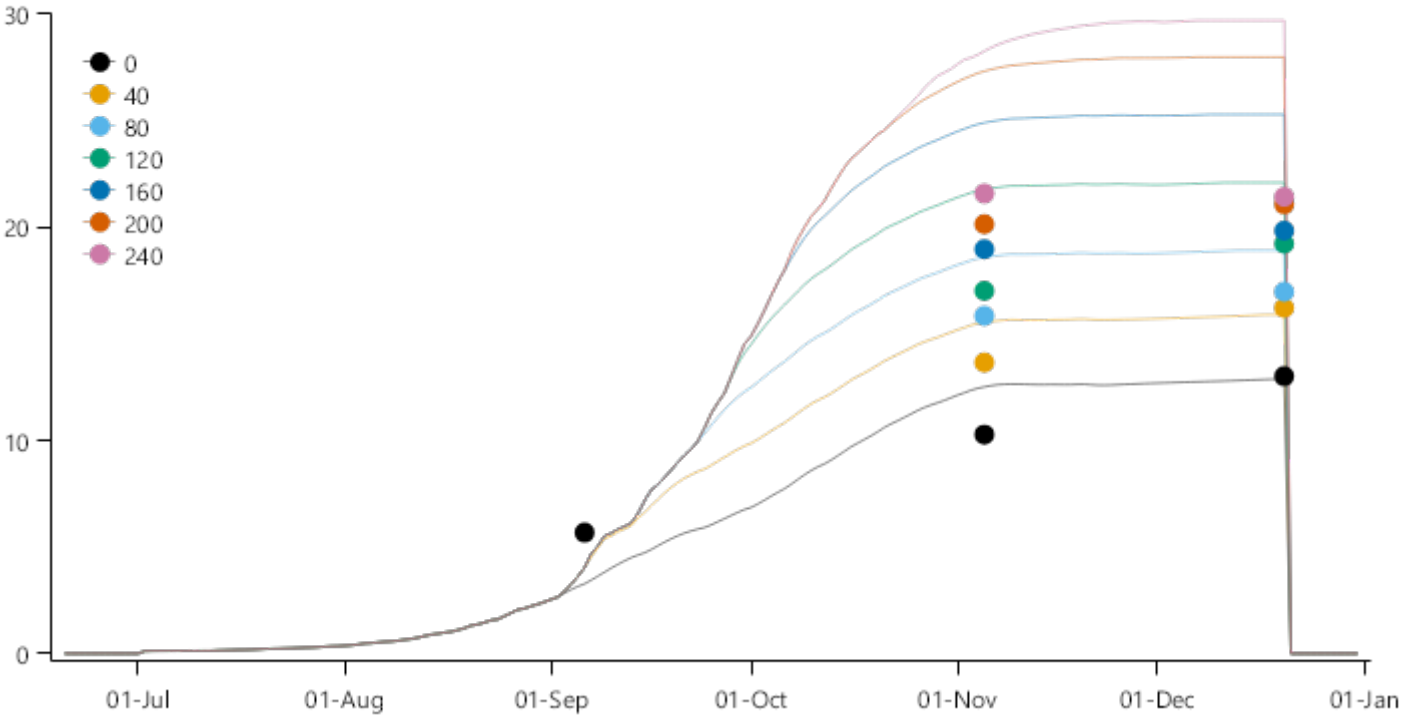
Biomass



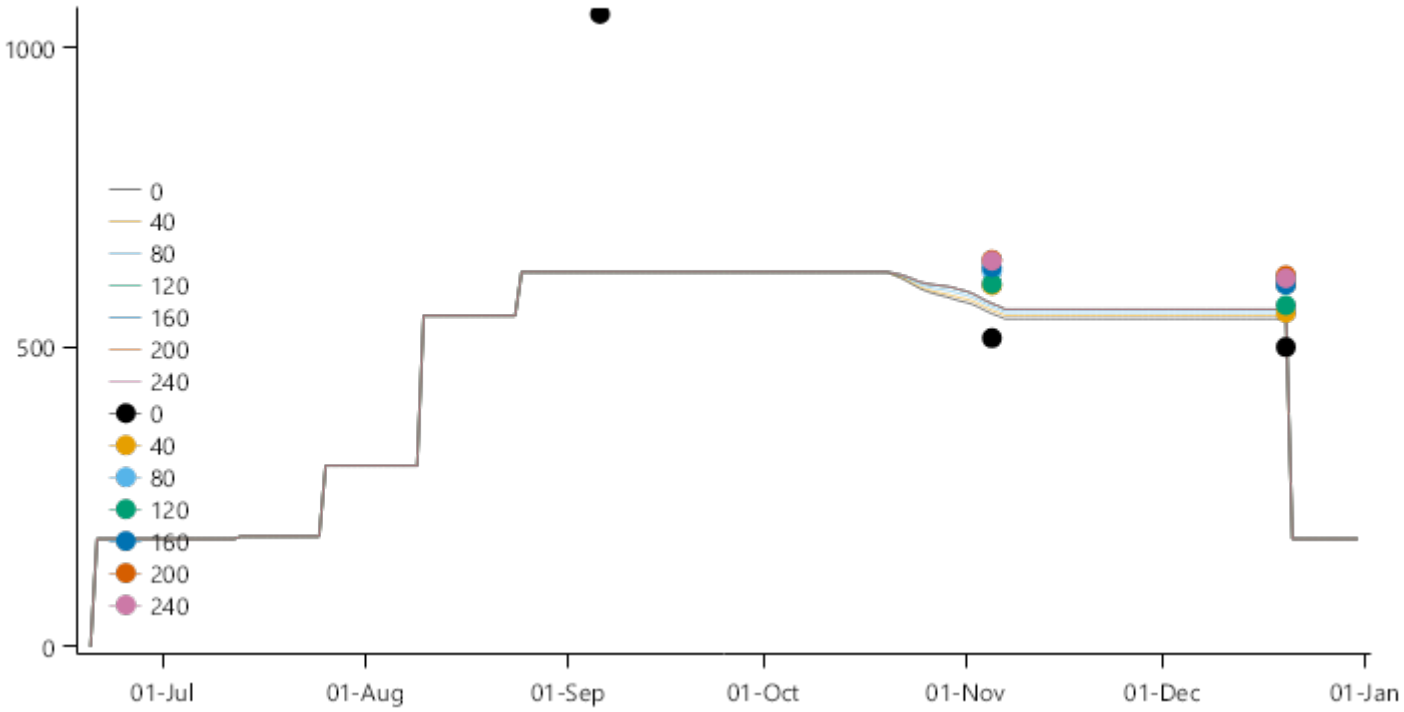
Biomass Timeseries



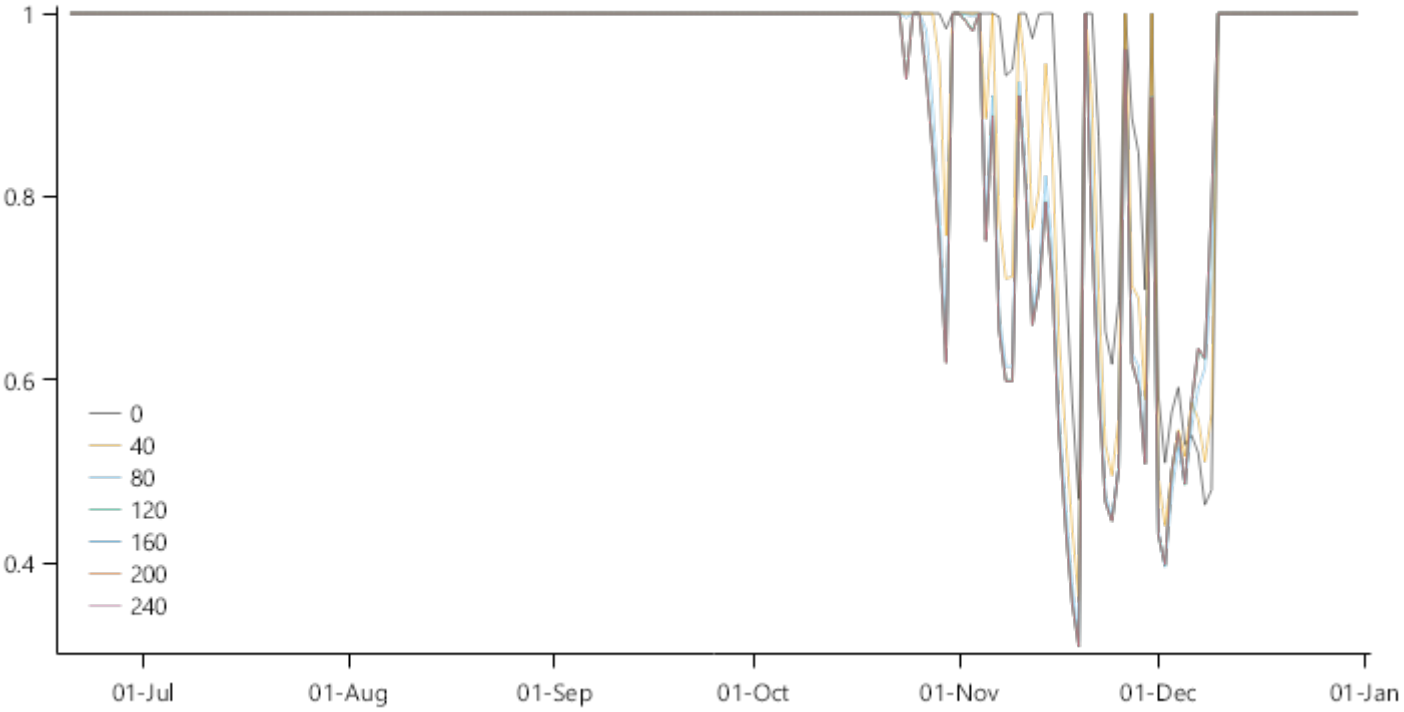
N Uptake Timeseries



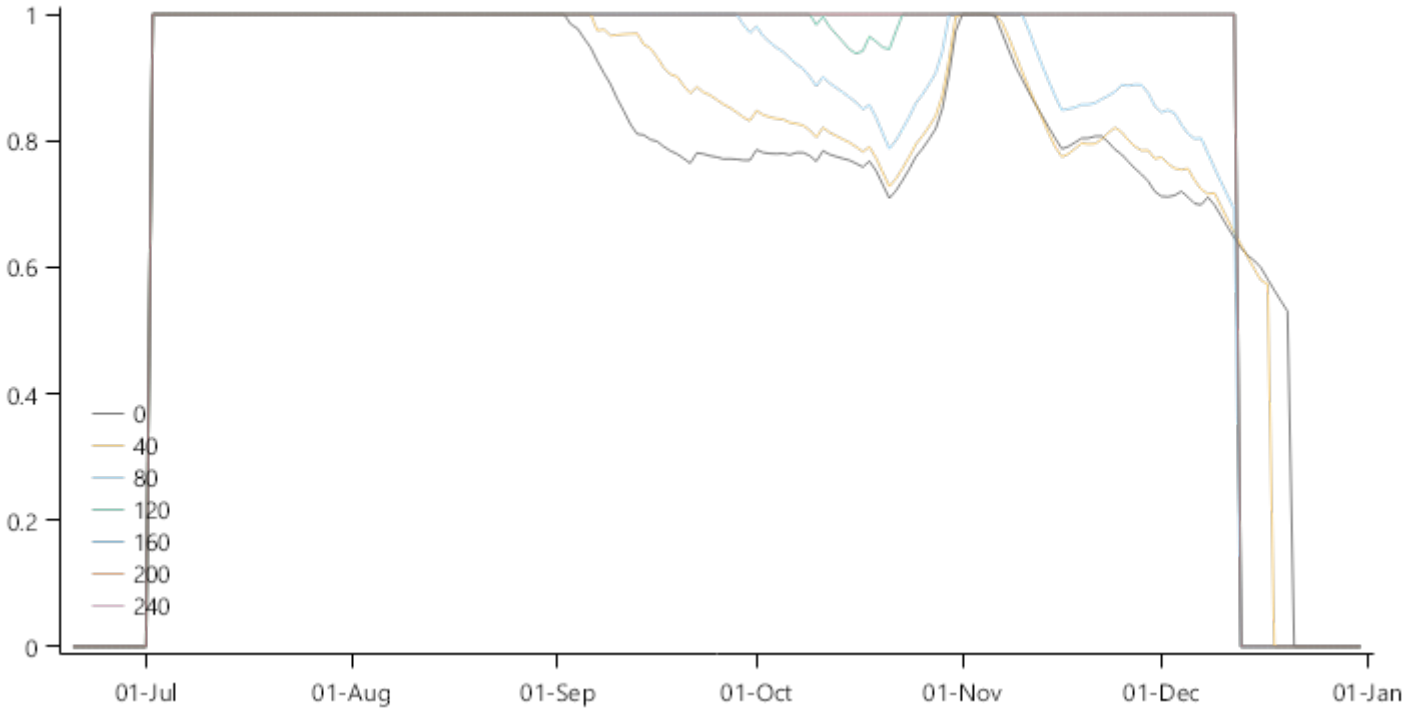
Stem Number Timeseries



Water Stress



N Stress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0.2
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200
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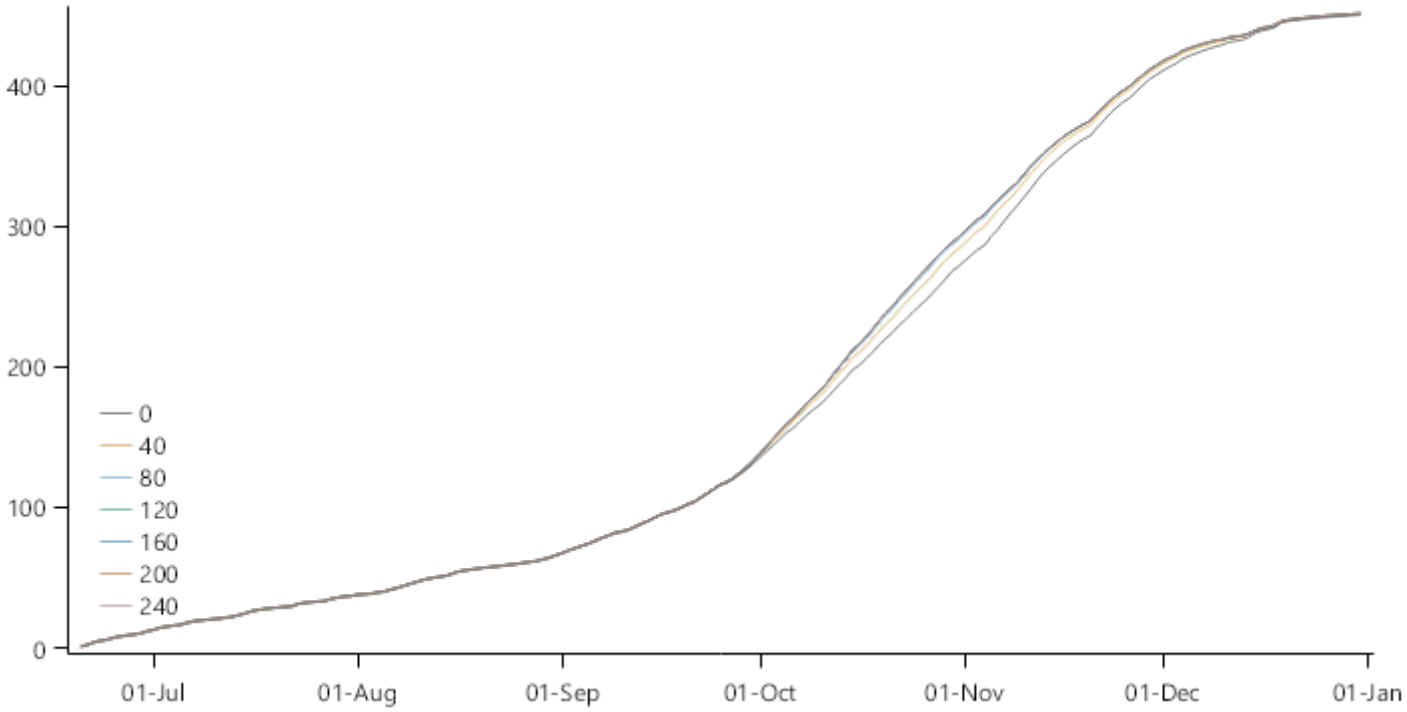
01-Jul
01-Aug
01-Sep
01-Oct
01-Nov
01-Dec
01-Jan

ET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01-Jul
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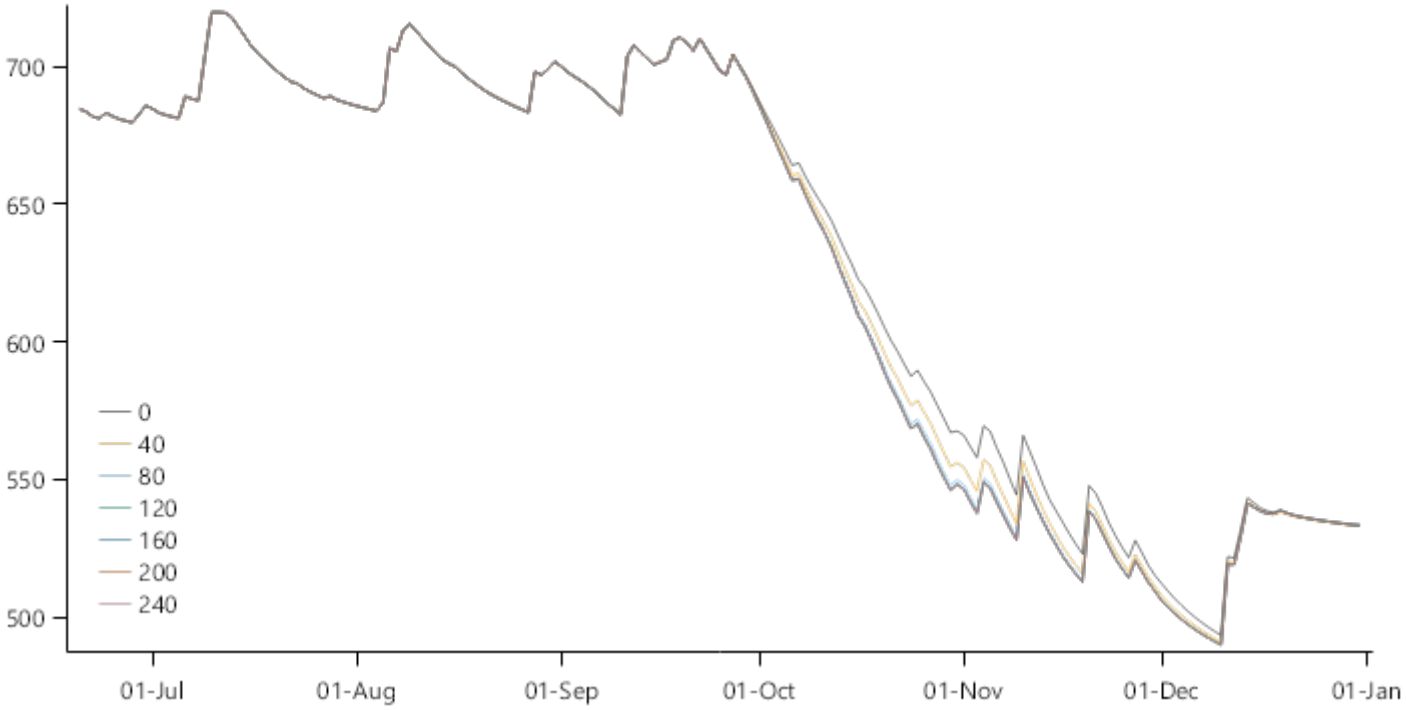
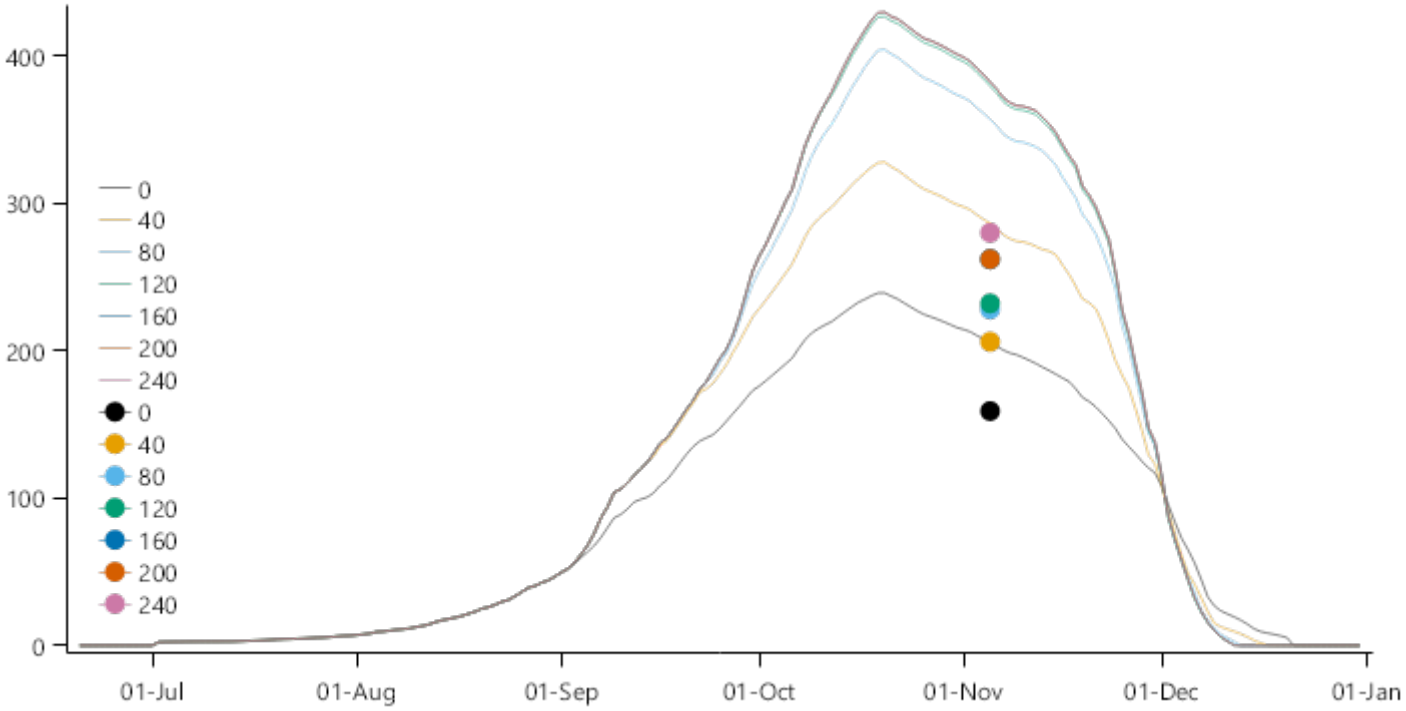
01-Jan

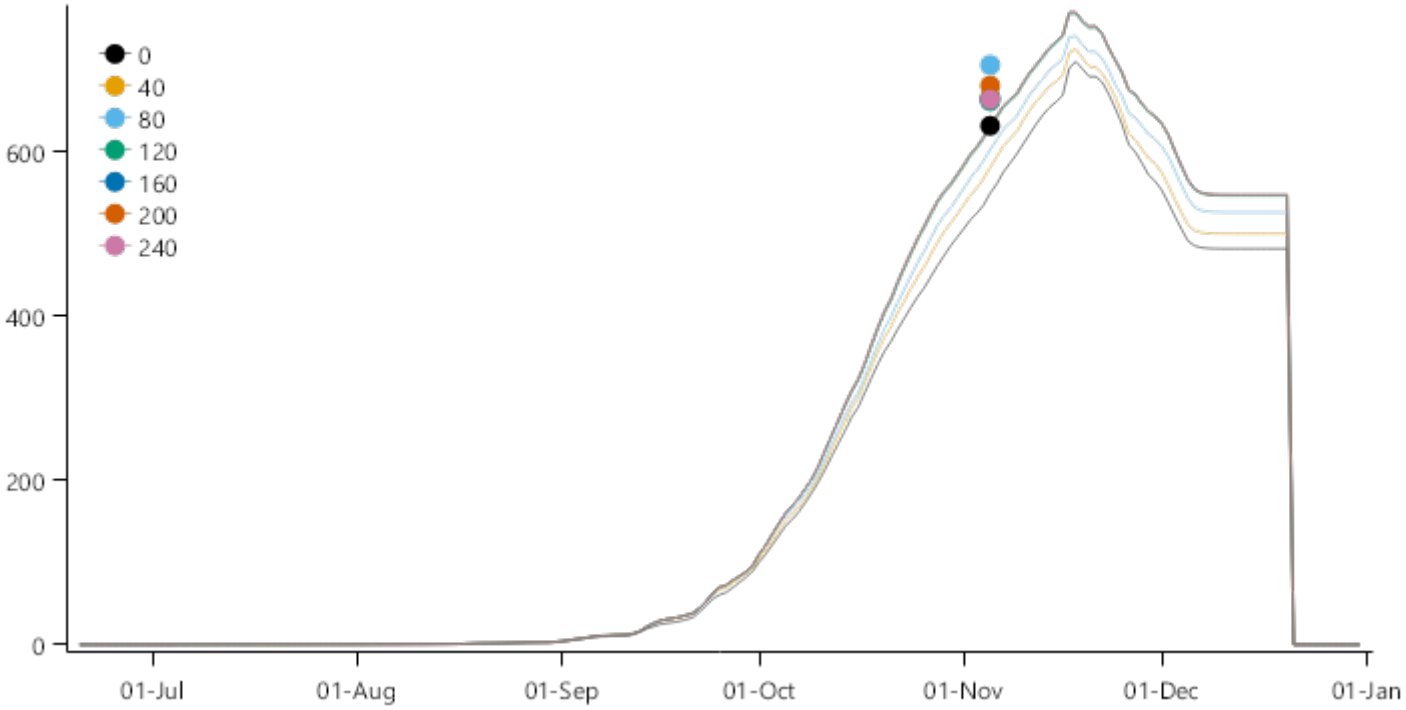
Profile Water



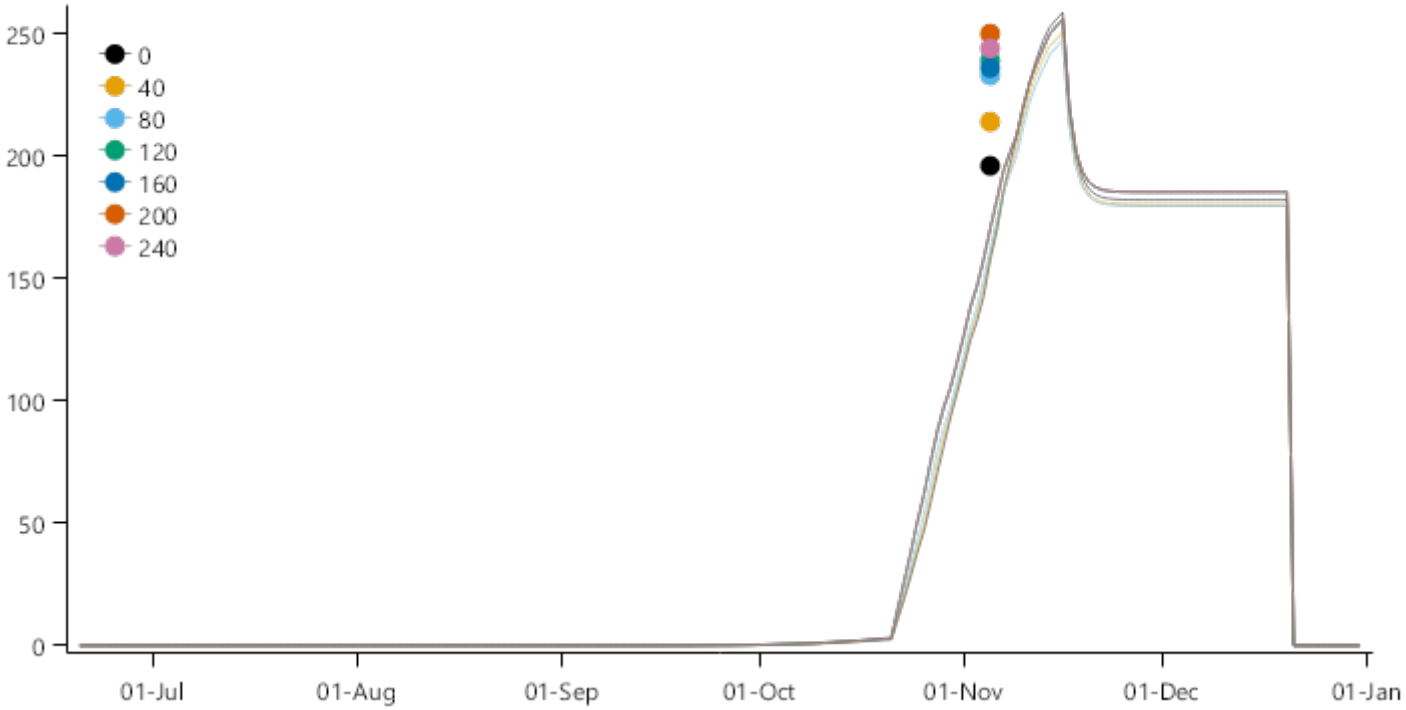
LeafWt Timeseries

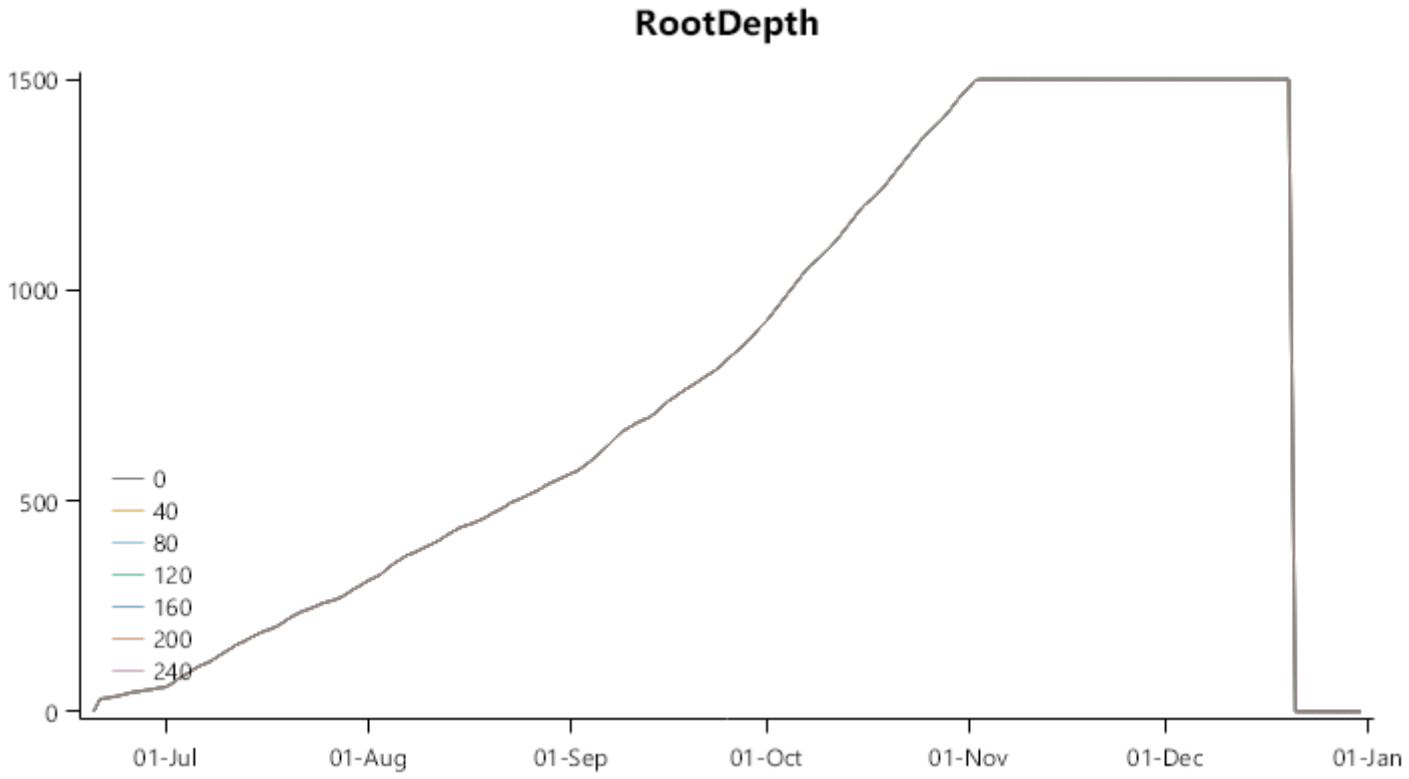


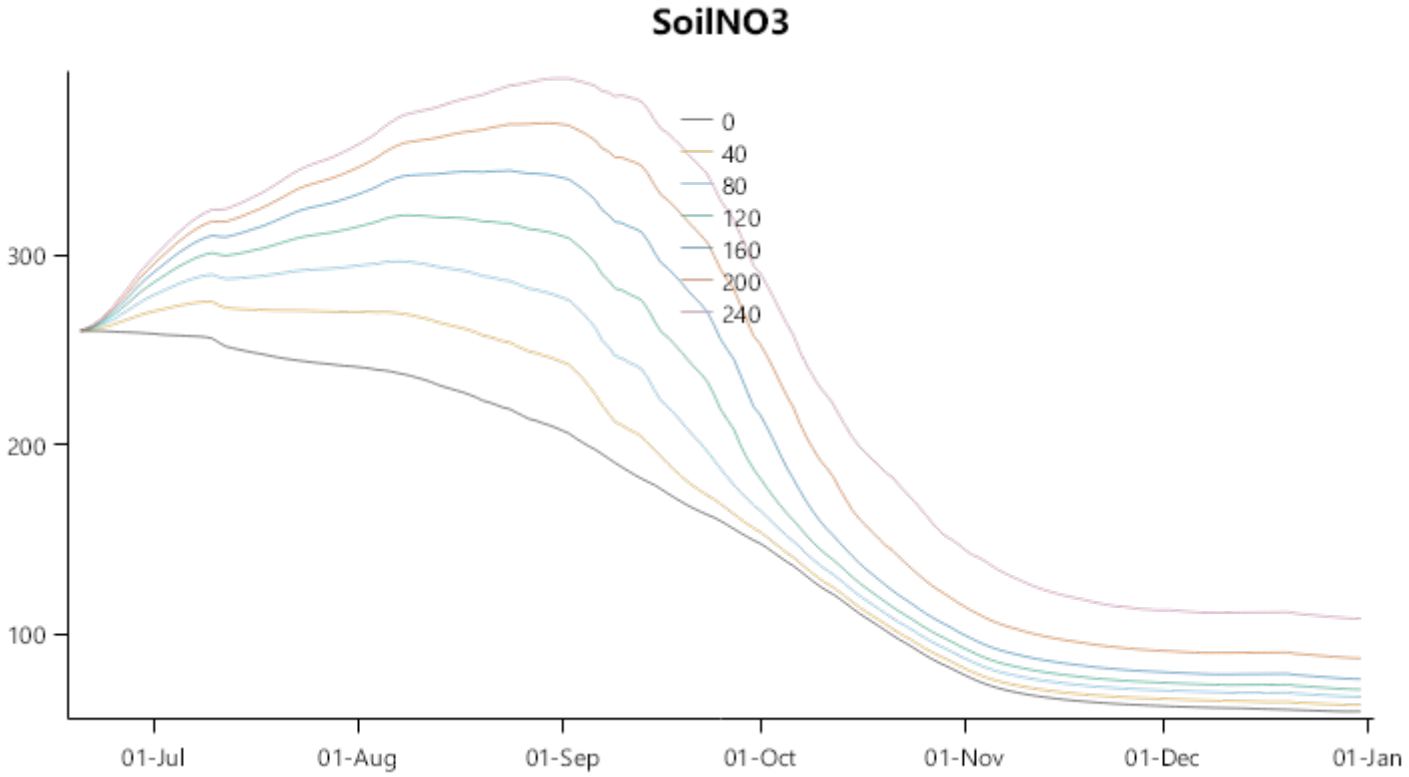
StemWt Timeseries



SpikeWt Timeseries







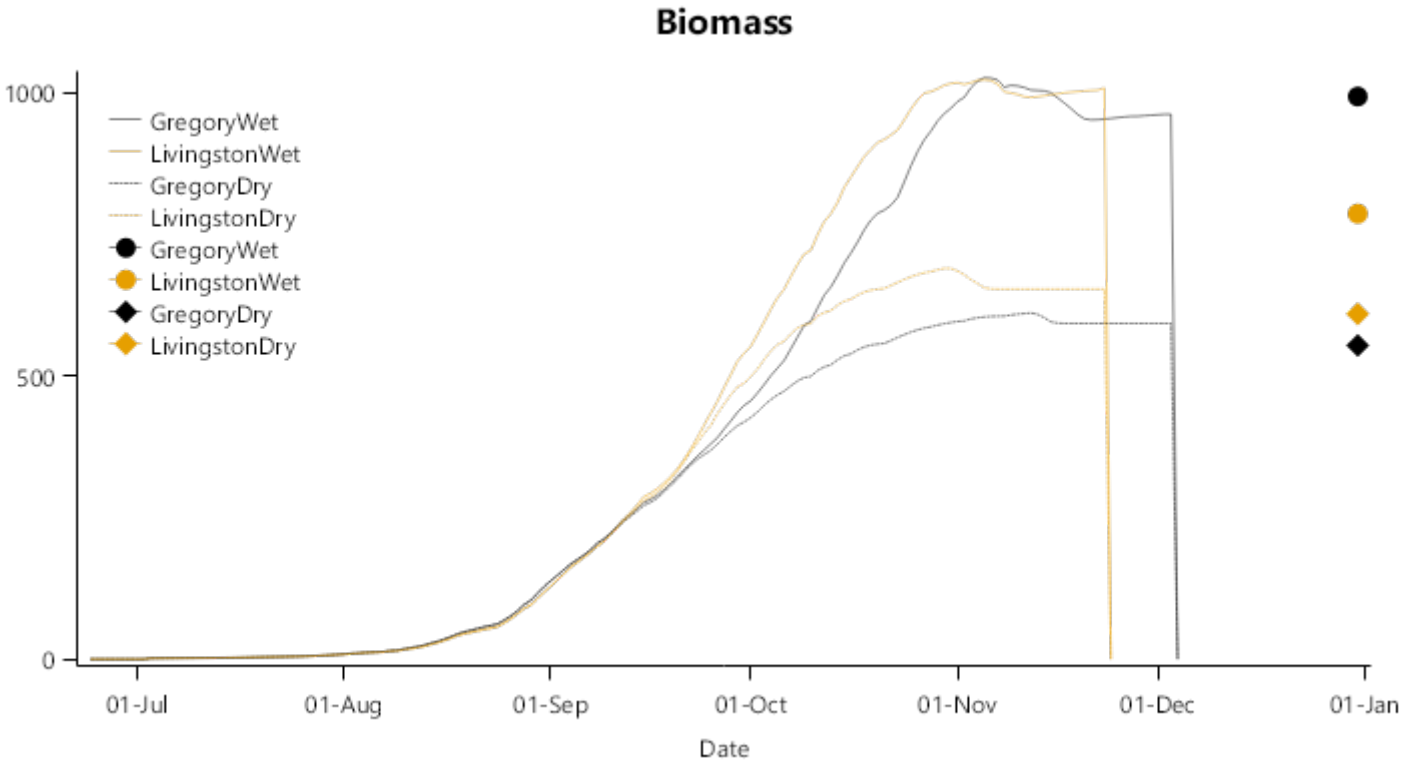
2.6.10 Wagga1314

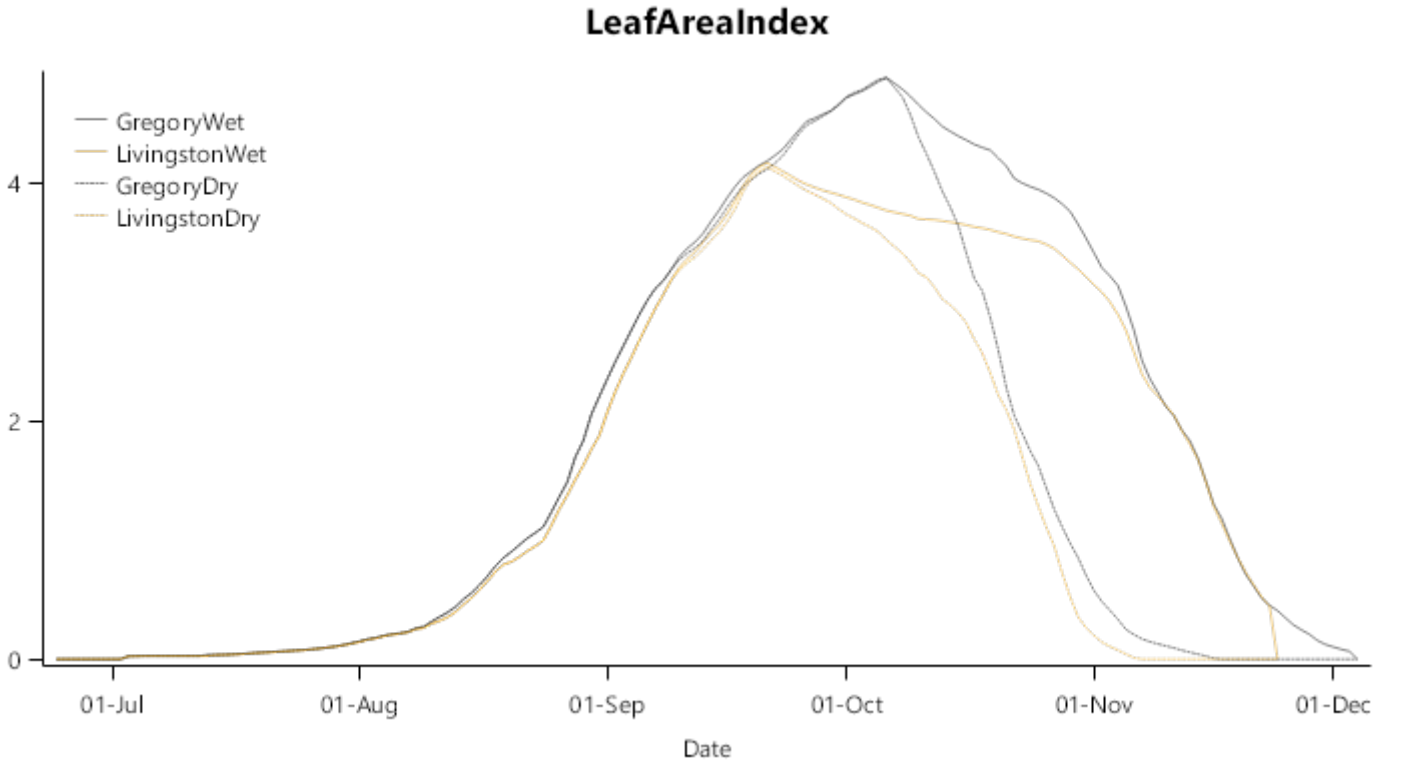
The dataset of K.T. Zeleke et al., 2016 includes plantings of two wheat varieties (Gregory, Livingston) under two water regimes (dry and irrigated) for 2013 and 2014 at the Wagga Wagga Agricultural Research Institute. Yields ranged from 1.63 t/ha to 6.01 t/ha.

List of experiments.

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

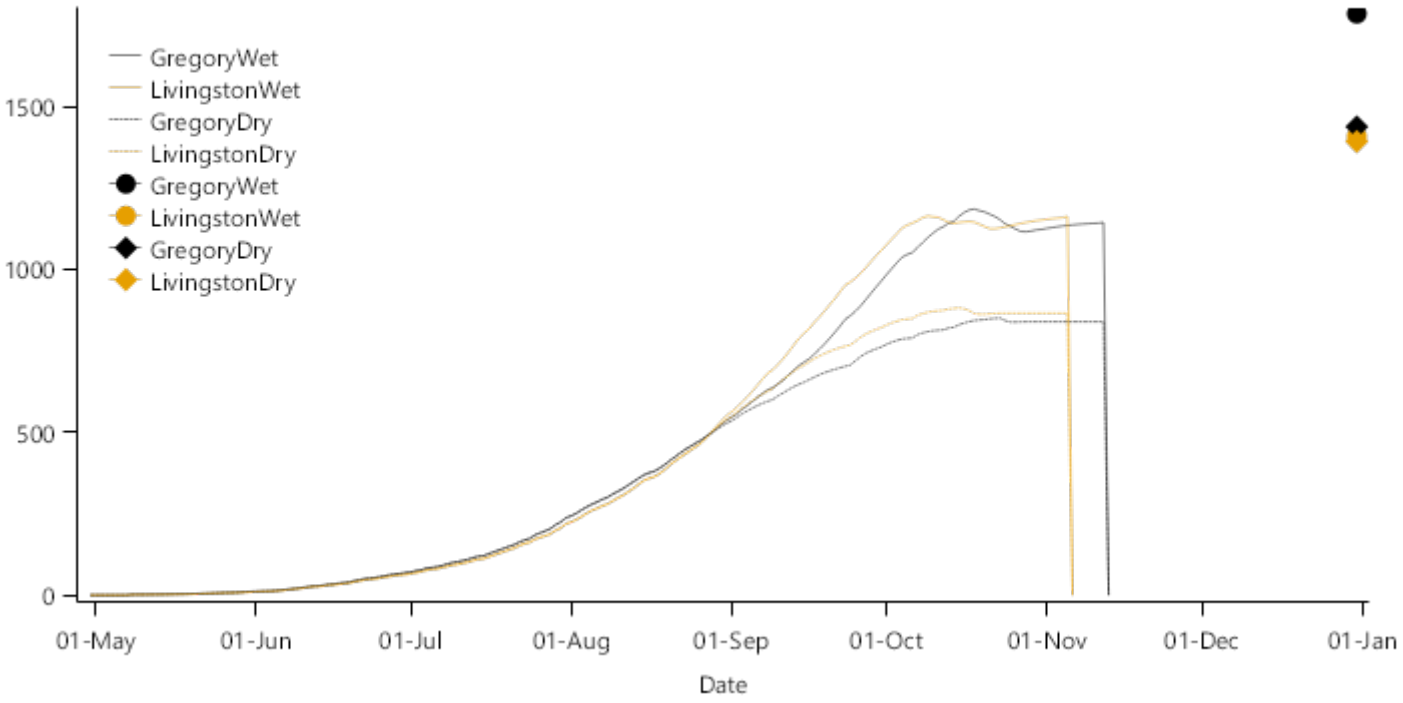
2.6.10.1 Wagga2013



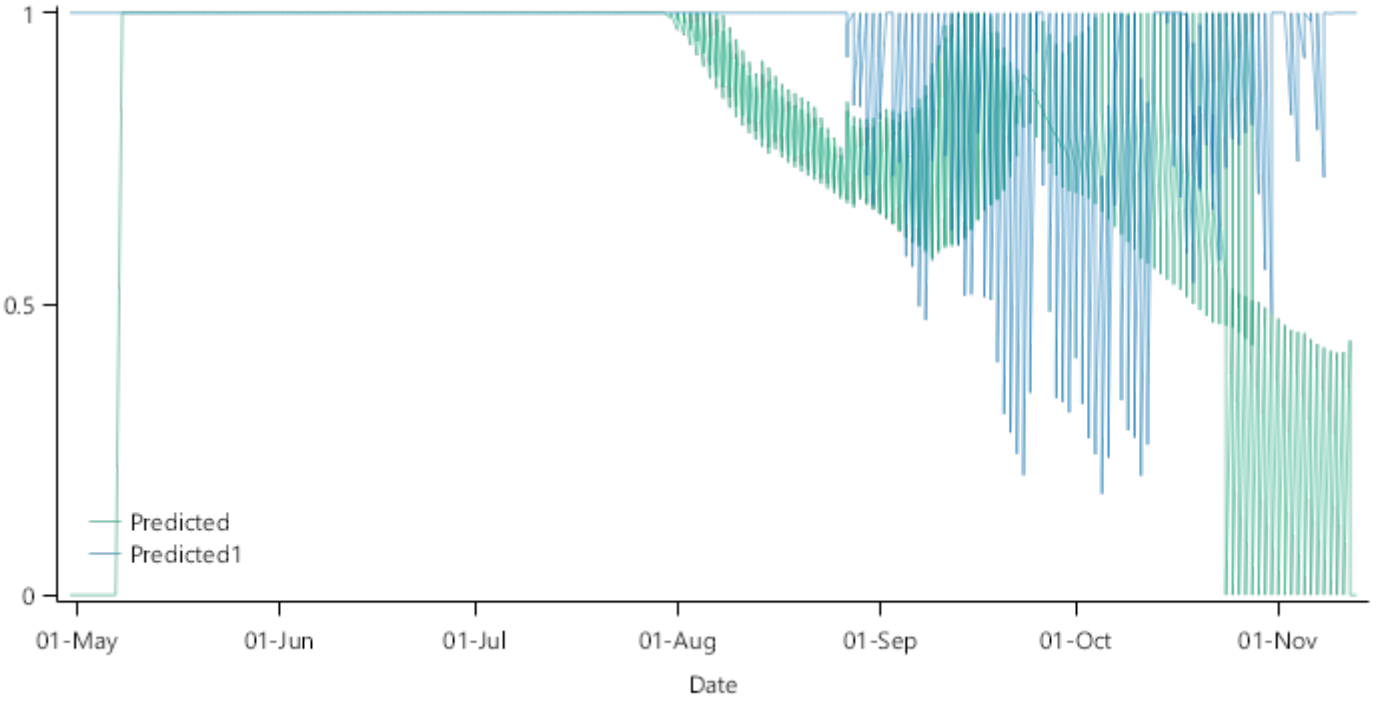


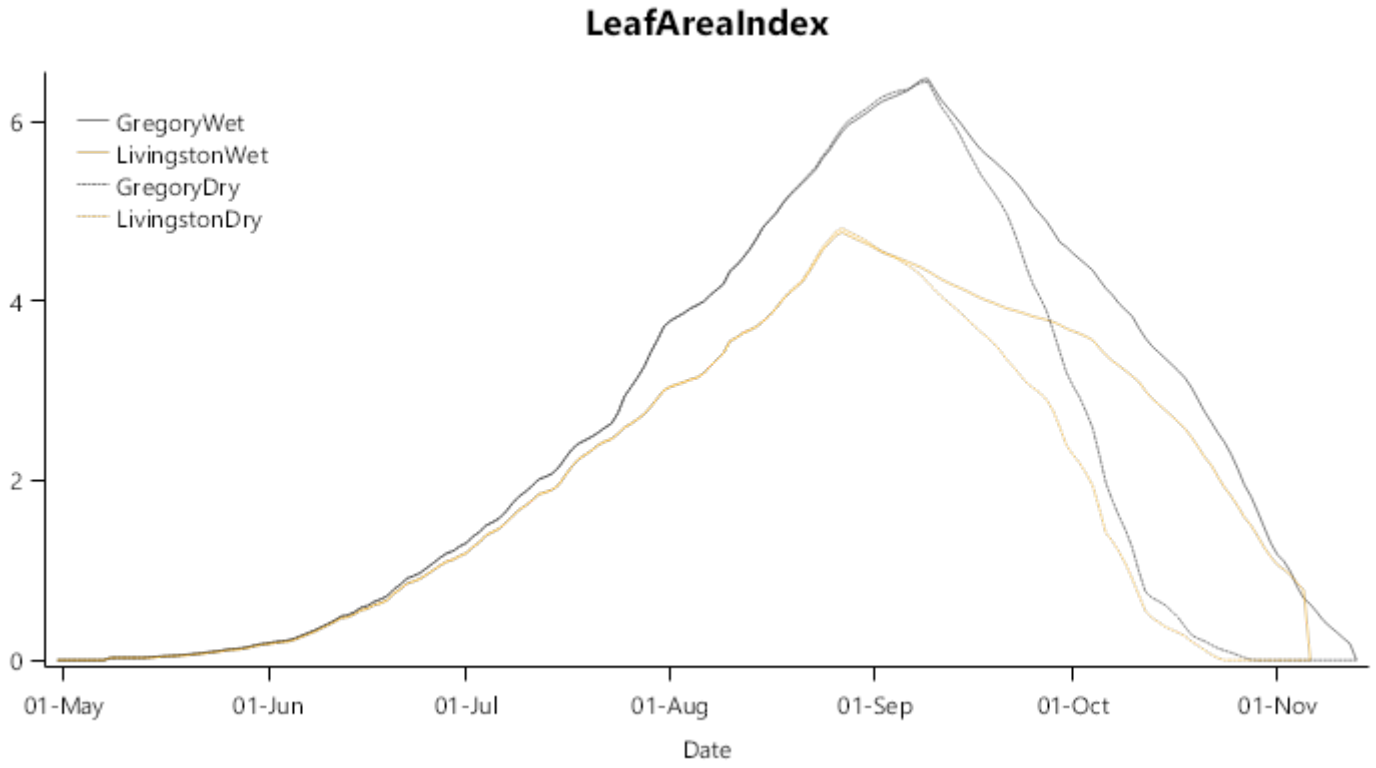
2.6.10.2 Wagga2014

Biomass



Stress





2.6.11 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.

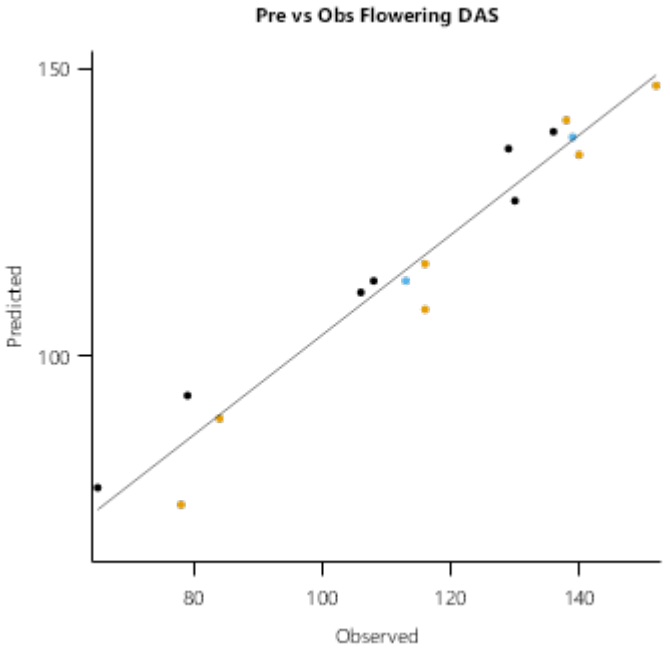
YarrabahCreek

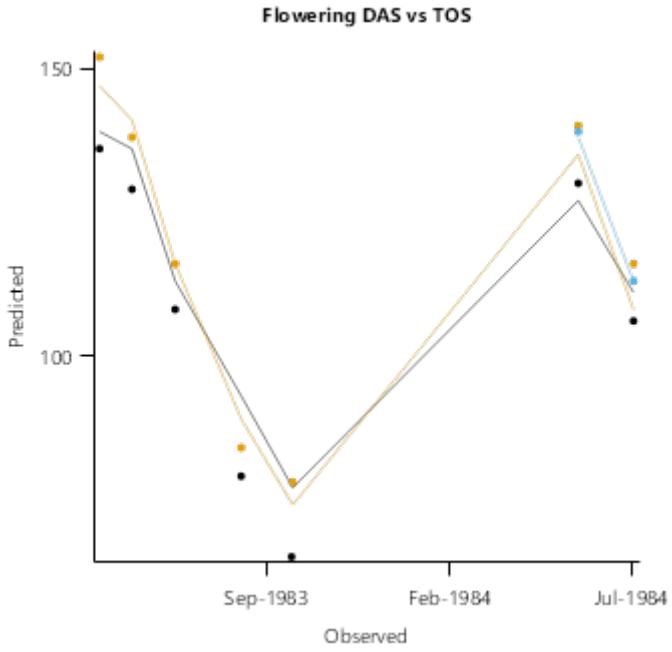
2.6.12 Griffith

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.

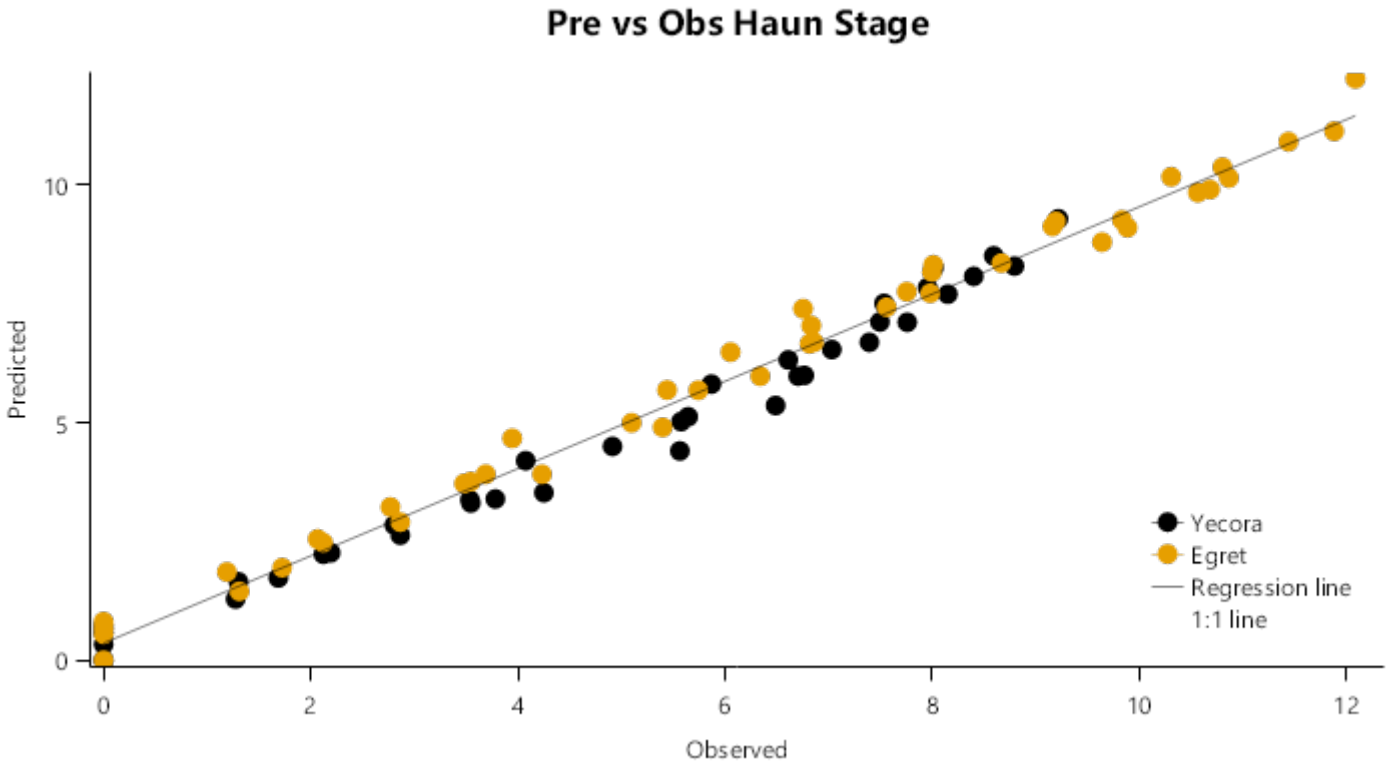
List of experiments.

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

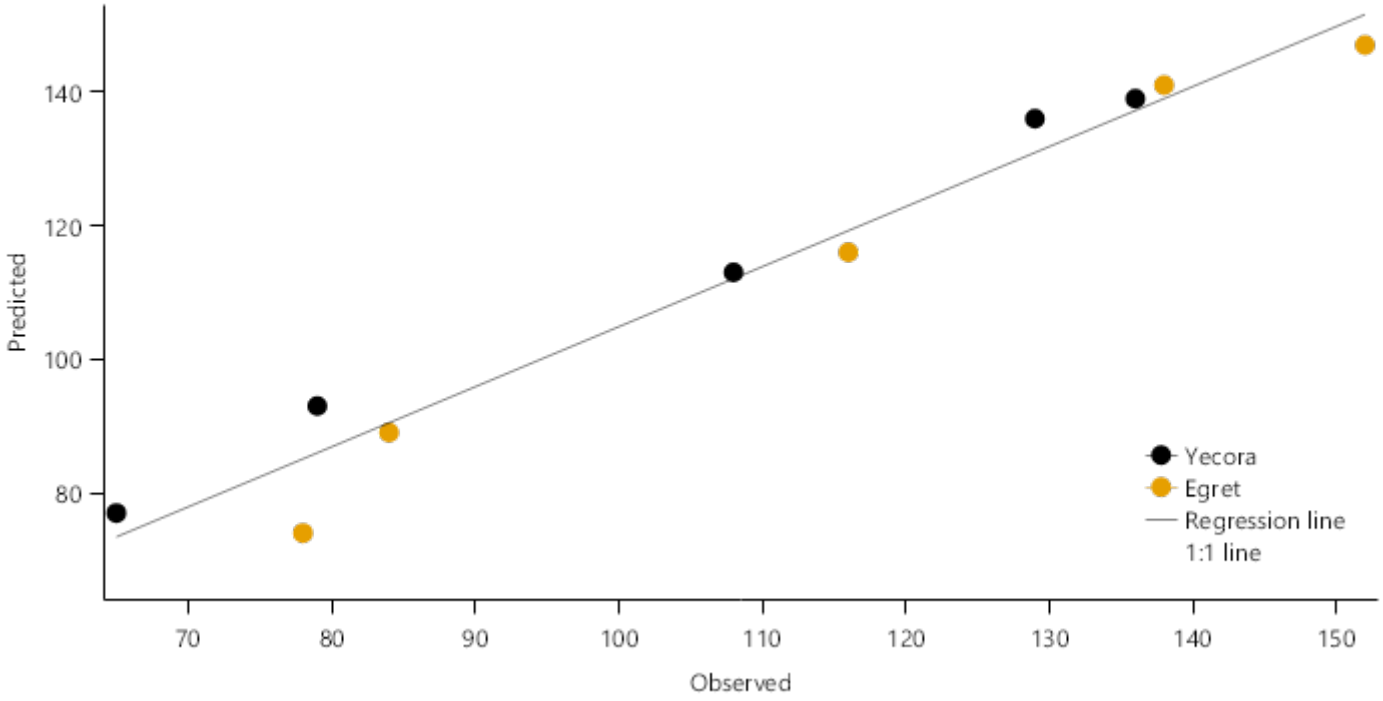




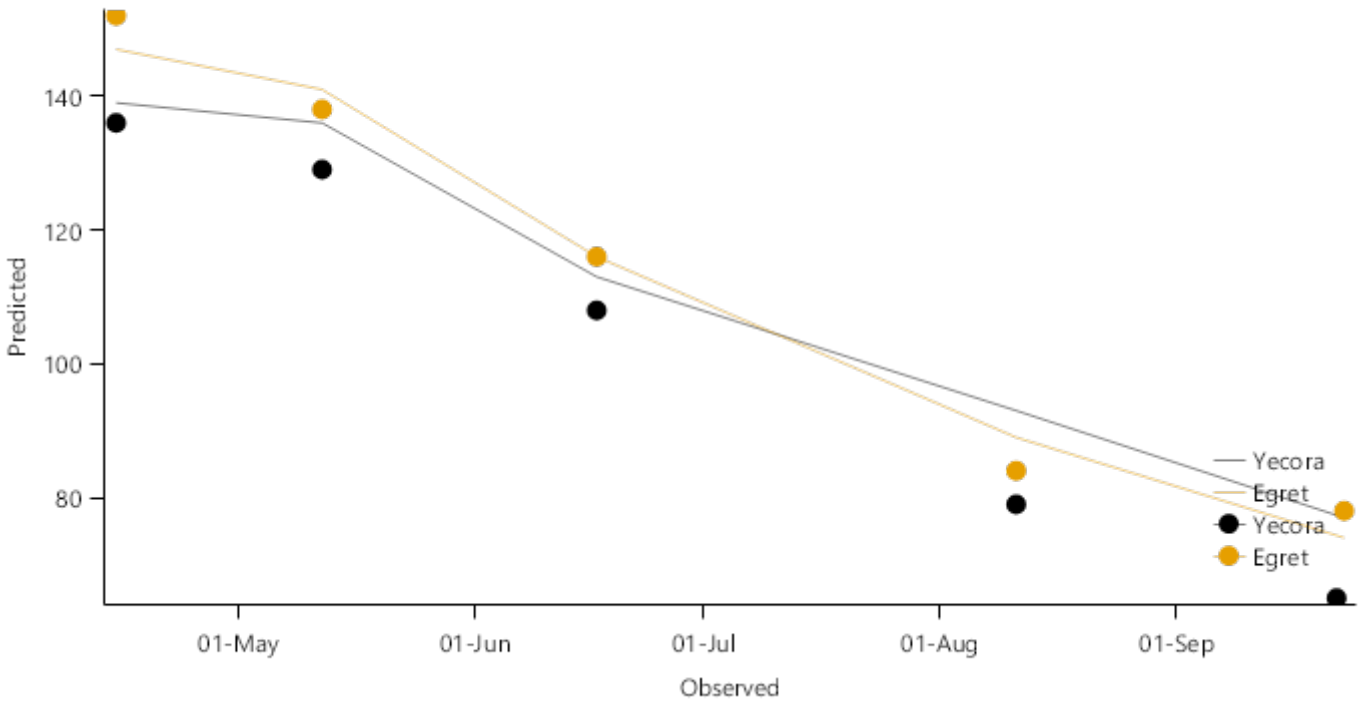
2.6.12.1 Griffith1983



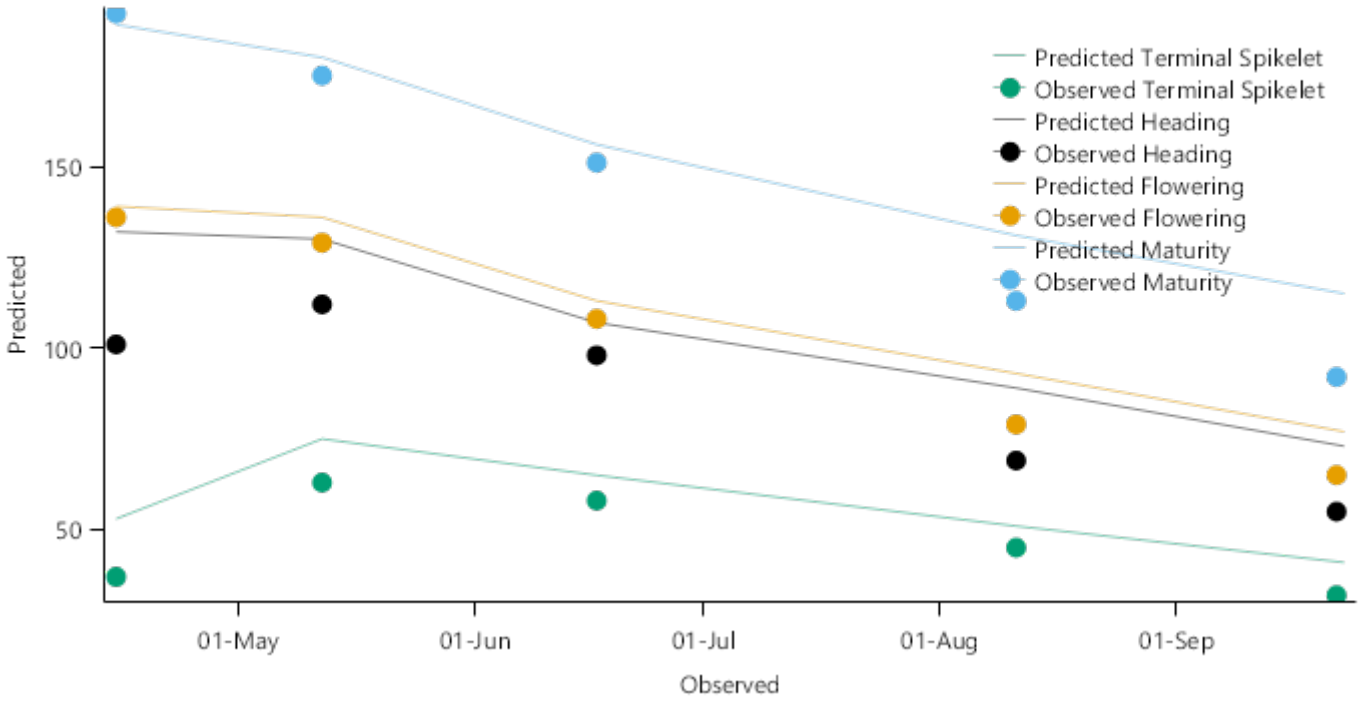
Pre vs Obs Flowering DAS



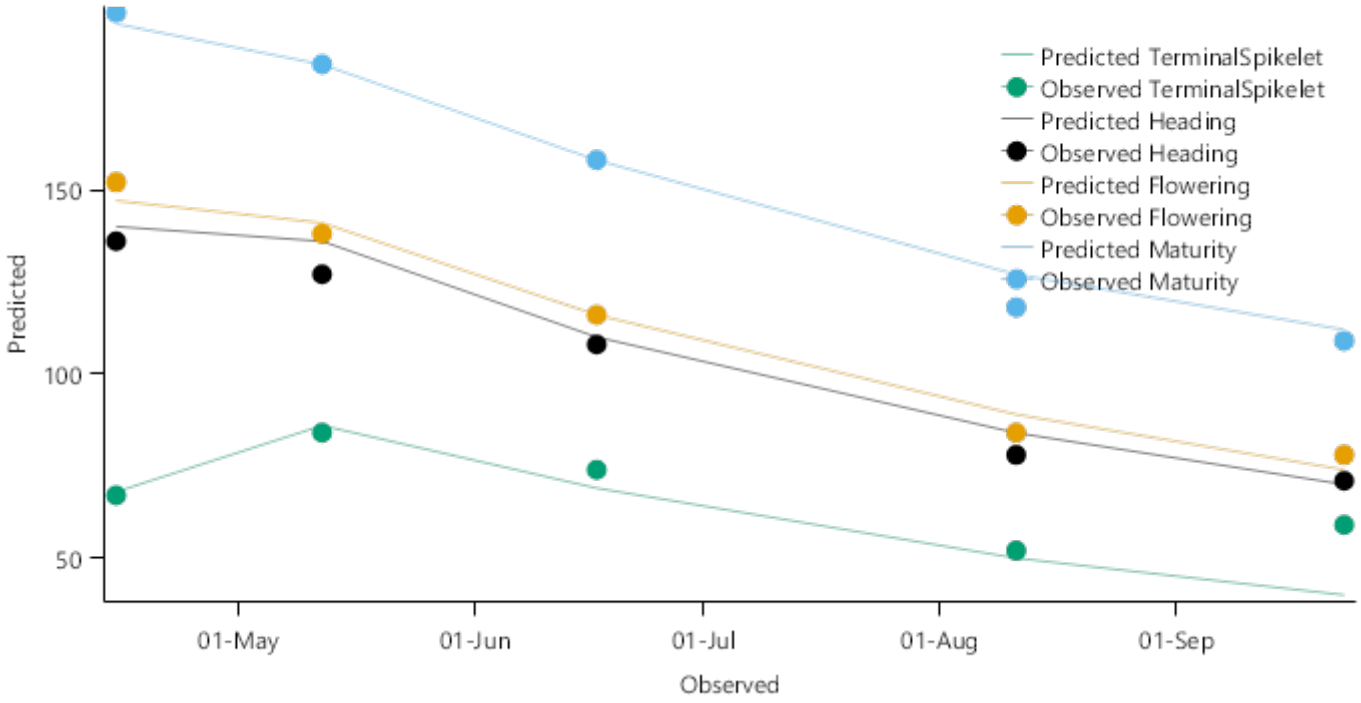
Flowering DAS vs TOS

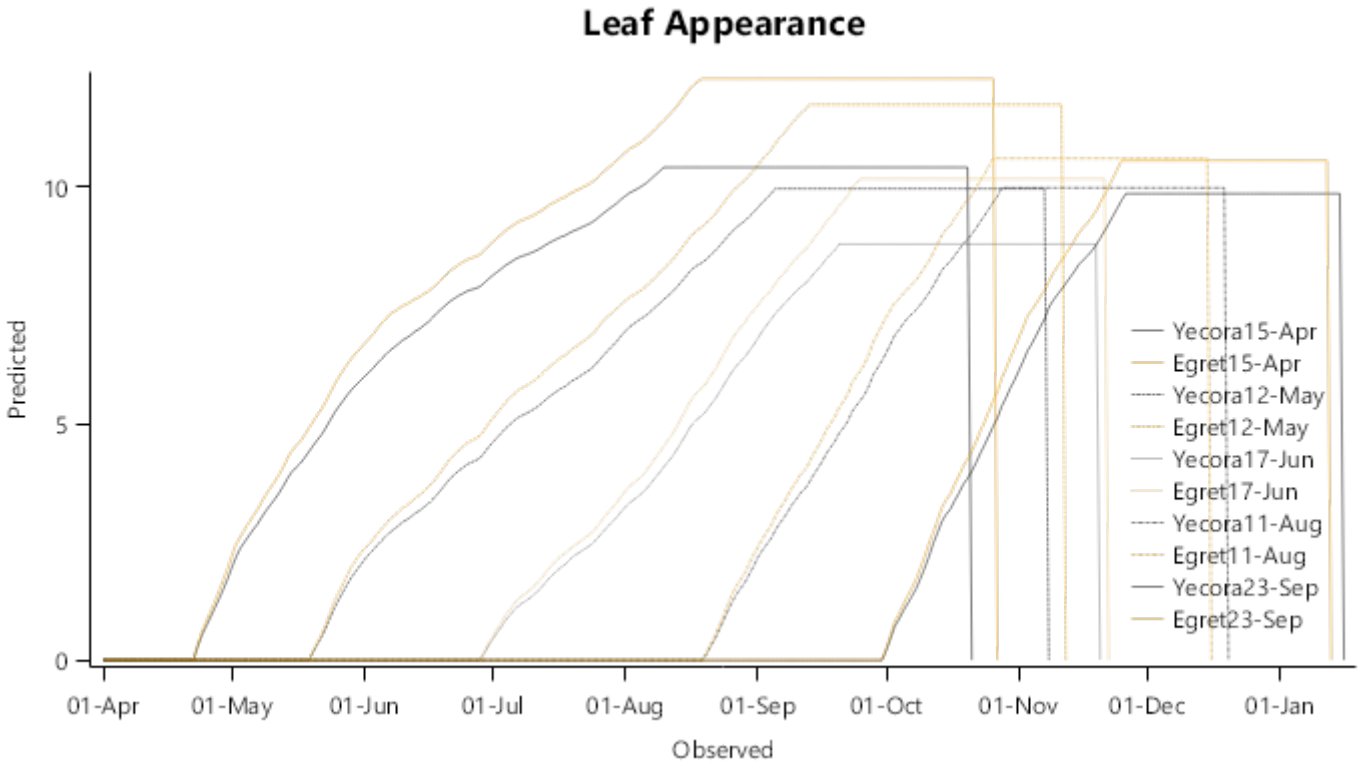


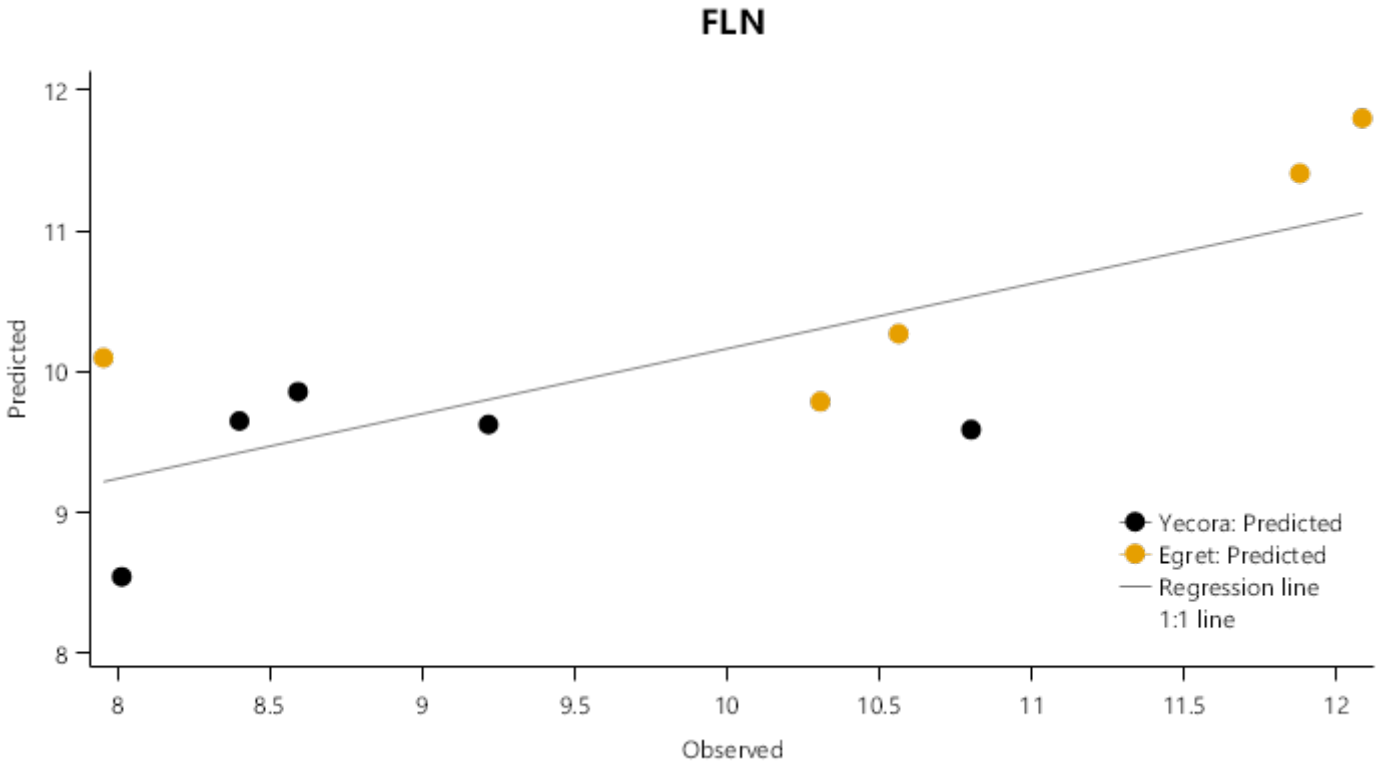
Yecora



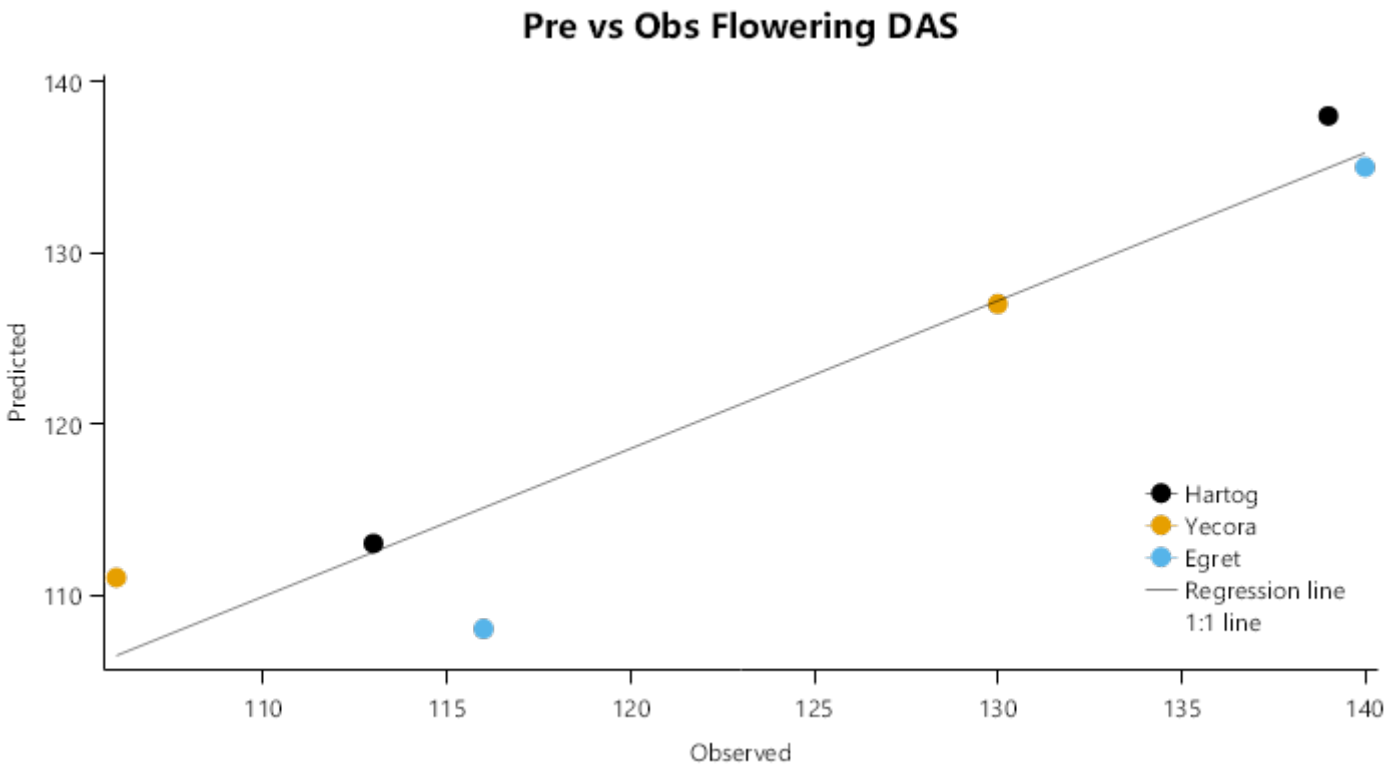
Egret

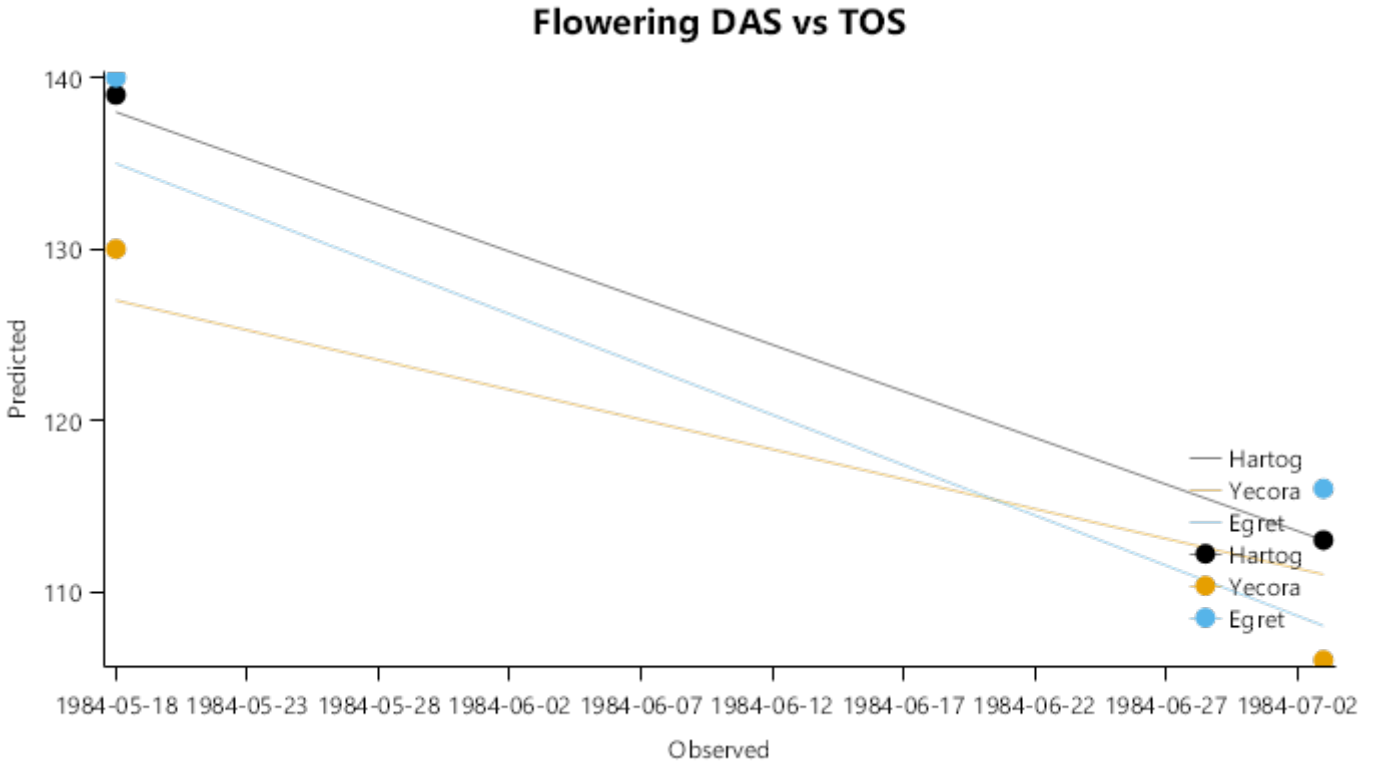






2.6.12.2 Griffith1984





2.7 Europe

2.7.1 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.

Lonzee04

Lonzee06

Lonzee08

2.8 NorthAmerica

2.8.1 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.

List of experiments.

Experiment Name	Design (Number of Treatments)
ArizonaFACE92	CO2 x Irr (4)
ArizonaFACE93	CO2 x Irr (4)

2.8.1.1 ArizonaFACE92

This trial was 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:

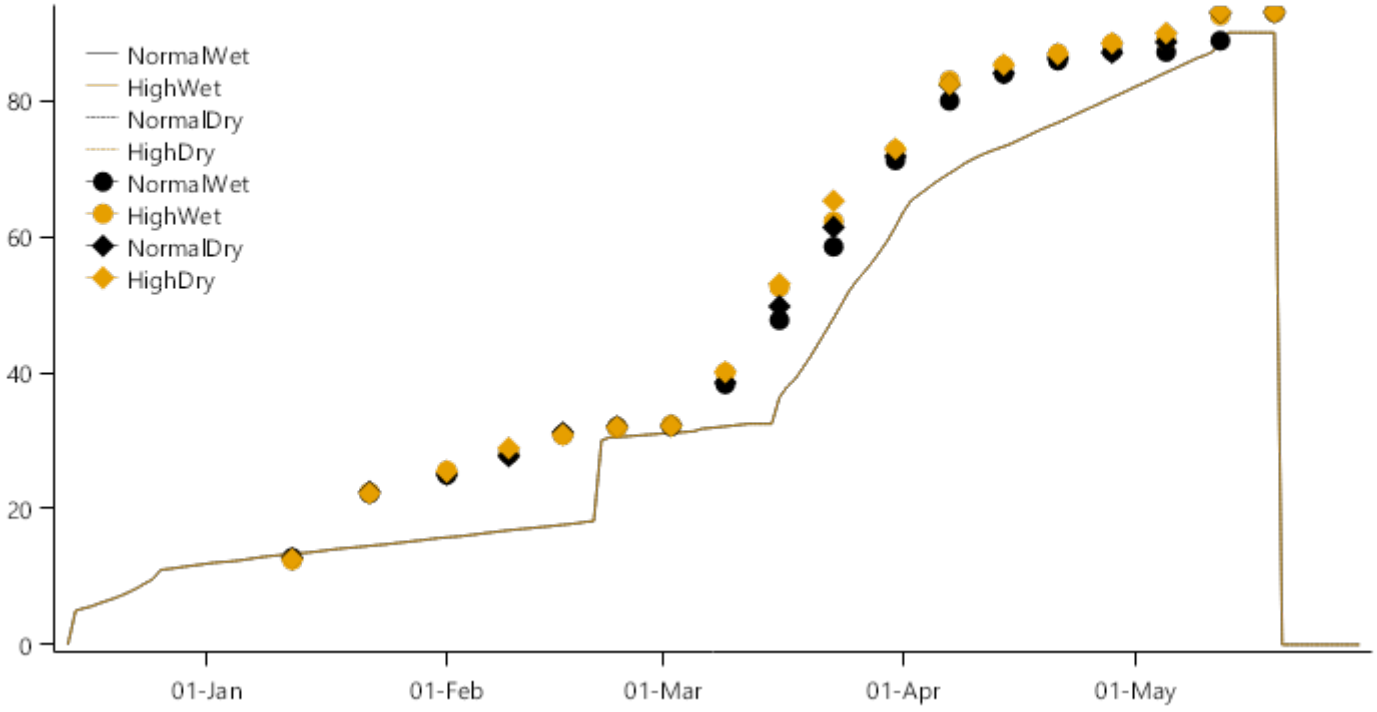
1. Normal CO2 (370 ppm) (that is no longer normal)
2. High CO2 (550 ppm)

Irrigation treatmetnts were also applied with:

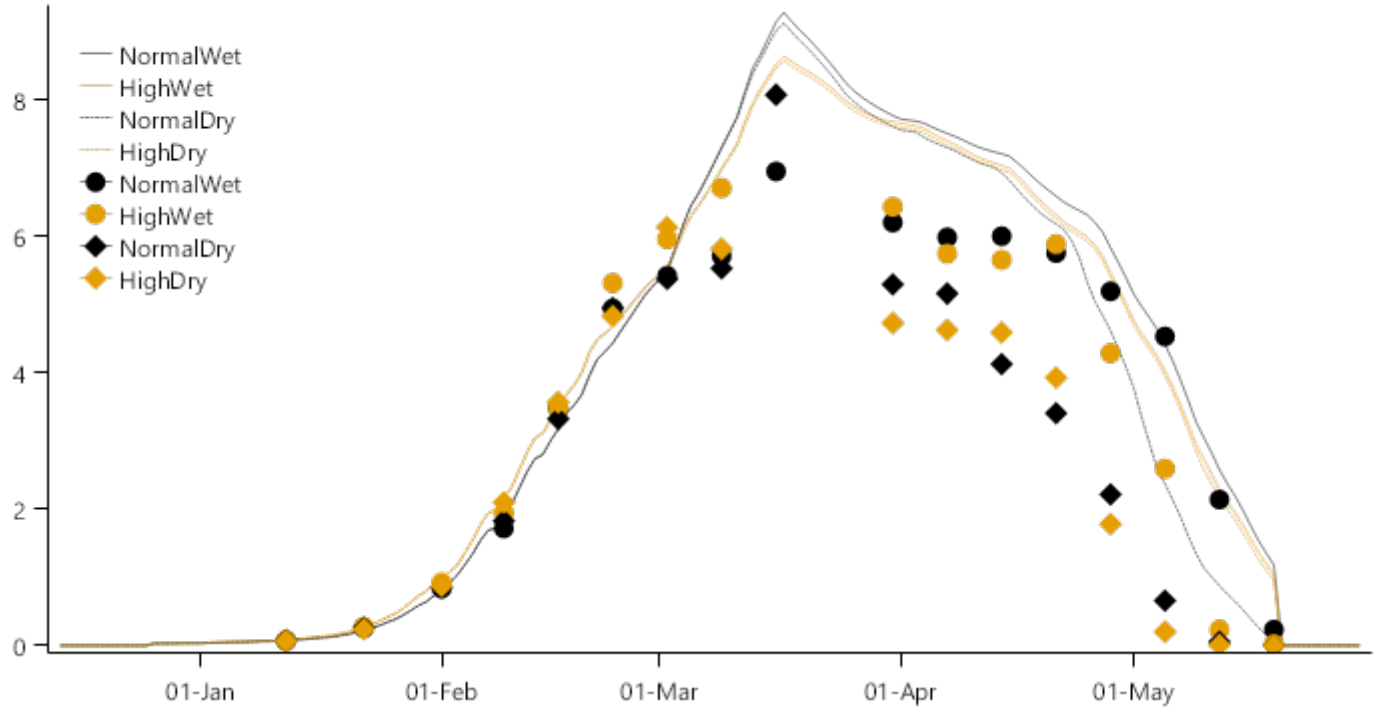
1. High Irrigation (~600 mm)
2. Low irrigation (~265 mm)

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

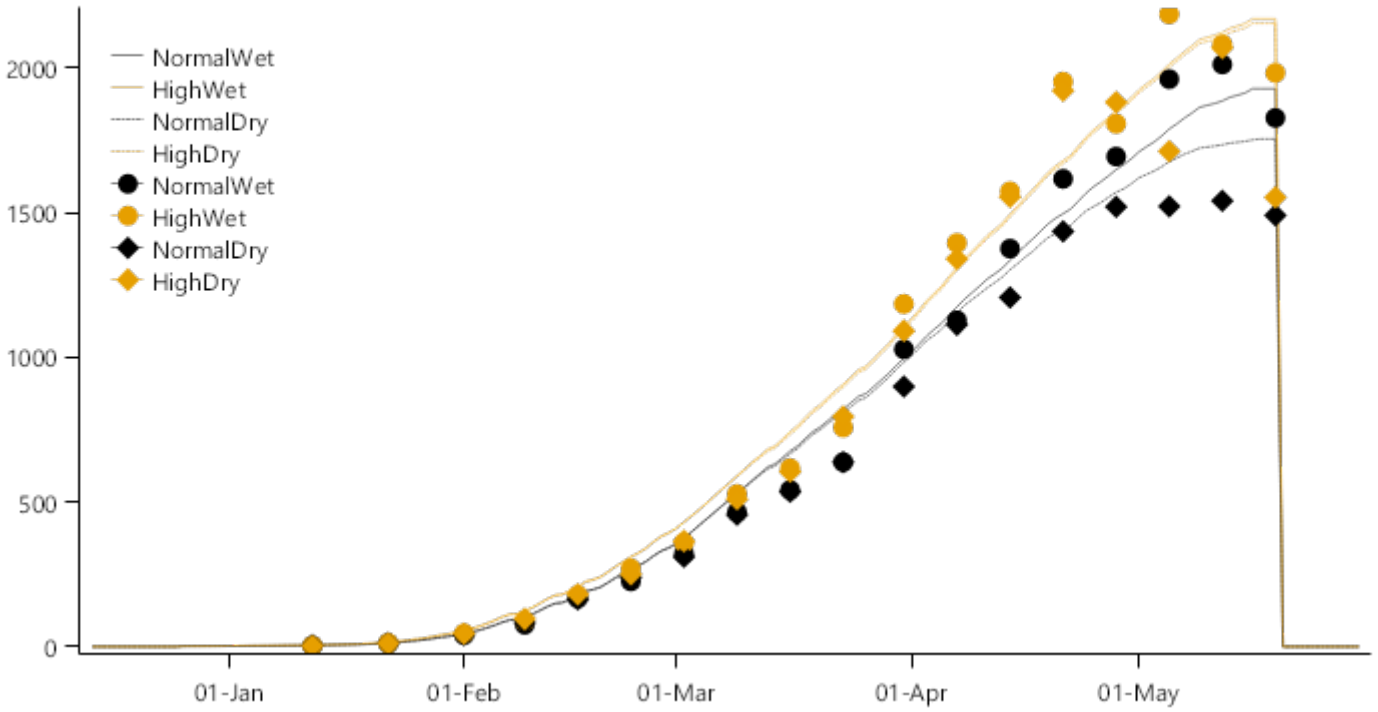
Phenology



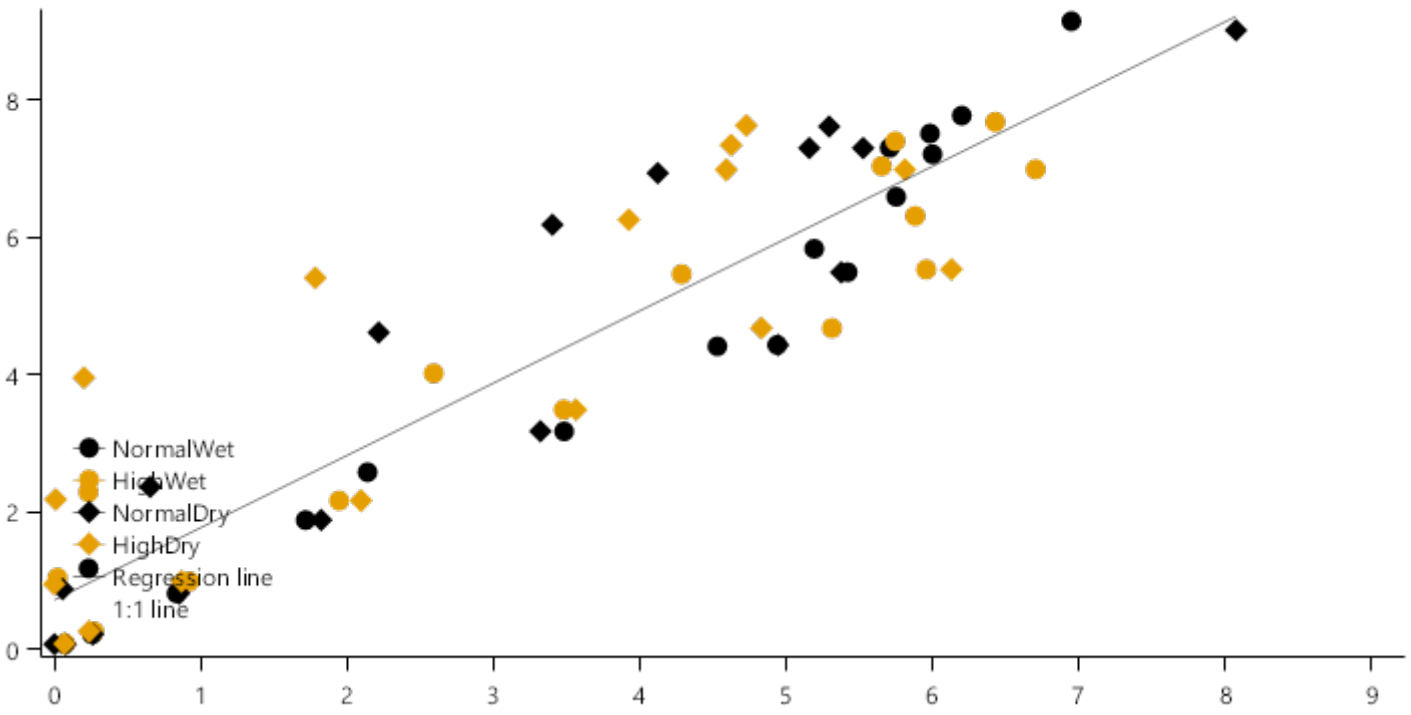
LAI



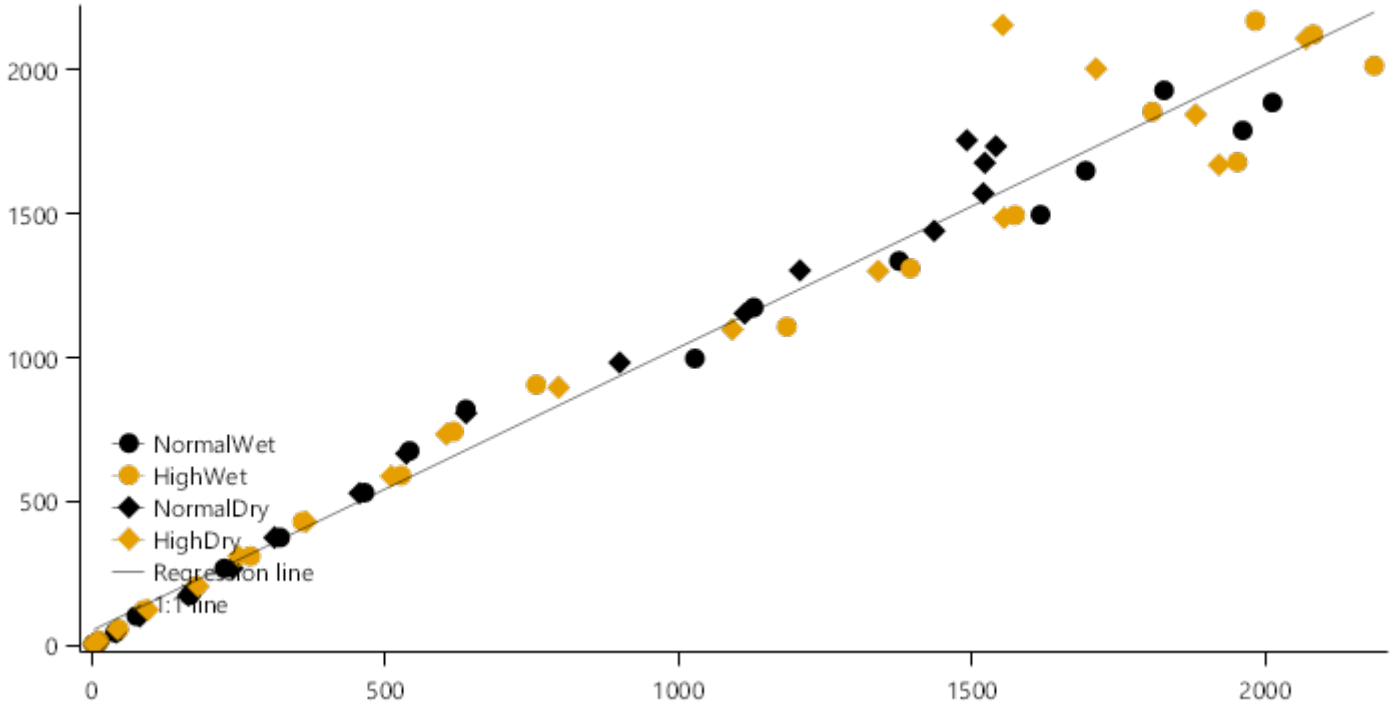
AboveGroundWt



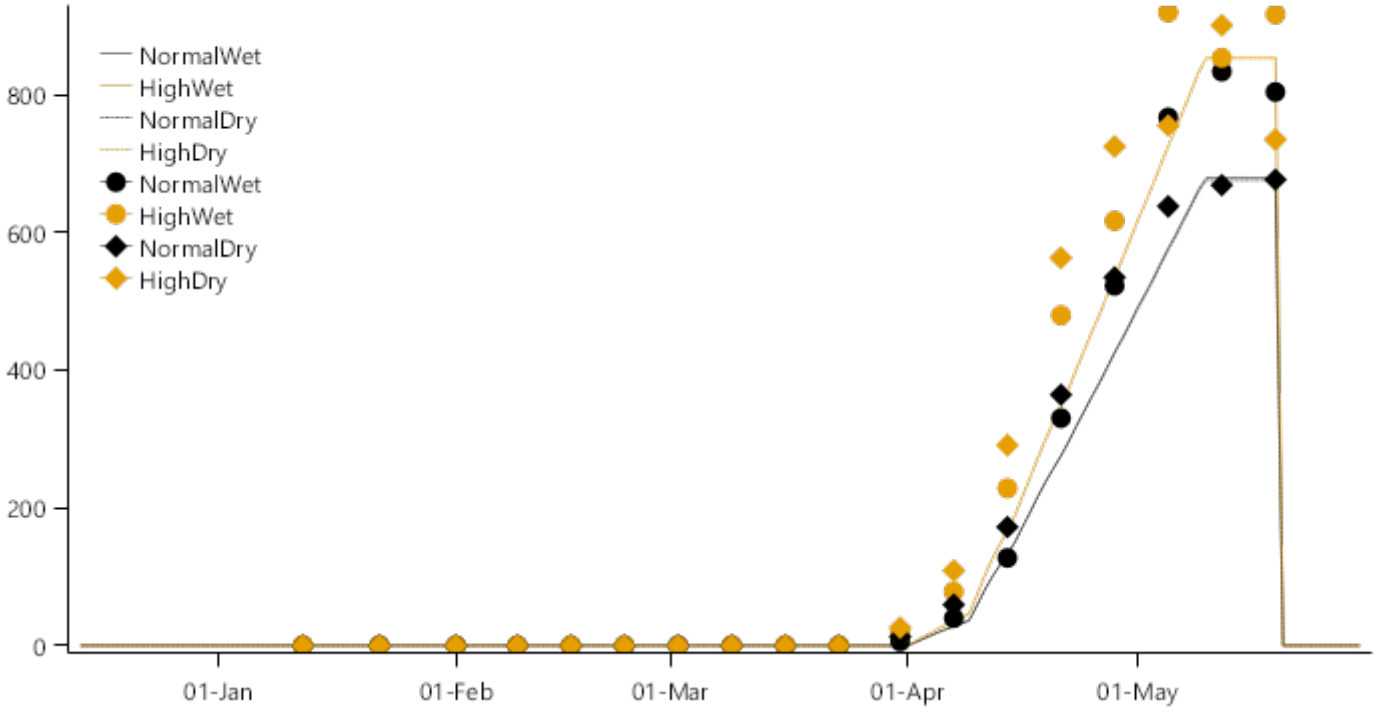
Pre vs Obs LAI



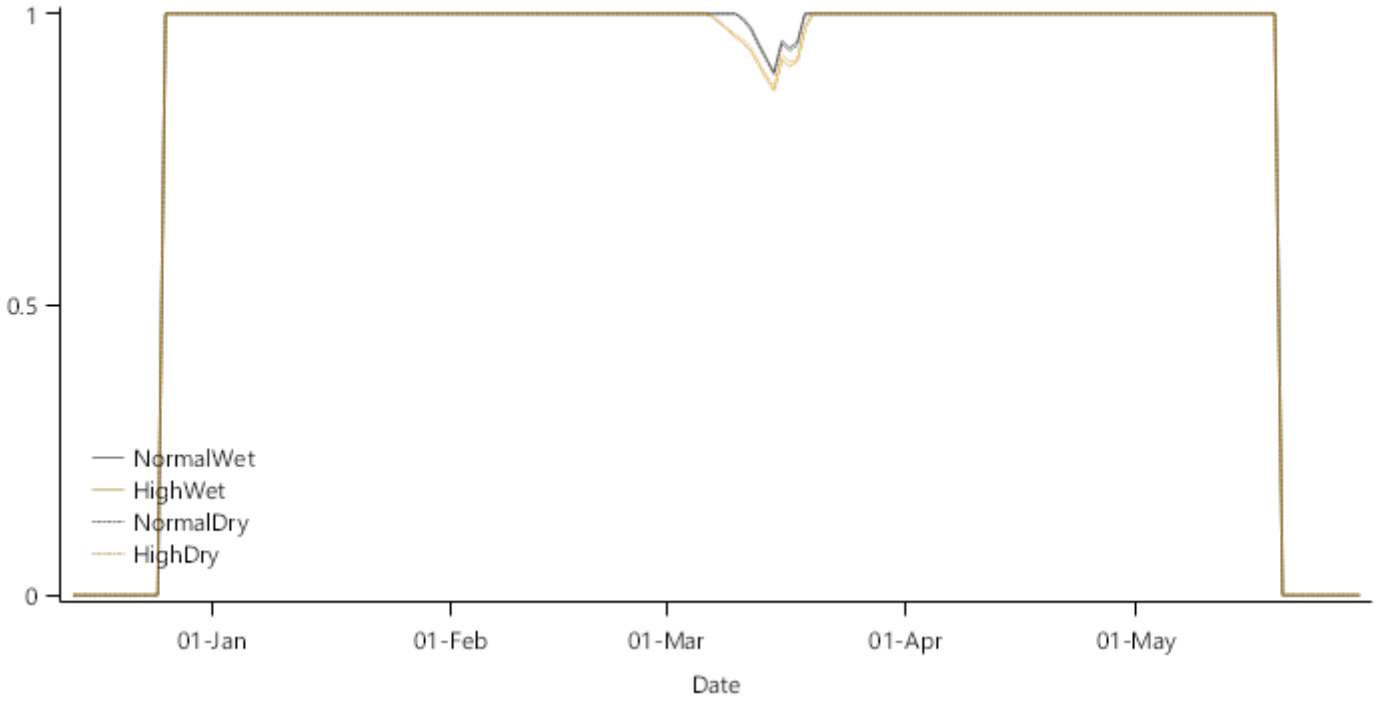
Pre vs Obs AboveGroundWt



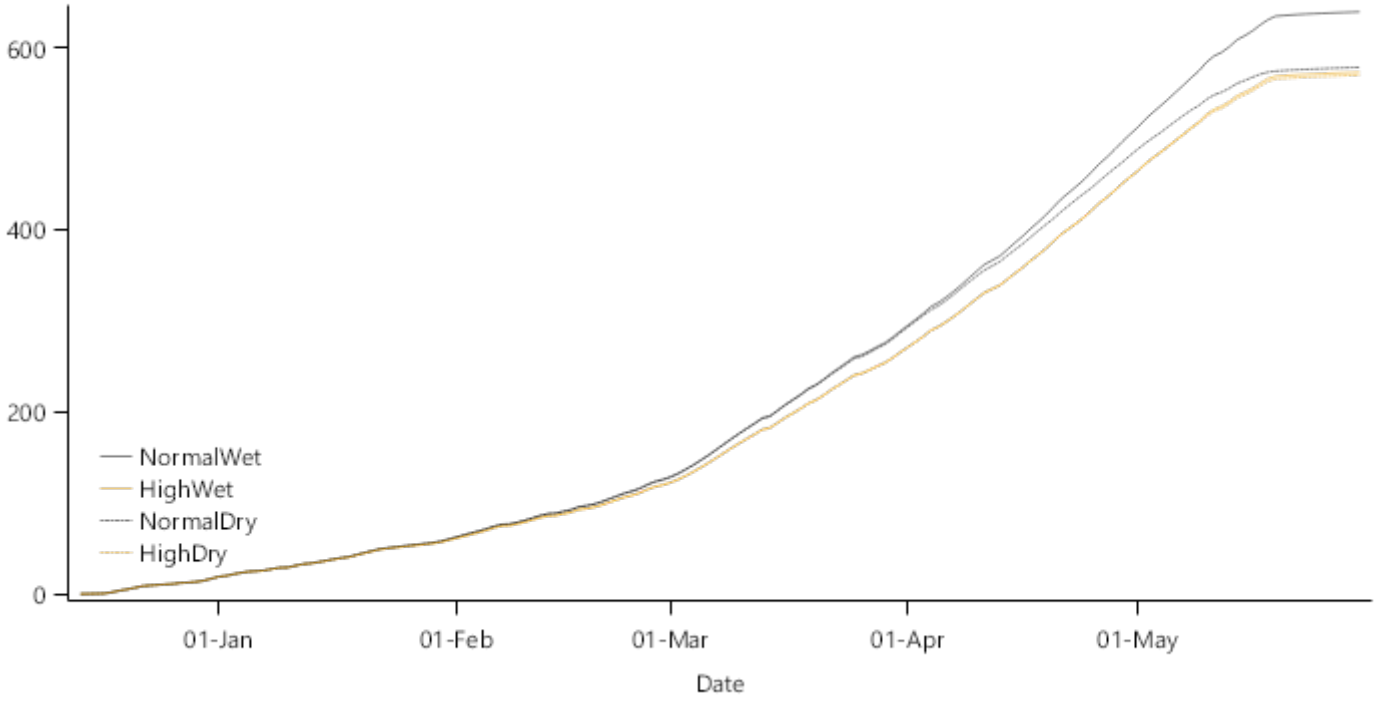
GrainWt

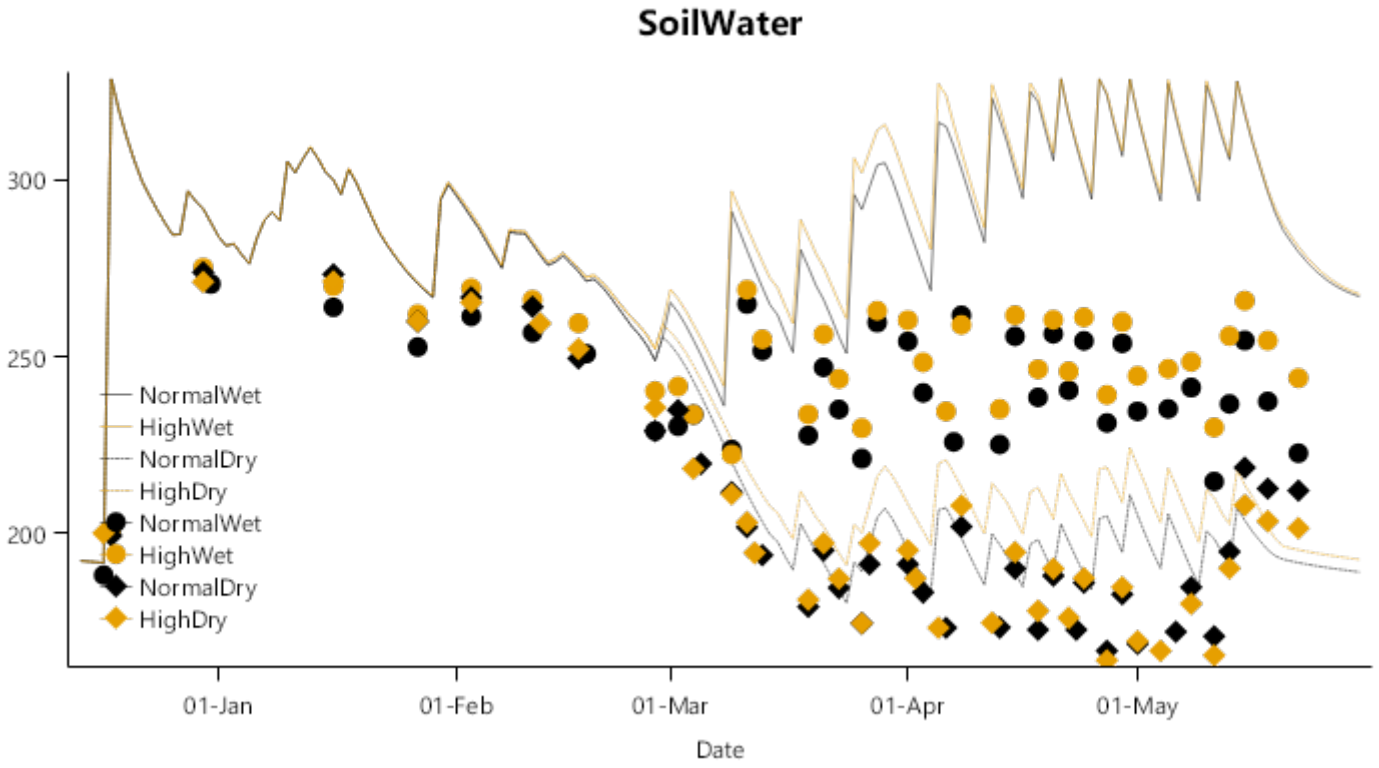


N Stress

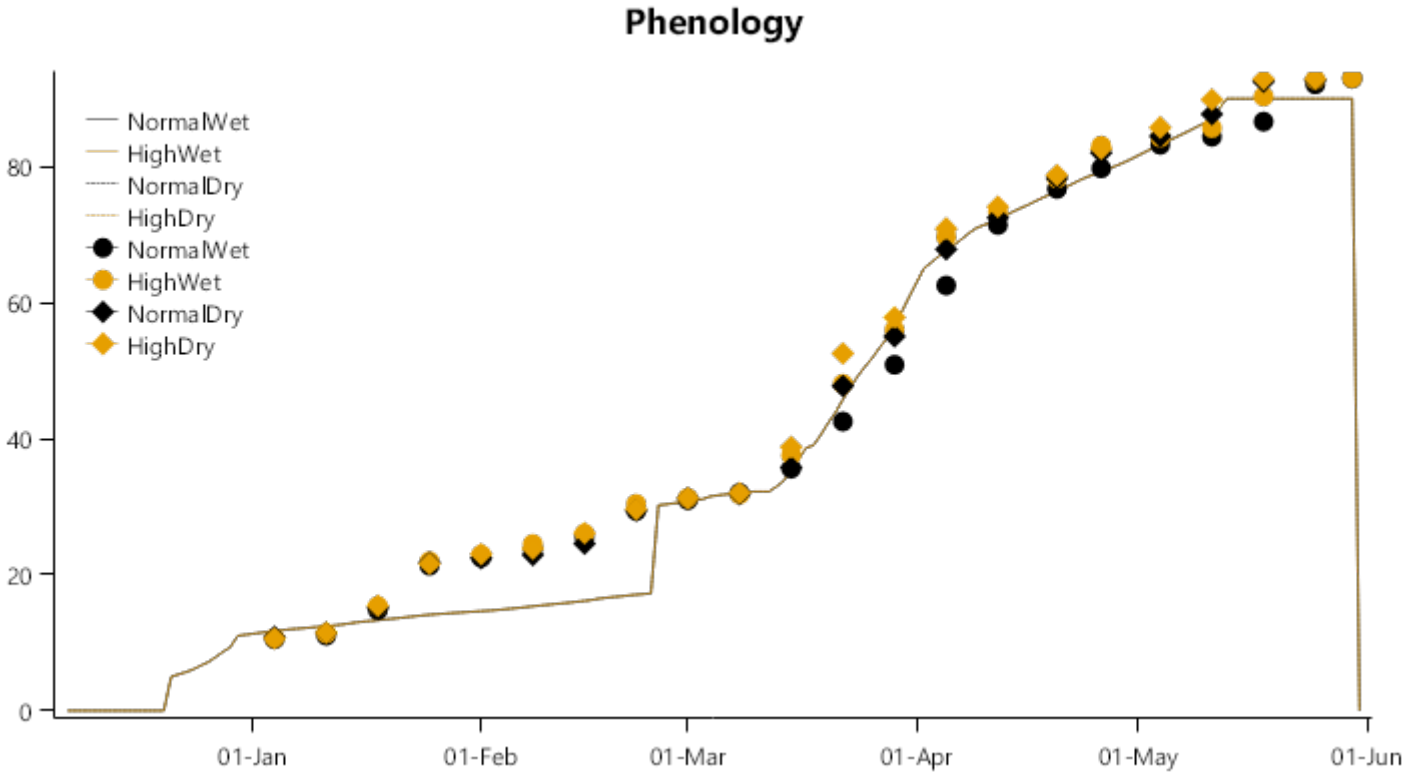

1
0.5
0
NormalWet
HighWet
NormalDry
HighDry
01-Jan
01-Feb
01-Mar
01-Apr
01-May
Date

ET

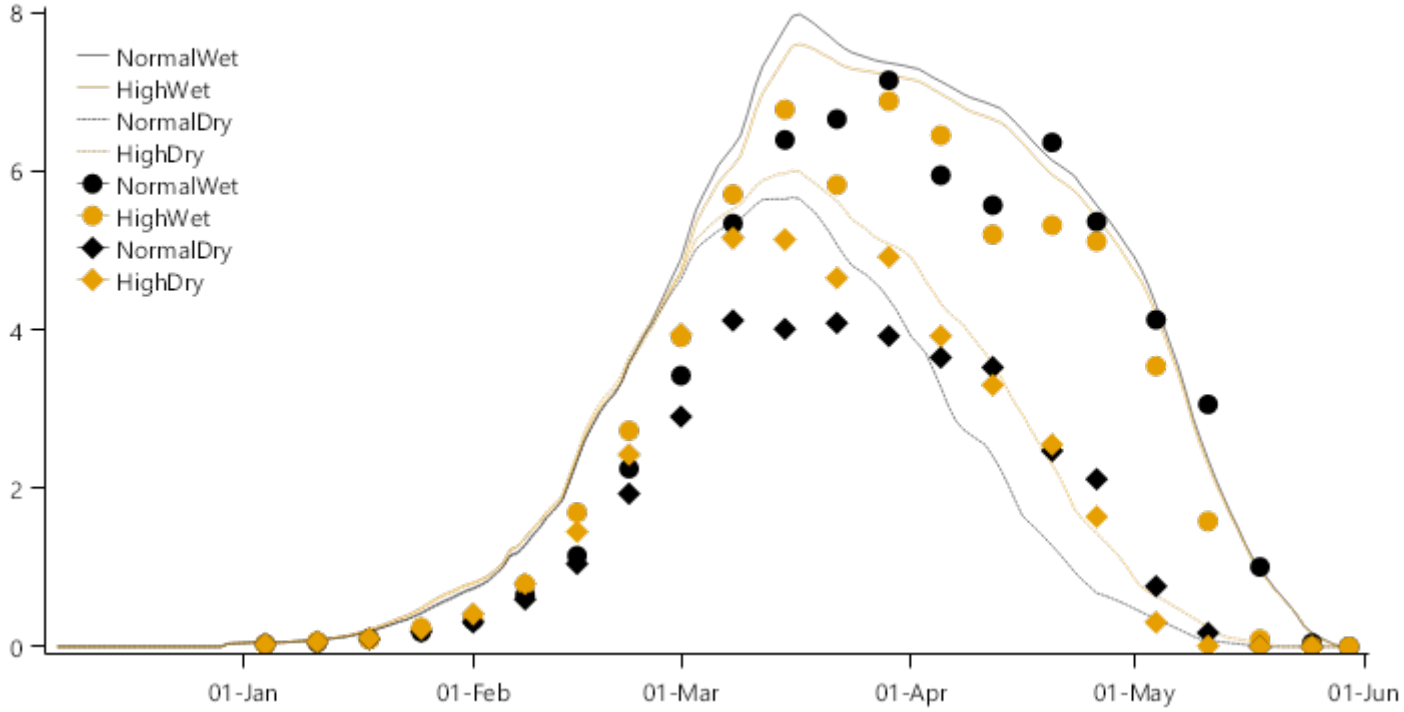

600
400
200
0
NormalWet
HighWet
NormalDry
HighDry
01-Jan
01-Feb
01-Mar
01-Apr
01-May
Date



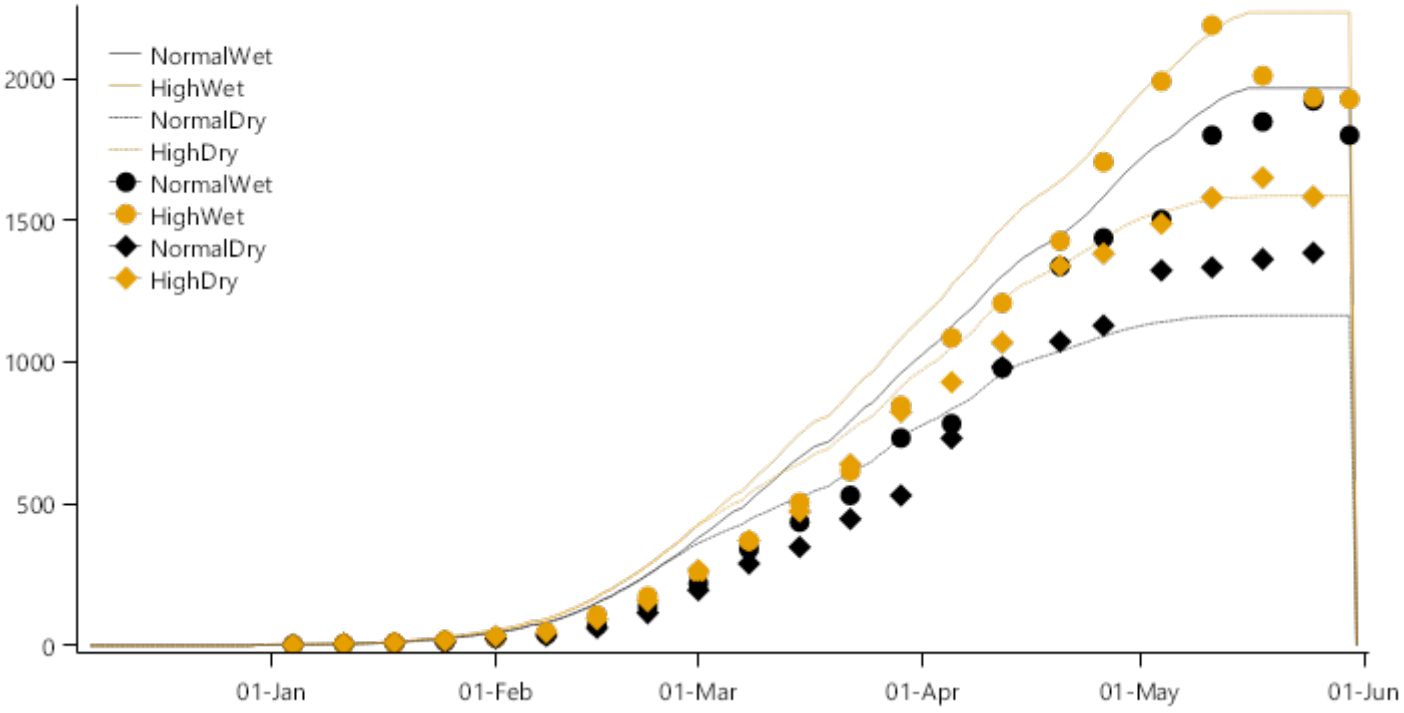
2.8.1.2 ArizonaFACE93

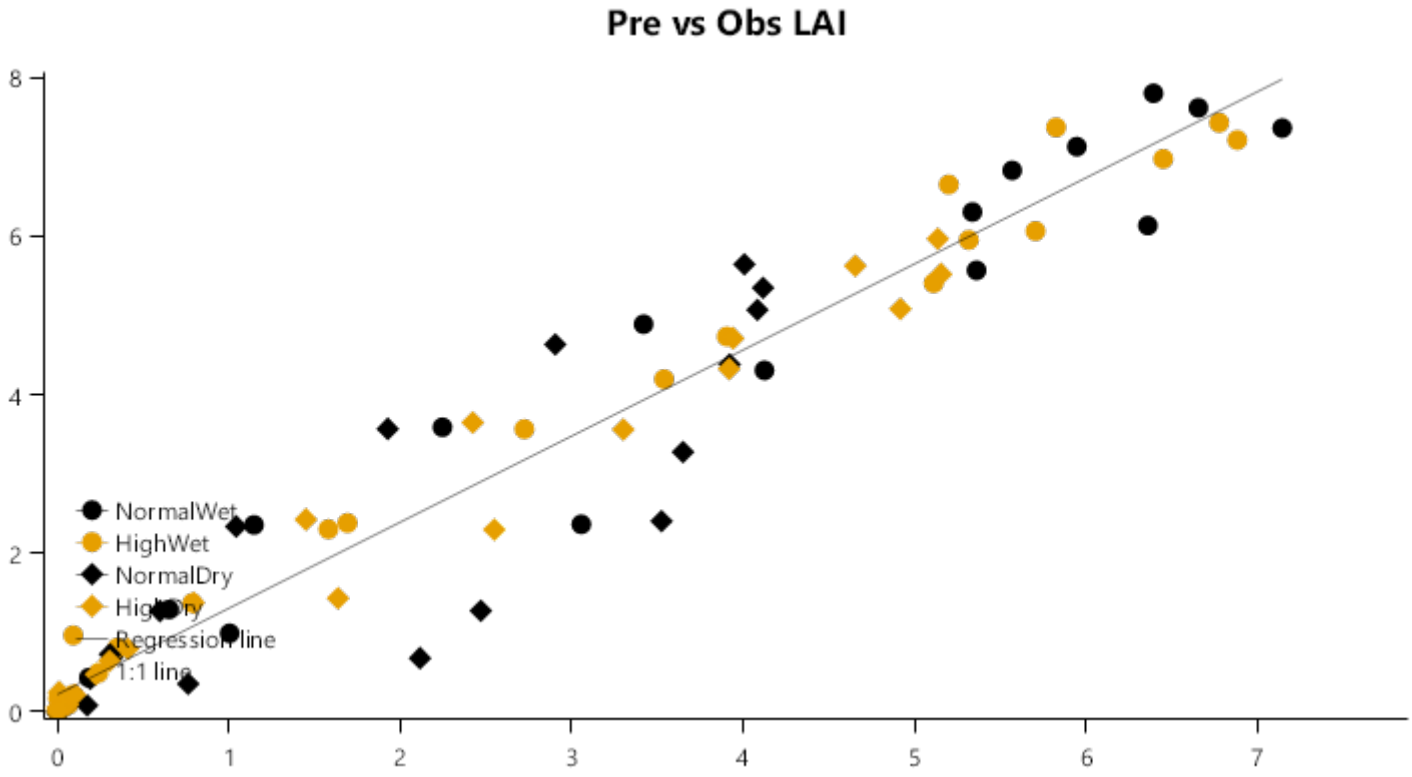


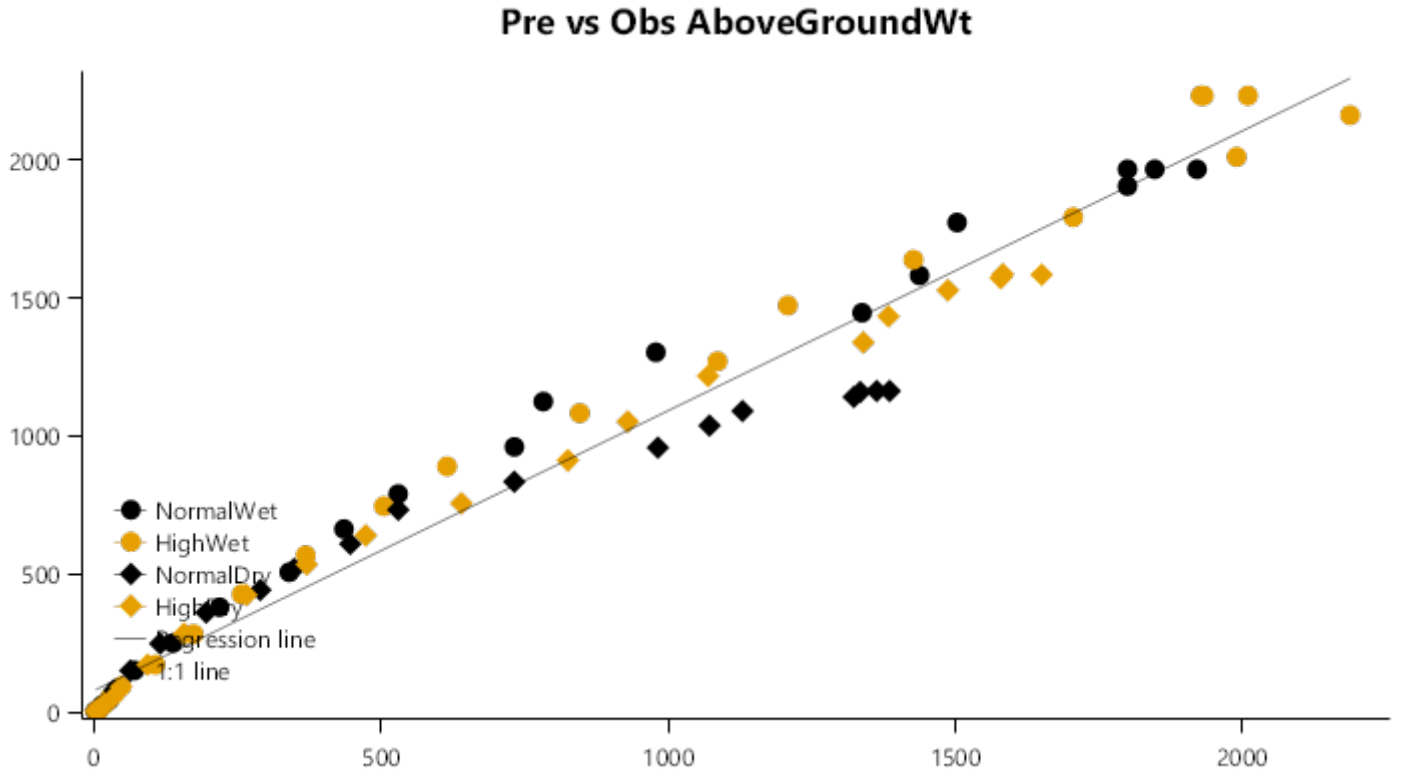
LAI



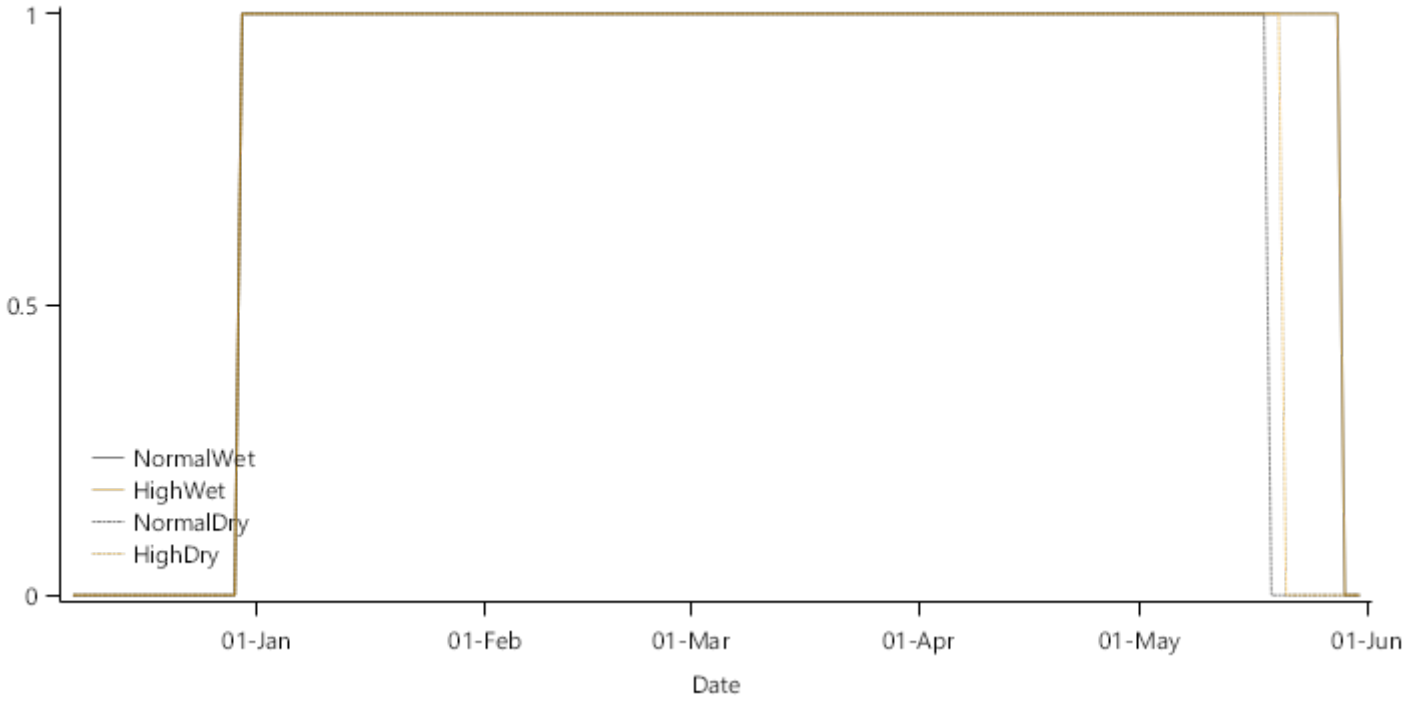
AboveGroundWt



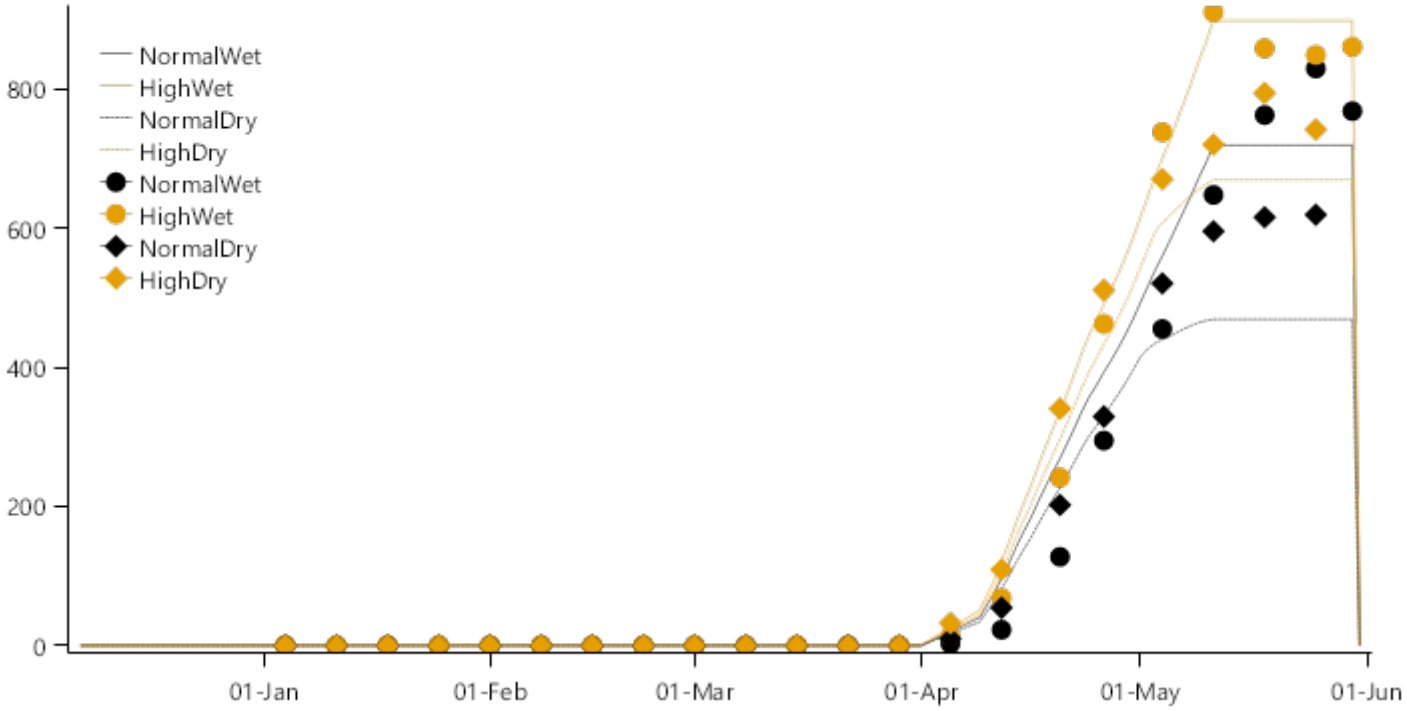

Pre vs Obs LAI
8
6
4
2
0
0
1
2
3
4
5
6
7
NormalWet
HighWet
NormalDry
HighDry
Regression line
1:1 line

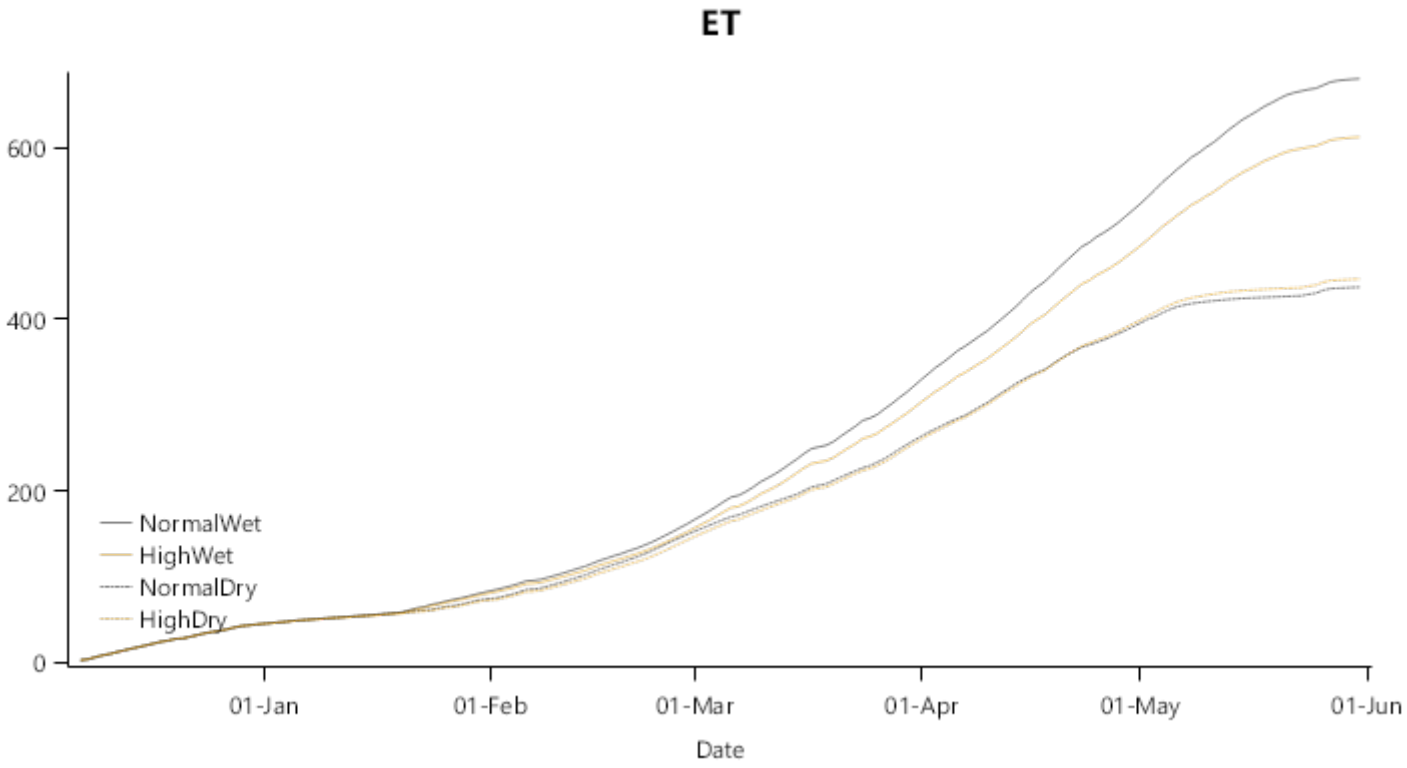

Pre vs Obs AboveGroundWt
2000
1500
1000
500
0
0
500
1000
1500
2000
NormalWet
HighWet
NormalDry
HighDry
Regression line
1:1 line

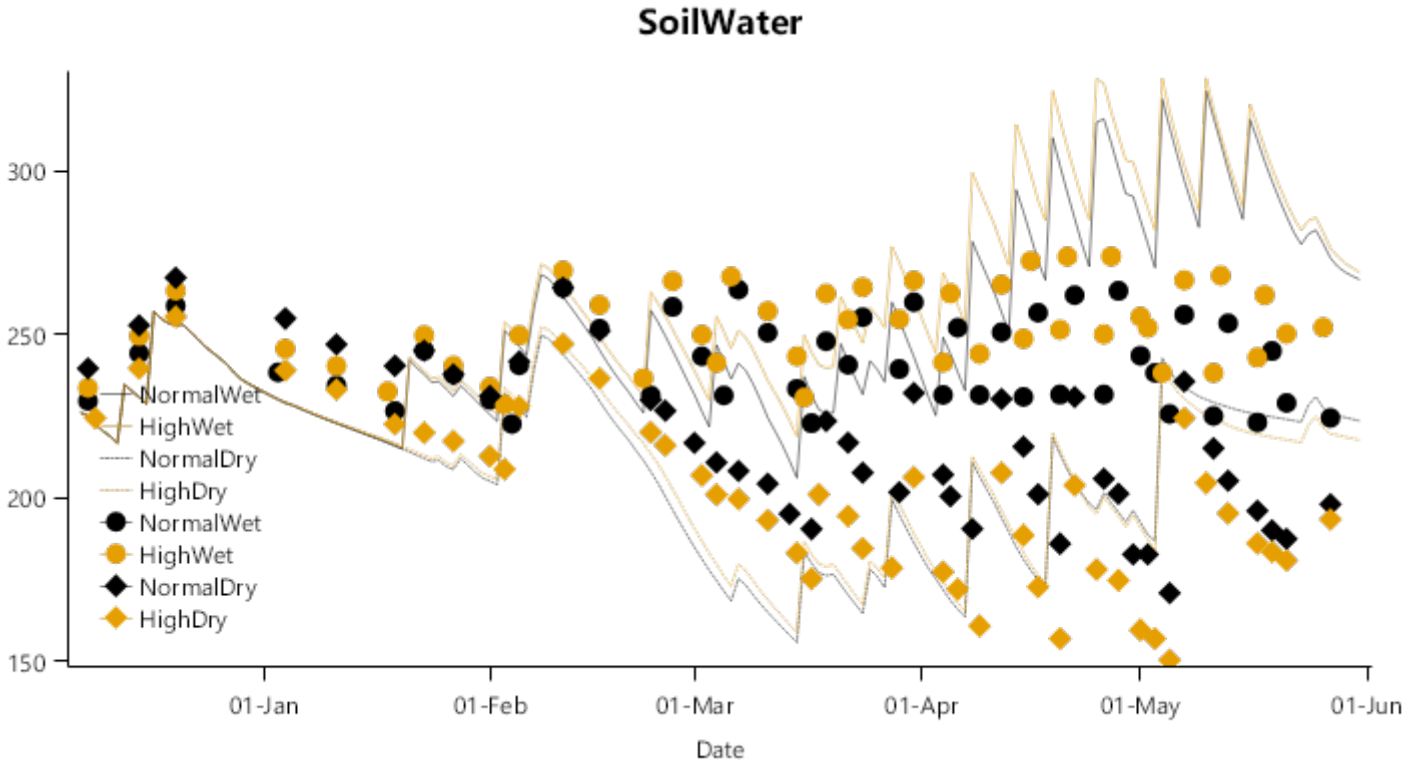
N Stress



GrainWt







2.9 China

2.9.1 ChinaFlux

Yucheng02

Yucheng03

Yucheng04

2.10 Iran

Gorgan05

2.11 Africa

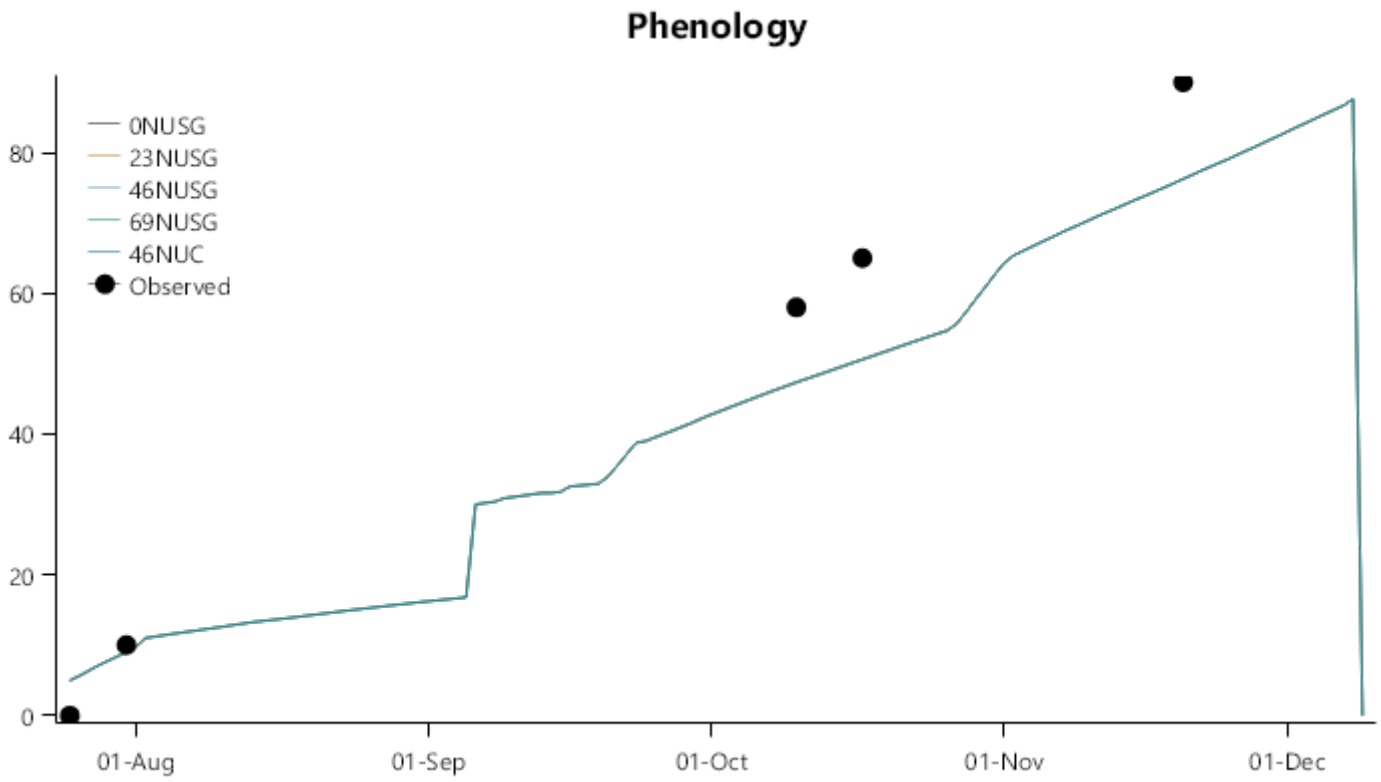
This trial was run in the Jamma district of the Amhara region of the Ethiopia country of the Africa contenentand is described in full by Getu, 2012. 'HAR 1685' Wheat was sown in 20 cm row spacing. Different N fertiliser treatments were applied:

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

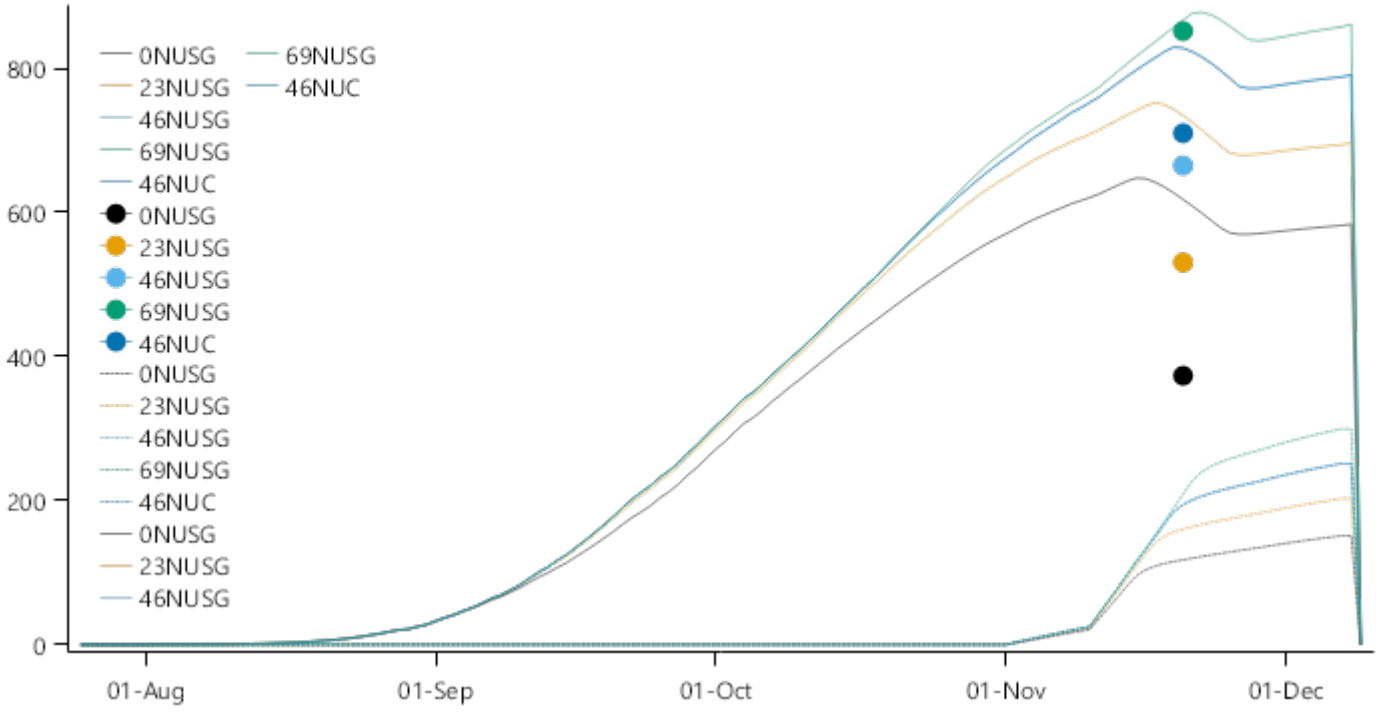
List of experiments.

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

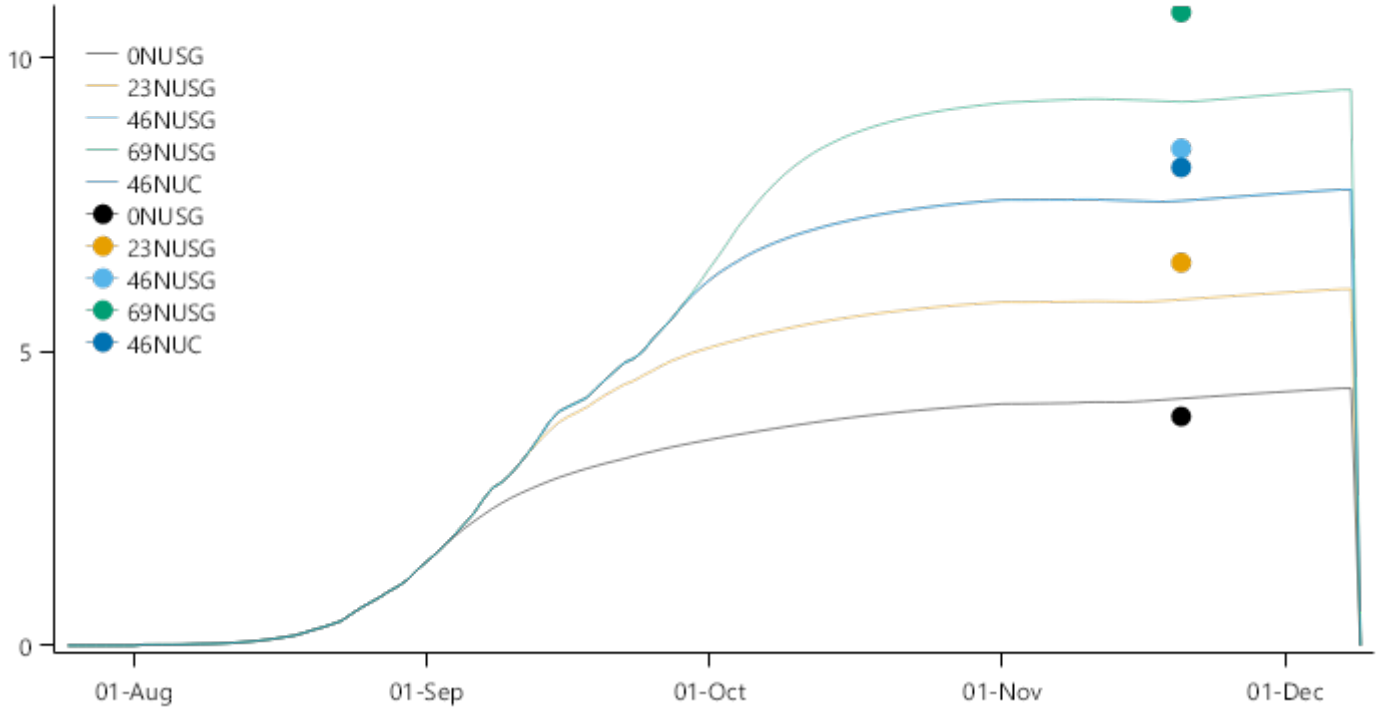
2.11.1 Jamma

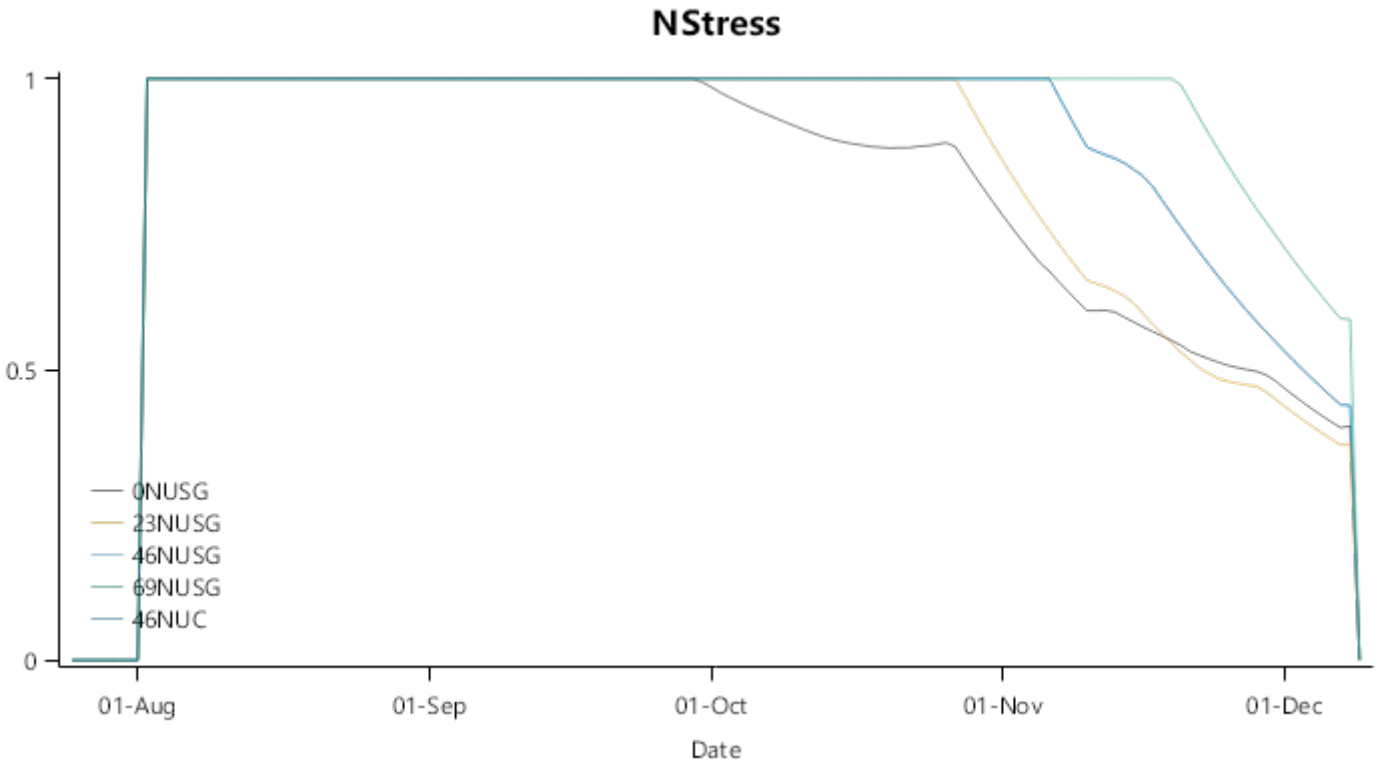


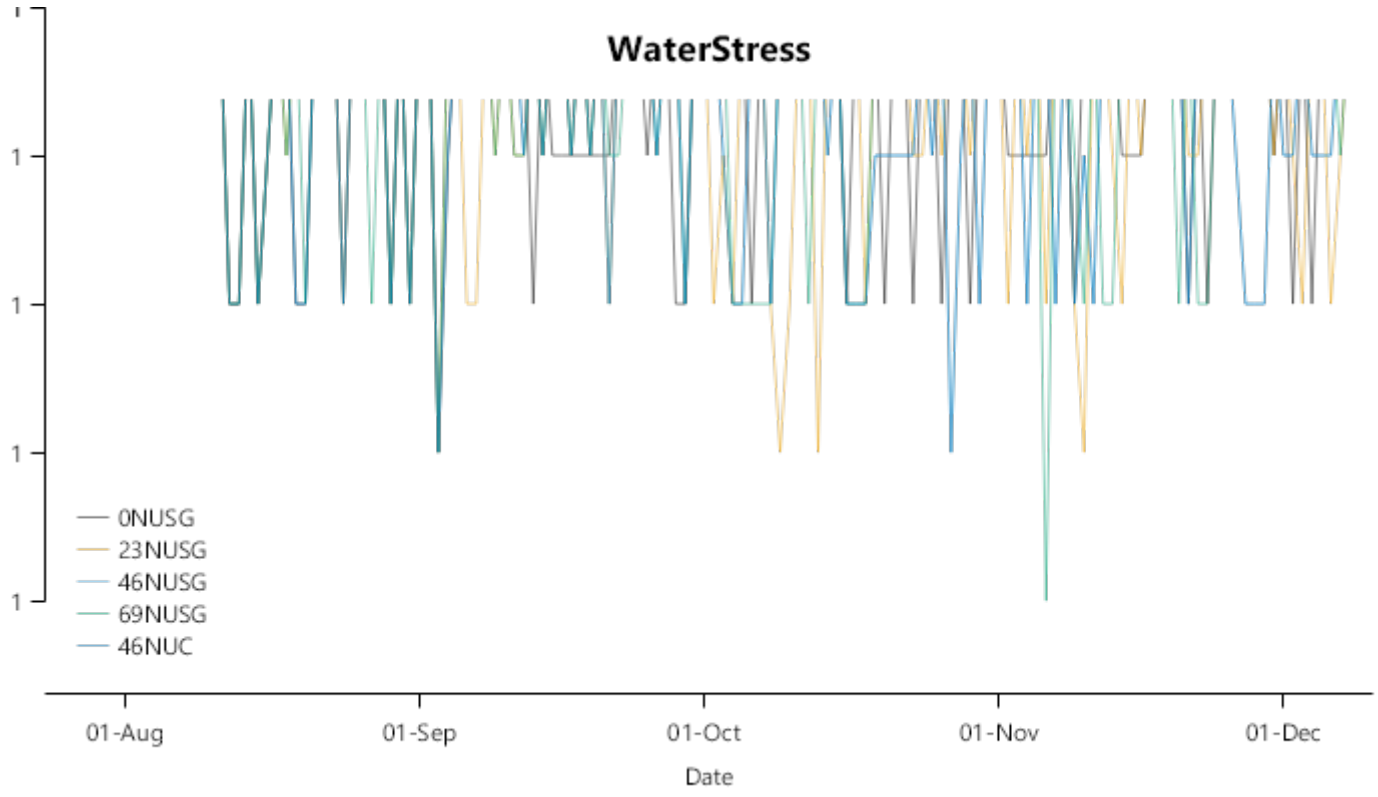
Biomass



BiomassN

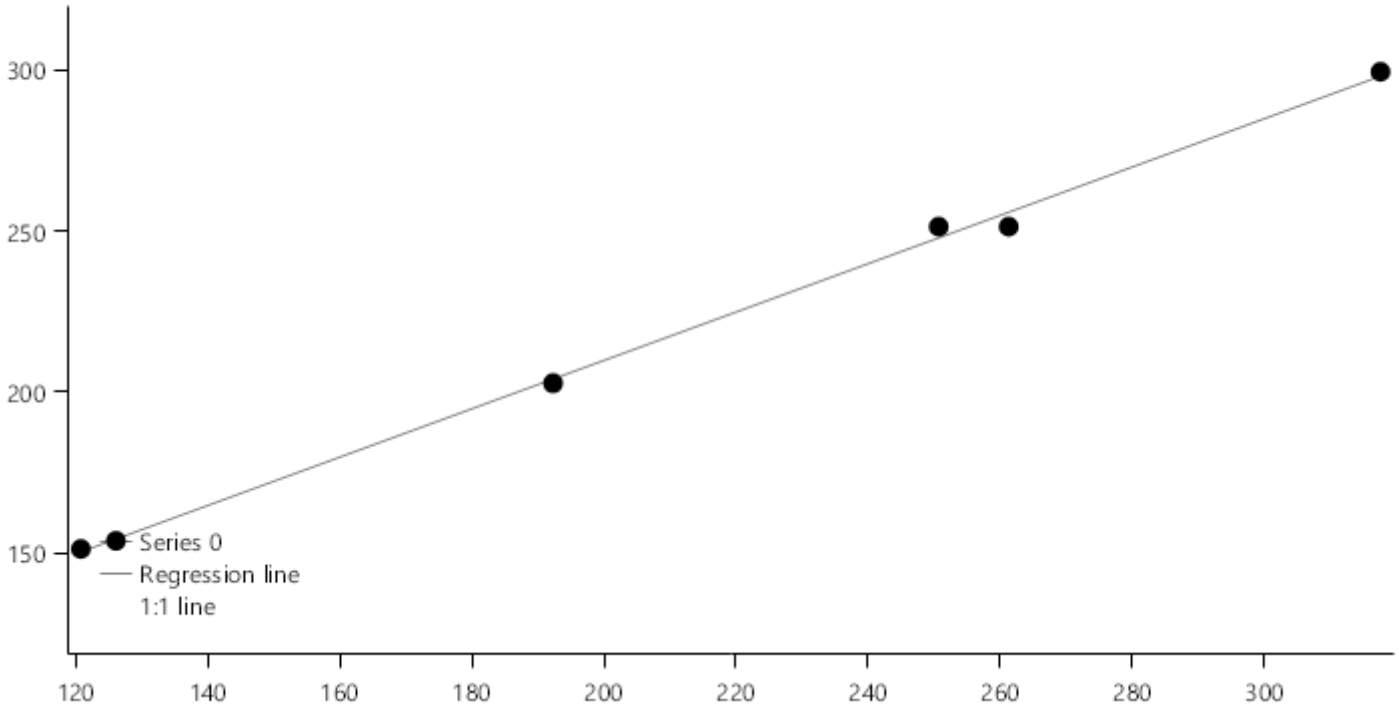


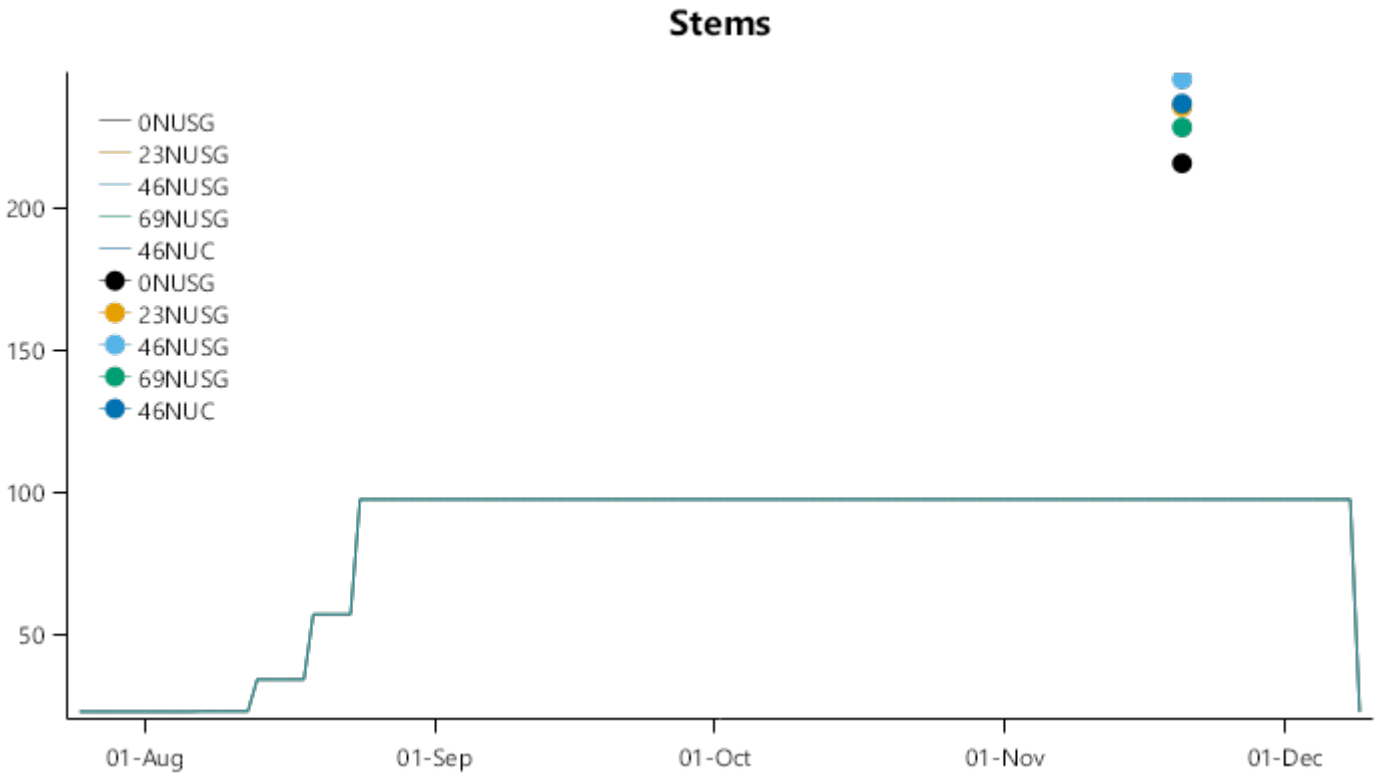

NStress
1
0.5
0
0NUSG
23NUSG
46NUSG
69NUSG
46NUC
01-Aug
01-Sep
01-Oct
01-Nov
01-Dec
Date


WaterStress
1
1
1
1
0NUSG
23NUSG
46NUSG
69NUSG
46NUC
01-Aug
01-Sep
01-Oct
01-Nov
01-Dec
Date

SoilNO3

Harvest Yield

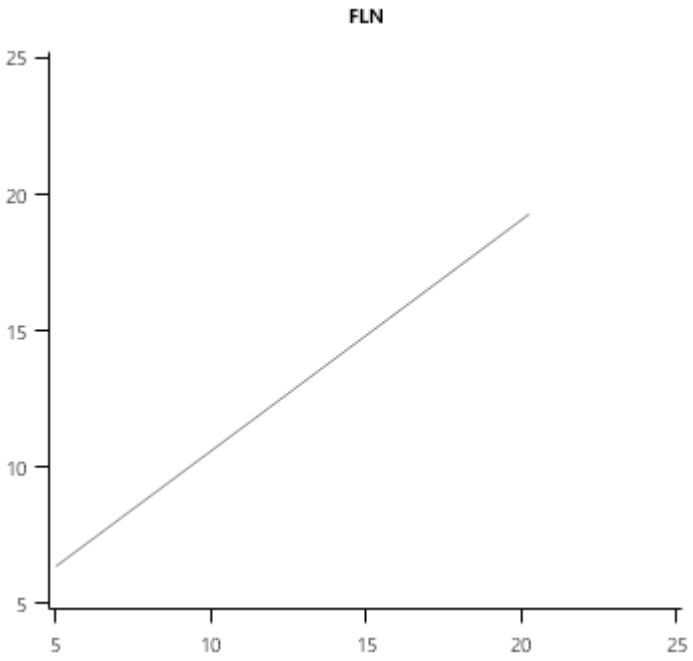




2.12 ControlledEnvironment

List of experiments.

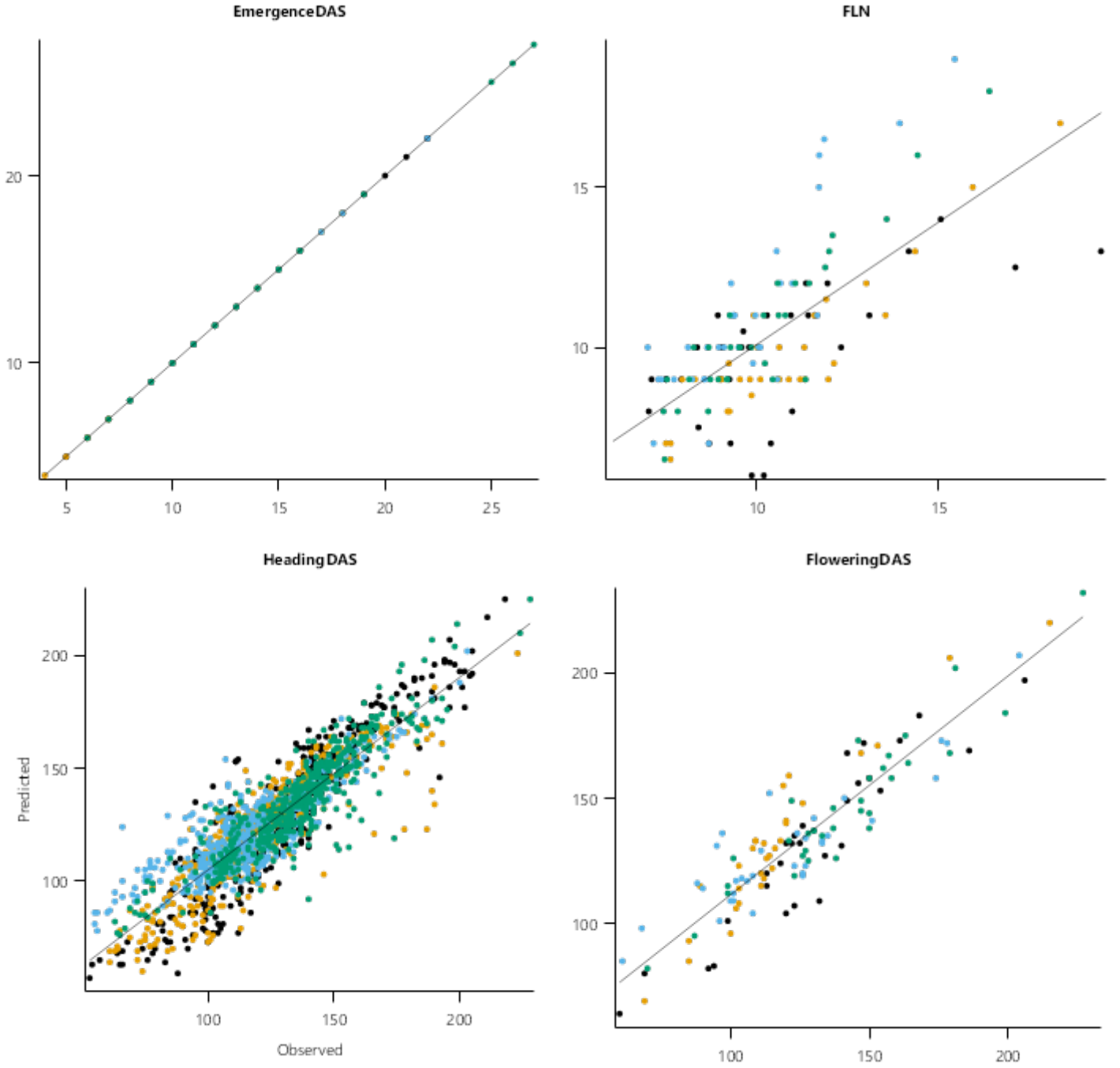
Experiment Name	Design (Number of Treatments)
LaTrobeCE	Treat x CV x Durat (276)
PalmerstonNorthCE	Treat x Cv x Durat (208)
LincolnCE	Treat x Cv x Durat (24)



2.13 NPIField2019

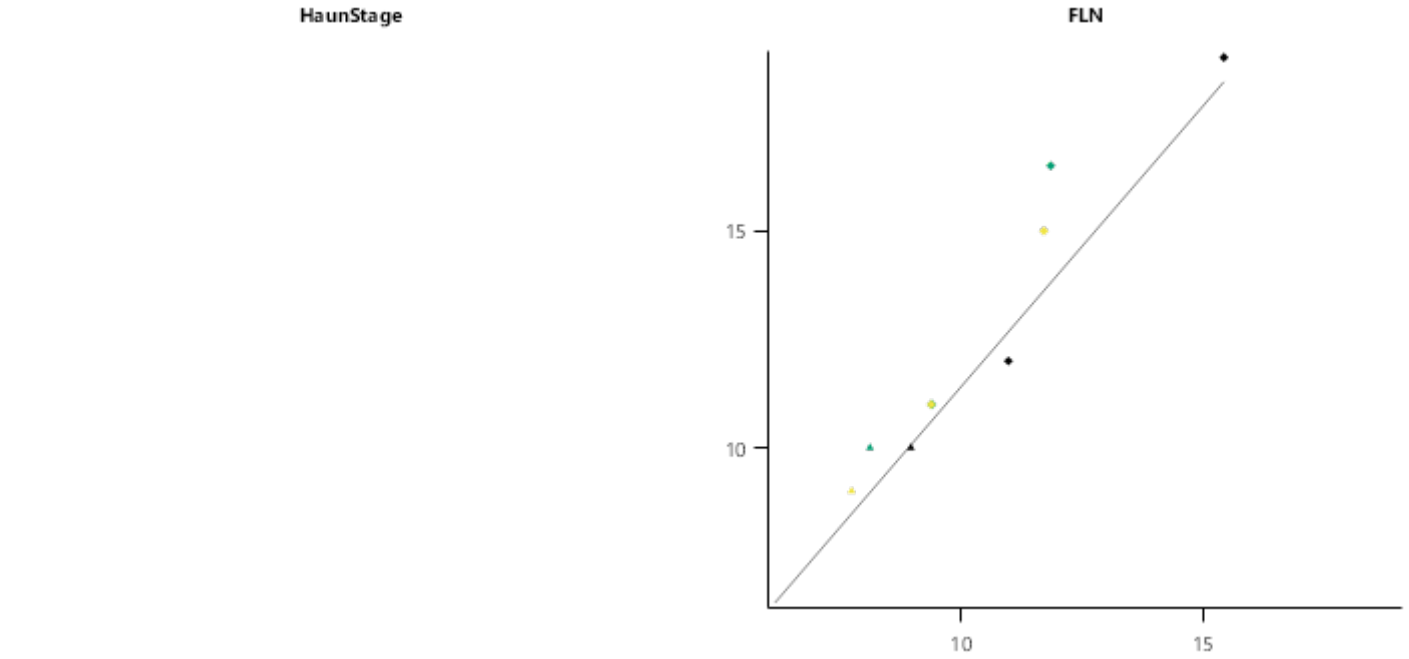
List of experiments.

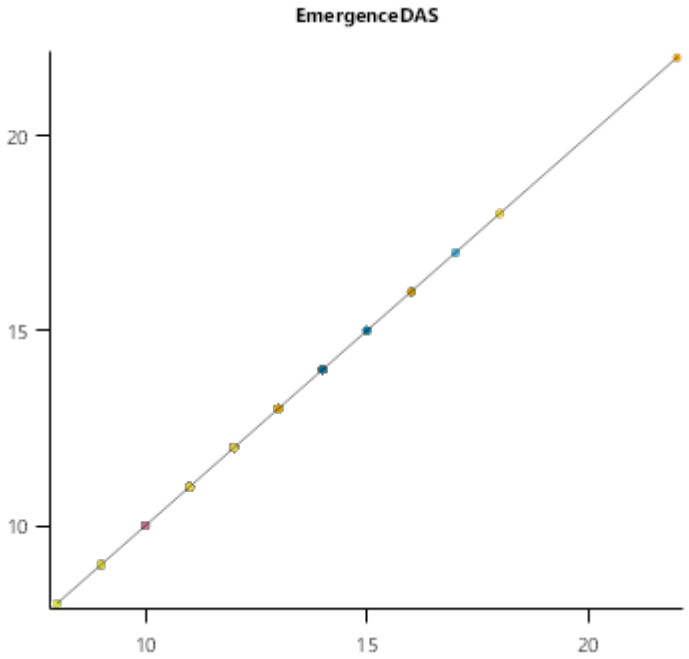
Experiment Name	Design (Number of Treatments)
WaggaWagga	TOS x Cv (512)
Callington	TOS x Cv (512)
Dale	TOS x Cv (512)
YanYean	TOS x Cv (512)



2.13.1 Dale

2.13.1.1 PredObs





2.14 NPIValidation

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)

Experiment Name	Design (Number of Treatments)
12JuneeJames-2-100	Cultivar (2)
12JuneeJames-2-50	Cultivar (1)
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)

Experiment Name	Design (Number of Treatments)
BCVT_Wongan_Hills_1998-06-09	Cultivar (1)
BCVT_Wongan_Hills_2001-06-11	Cultivar (1)
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)

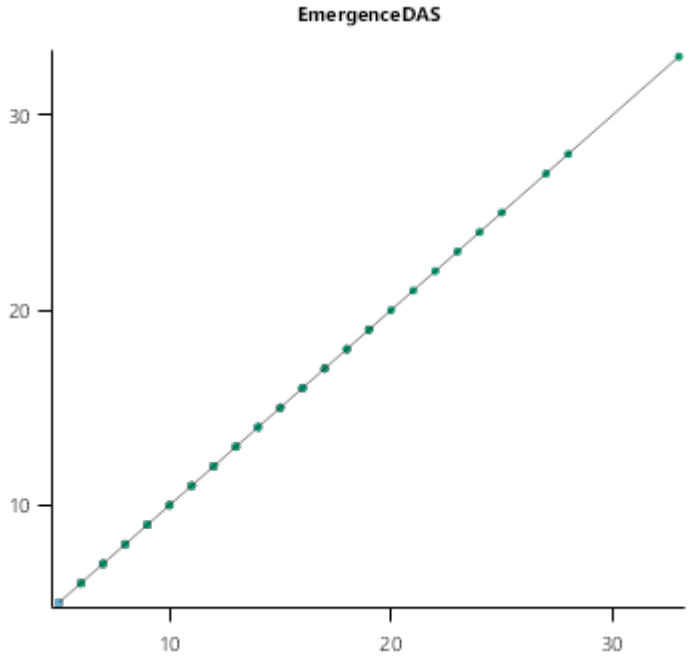
Experiment Name	Design (Number of Treatments)
PTOS_10Kairi-4	Cultivar (7)
PTOS_10Kairi-5	Cultivar (9)
PTOS_10Mackay-1	Cultivar (8)
PTOS_10Mackay-2	Cultivar (8)
PTOS_10Mackay-3	Cultivar (7)
PTOS_10Mackay-4	Cultivar (7)
PTOS_10Mackay-5	Cultivar (9)
HAGT_09Roseworthy-1	Cultivar (2)
HAGT_09Roseworthy-2	Cultivar (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)

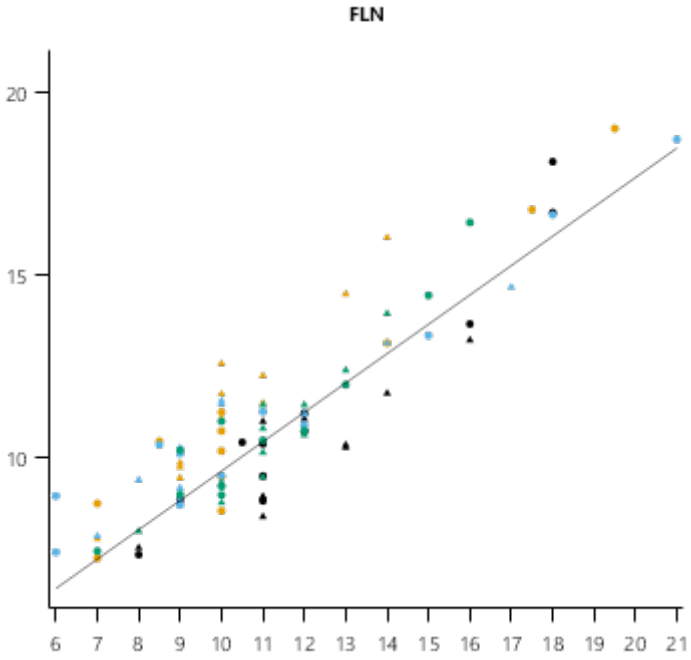
Experiment Name	Design (Number of Treatments)
18HartMESW-TOS3	Cultivar (5)
18HartMESW-TOS4	Cultivar (5)
18LoxtonMESW-TOS1	Cultivar (5)
18LoxtonMESW-TOS2	Cultivar (5)
18LoxtonMESW-TOS3	Cultivar (5)
18LoxtonMESW-TOS4	Cultivar (5)
18MilduraMESW-TOS1	Cultivar (5)
18MilduraMESW-TOS2	Cultivar (5)
18MilduraMESW-TOS3	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)

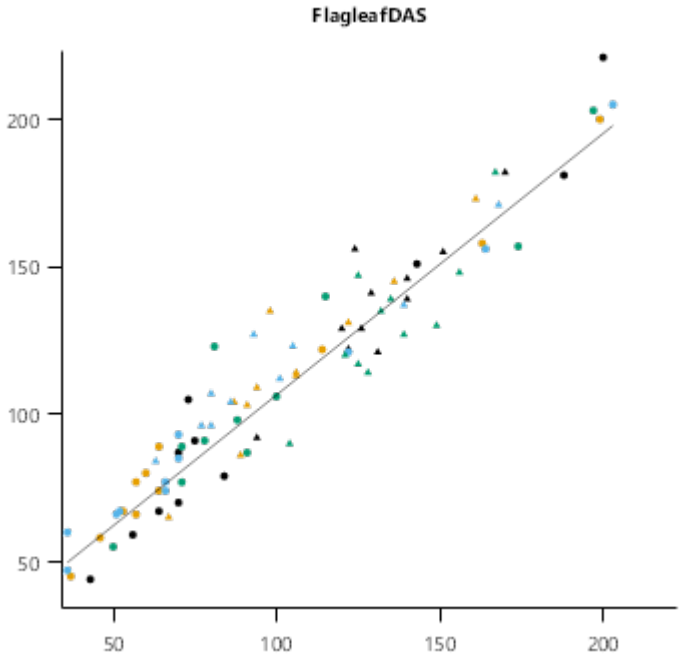
2.15 NPIField2020

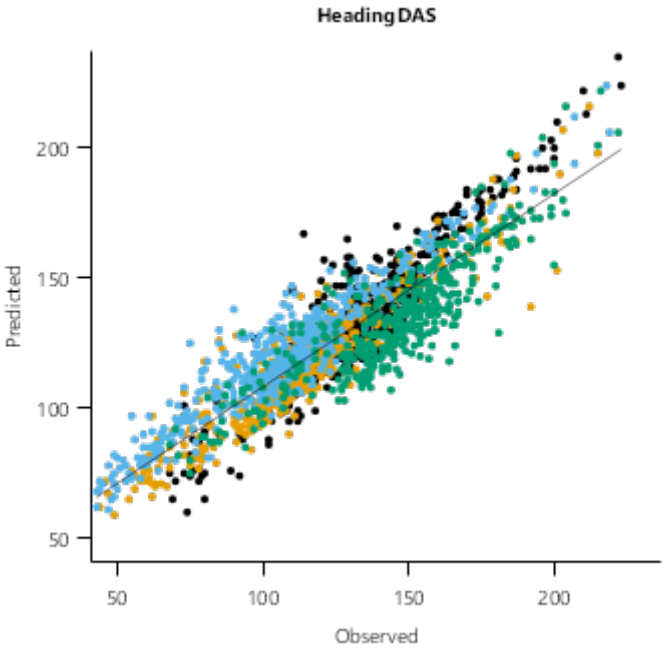
List of experiments.

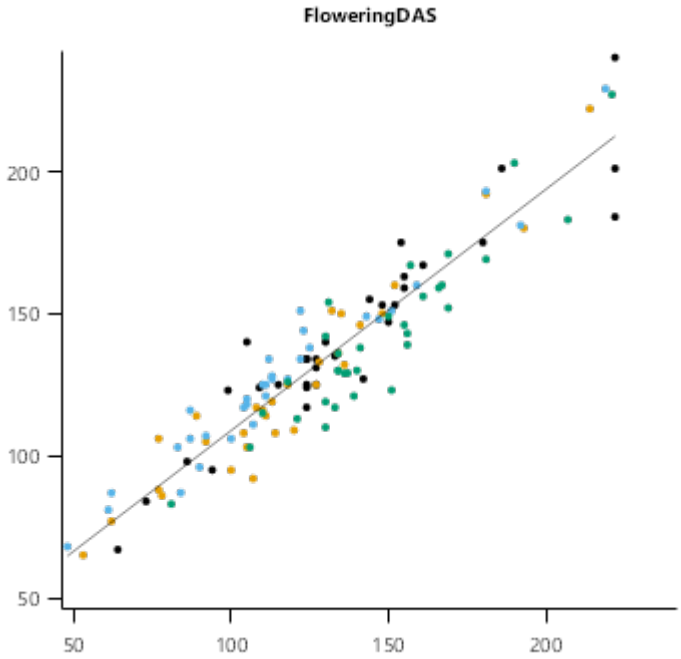
Experiment Name	Design (Number of Treatments)
WaggaWagga2020	TOS x Cv (504)
Urrbrae2020	TOS x Cv (504)
Dale2020	TOS x Cv (504)
YanYean2020	TOS x Cv (441)





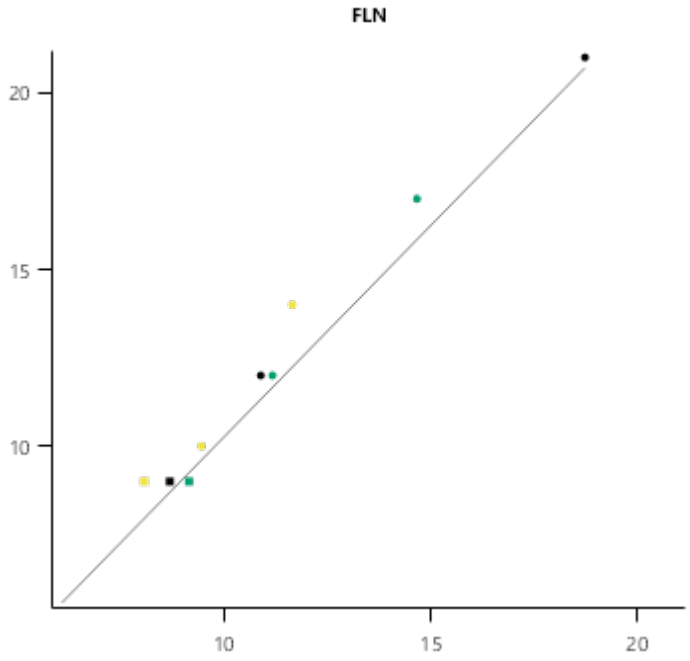


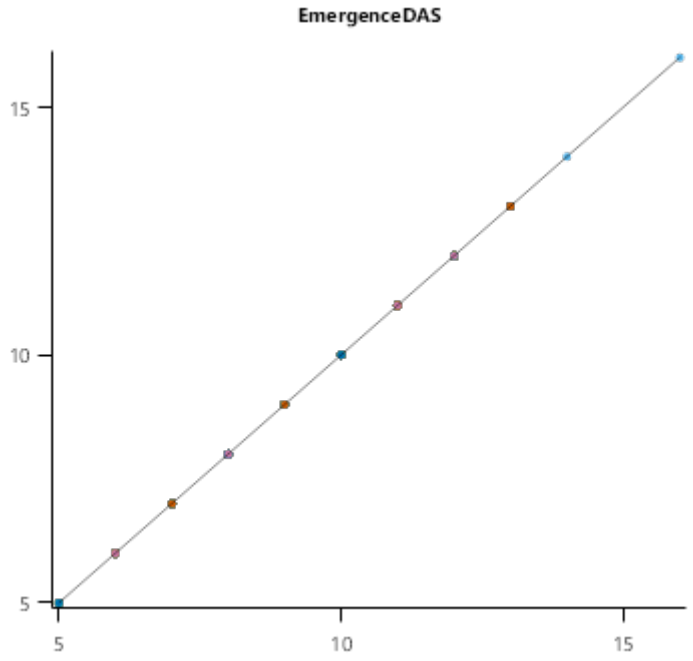


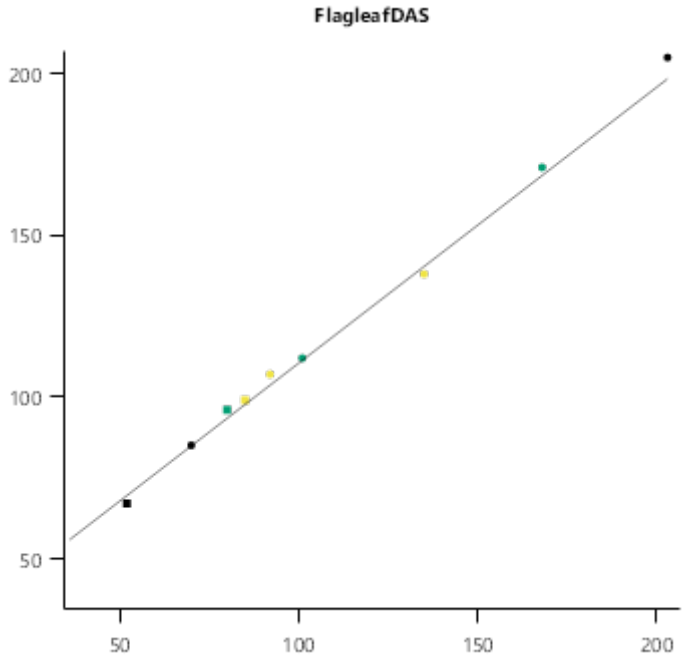


2.15.1 Dale2020

2.15.1.1 PredObs







3 Sensibility

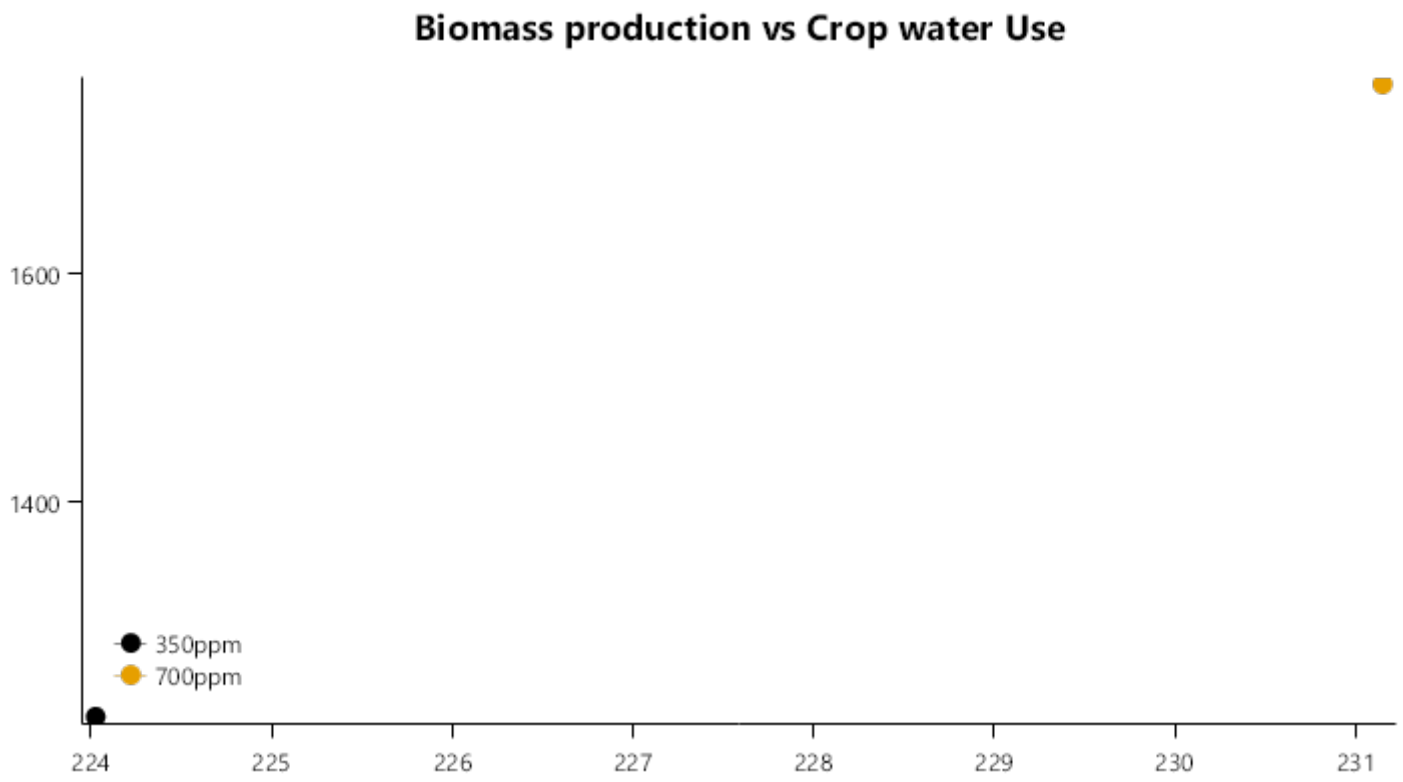
3.1 CO2AndTranspirationEfficiency

List of experiments.

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

3.1.1 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.



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