UNIVERSITÀ DEGLI STUDI DI PALERMO

AGRICULTURE VICTORIA

In-field automatable tools for the determination of plant physiological responses and fruit quality parameters in ‘September Bright’ nectarines subjected to deficit irrigation strategies

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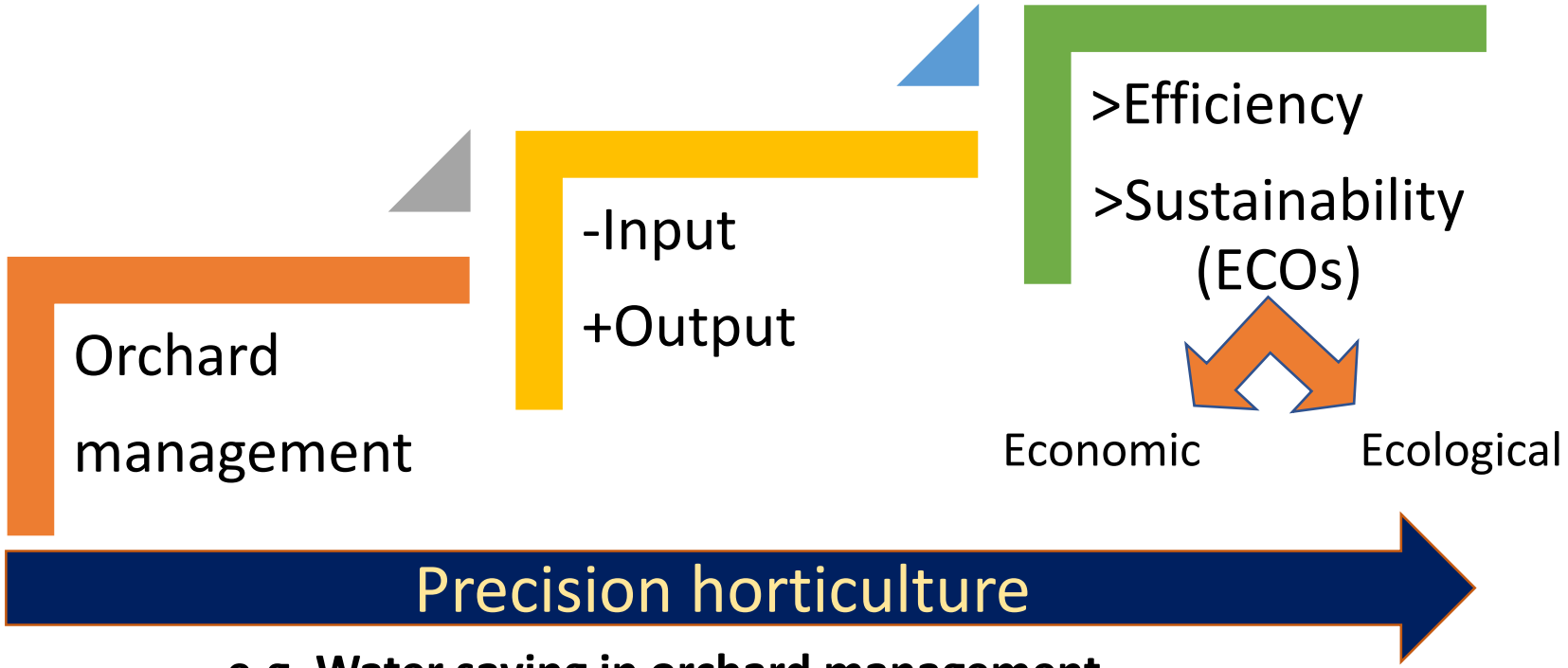
Background



e.g. Water saving in orchard management

*Estimate correctly **when** and **how much** water to provide with irrigation based on plant water status, rather than on soil water content/status.*

Are there any methods for continuous determination of tree water status?

HYPOTHESES

- Continuous fruit growth rates and leaf turgor pressure dynamics change under different irrigation treatments in nectarines.
- Deficit irrigation applied at different fruit growth stages differently affect tree physiology

OBJECTIVES

- Find out the most sensitive continuous indicator of water deficit.
- Test portable, non-destructive devices for in-field determination of leaf and fruit composition

RESEARCH QUESTIONS

- Are fruit growth and leaf turgor pressure related to each other?
- Can we associate fruit growth and leaf turgor pressure to midday stem water potential (Ψ_{stem})?
- Are near-infrared (NIR) and fluorescence spectroscopy suitable for in-field non-destructive determination of fruit and leaf composition (e.g. sugars, dry matter and flavonoids)?

Materials & methods

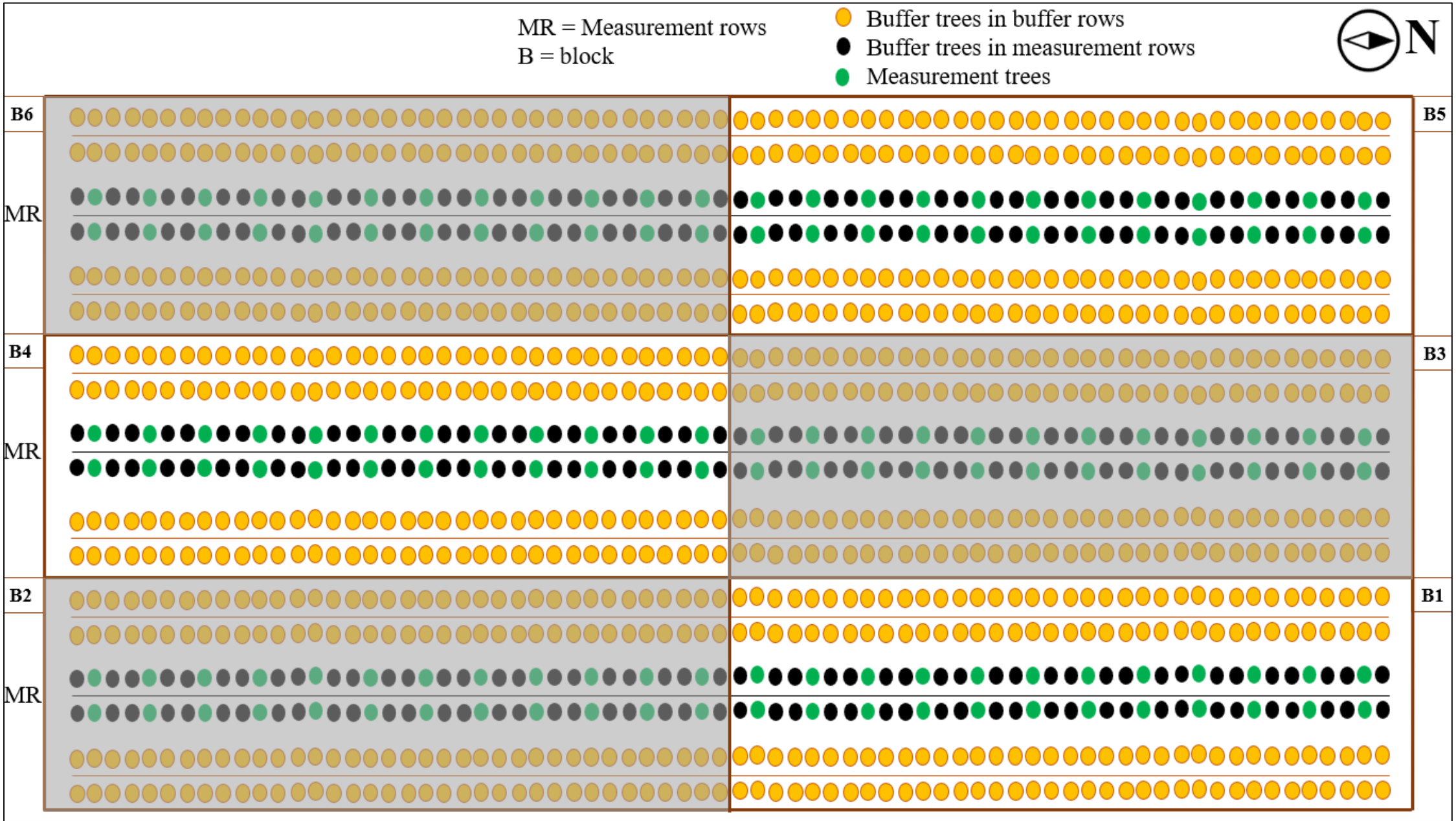
- Open Tatura system
- Drip irrigation

- 144 measurement trees Planting density: 2200 trees/ha
- 4-years-old trees
- ‘September Bright’ nectarines grafted on ‘Elberta’ rootstock
- 6 randomized blocks

Randomized block design

- **6 blocks**
  - 12 irrigation treatments
    - *2 Canopy orientation treatments*

144 measurement trees



Full factorial design (12x2)

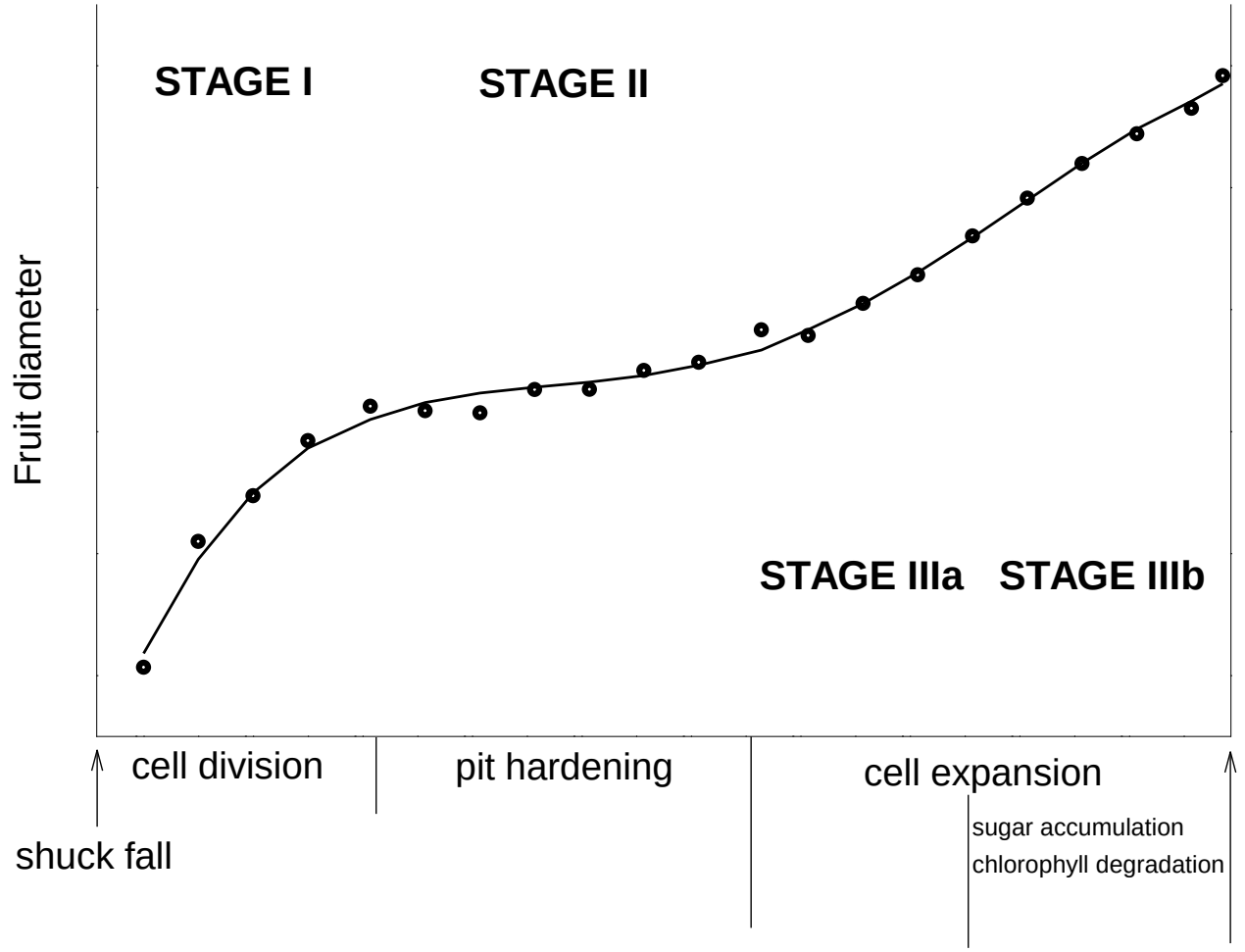
	Fruit growth stages			
	I	II	IIIa	IIIb
Irrigation treatments	0% of ETc	0% of ETc	0% of ETc	0% of ETc
	20% of ETc	20% of ETc	20% of ETc	20% of ETc
	40% of ETc	40% of ETc	40% of ETc	n.a.
	Full irrigation: 100% of ETc			

IRRIGATION TREATMENTS

- 12 treatments

CANOPY ORIENTATION TREATMENTS

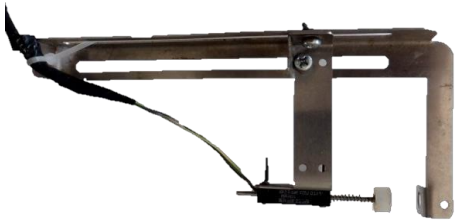
- 2 treatments (72 West & 72 East trees)



Multiple measurements were taken over time:

- Throughout the day (daily curves)
- At weekly intervals
- At growth stage intervals

Equipment used for field measurements

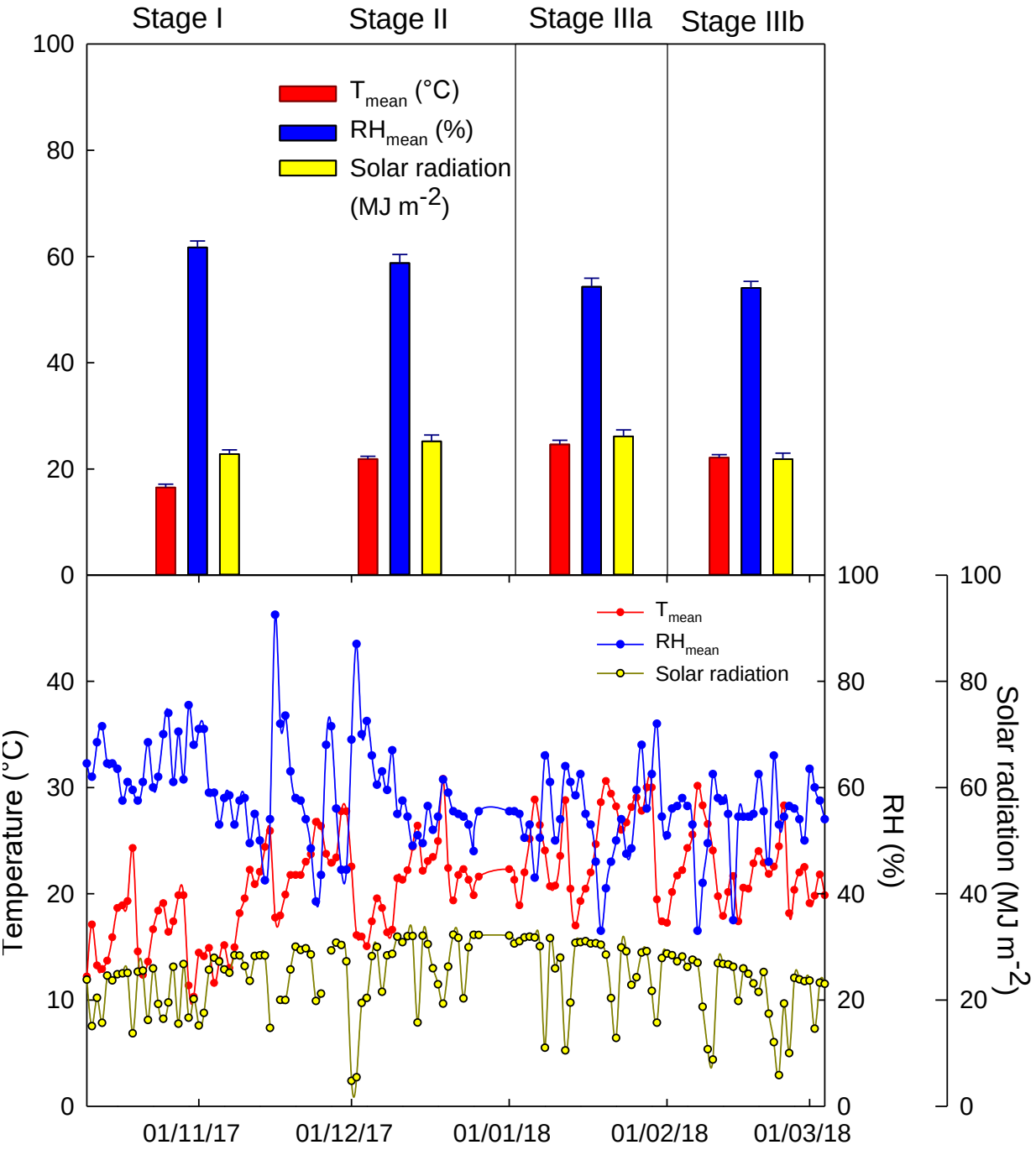


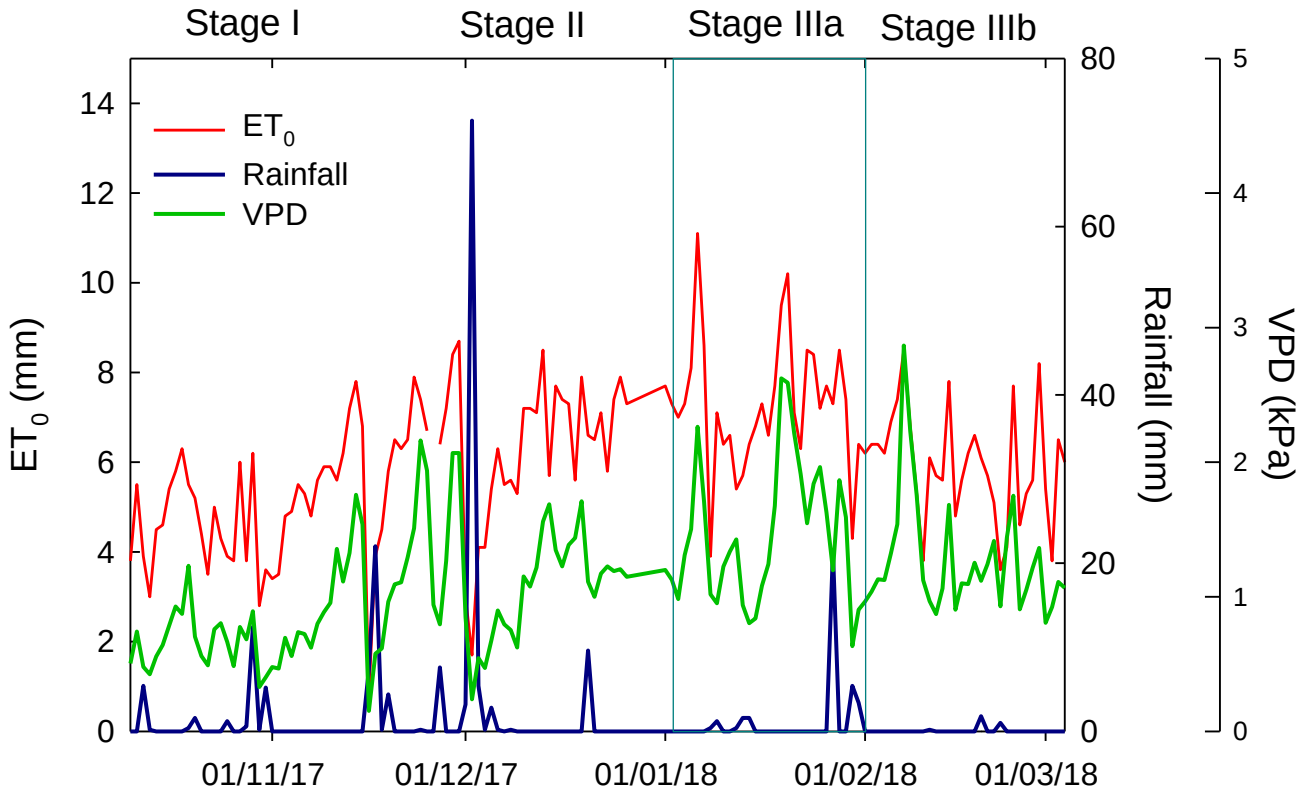
- **Fruit gauges** for continuous measurements of fruit growth
- **Leaf patch clamp pressure (LPCP) probes** for continuous measurements of leaf turgor pressure
- **Calibit** (digital calliper) for fruit diameter measurements
- **DeltaT AP4 dynamic porometer** for leaf stomatal conductance (g_s)
- **Light trolley** and ceptometer for canopy light interception
- **LICOR 6400** for photosynthesis and leaf fluorescence
- **SPAD meter** (SPAD index) for determination of chlorophyll content
- **Pressure chamber** for determination of stem water potential
- **DA-meter** (IAD index) for determination of chlorophyll degradation
- **Felix F-750 NIR portable device** for determination of SSC and DM
- **Multiplex Force-A fluorometer** for determination of flavonoids

Results (presented in red)

- Multiple Vs single winter buds – Influence of previous year irrigation treatments
- Multiple Vs single spring fruitlets – Influence of previous year irrigation treatments
- **Fruit diameter**
- **Effective area of shade (estimate of tree vigour and light interception)**
- **Stomatal conductance (g_s)**
- Trunk cross-sectional area (TCSA)
- Leaf photosynthetic activity (Pn)
- **Efficiency of PSII (ΦPSII)**
- Leaf relative water content (RWC)
- **Stem water potential (Ψ_{stem})**
- Leaf water potential (Ψ_{leaf})
- **SPAD index**
- Yield, fruit weight, crop load and flesh firmness
- IAD index
- **Anthocyanin and flavonol indices in fruit and leaves**
- **SSC and DM**
- Starch and sugars in wood
- **Leaf turgor pressure dynamics**
- **Fruit growth dynamics**

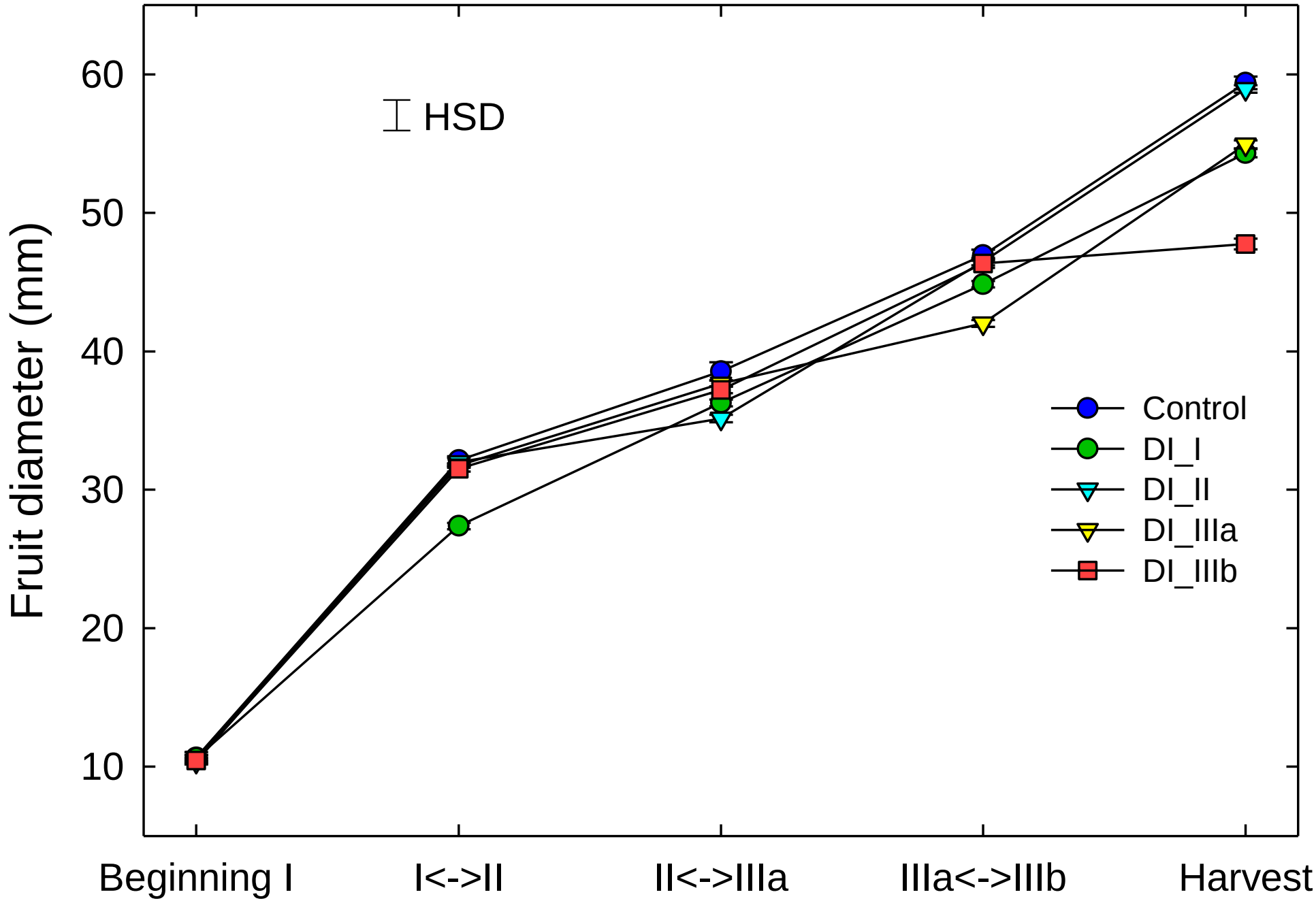
Weather and irrigation



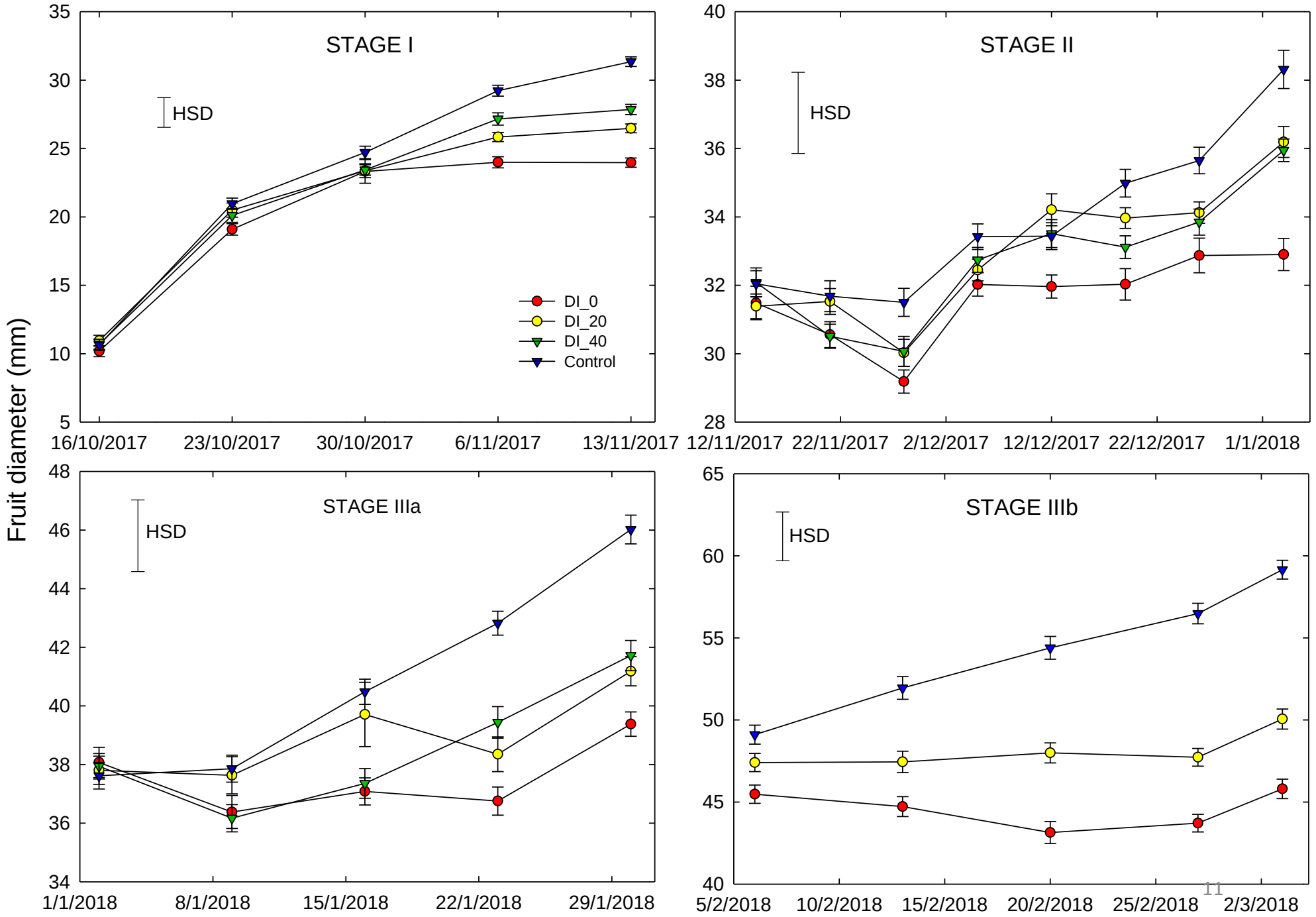


	Rainfall (mm)	Full irrigation (100% of ET_c, mm)	Rainfall + full irrigation (mm)
Stage I	64	73	137
Stage II	141	78	219
Stage IIIa	35	81	116
Stage IIIb	3	83	86
Total	243	315	559

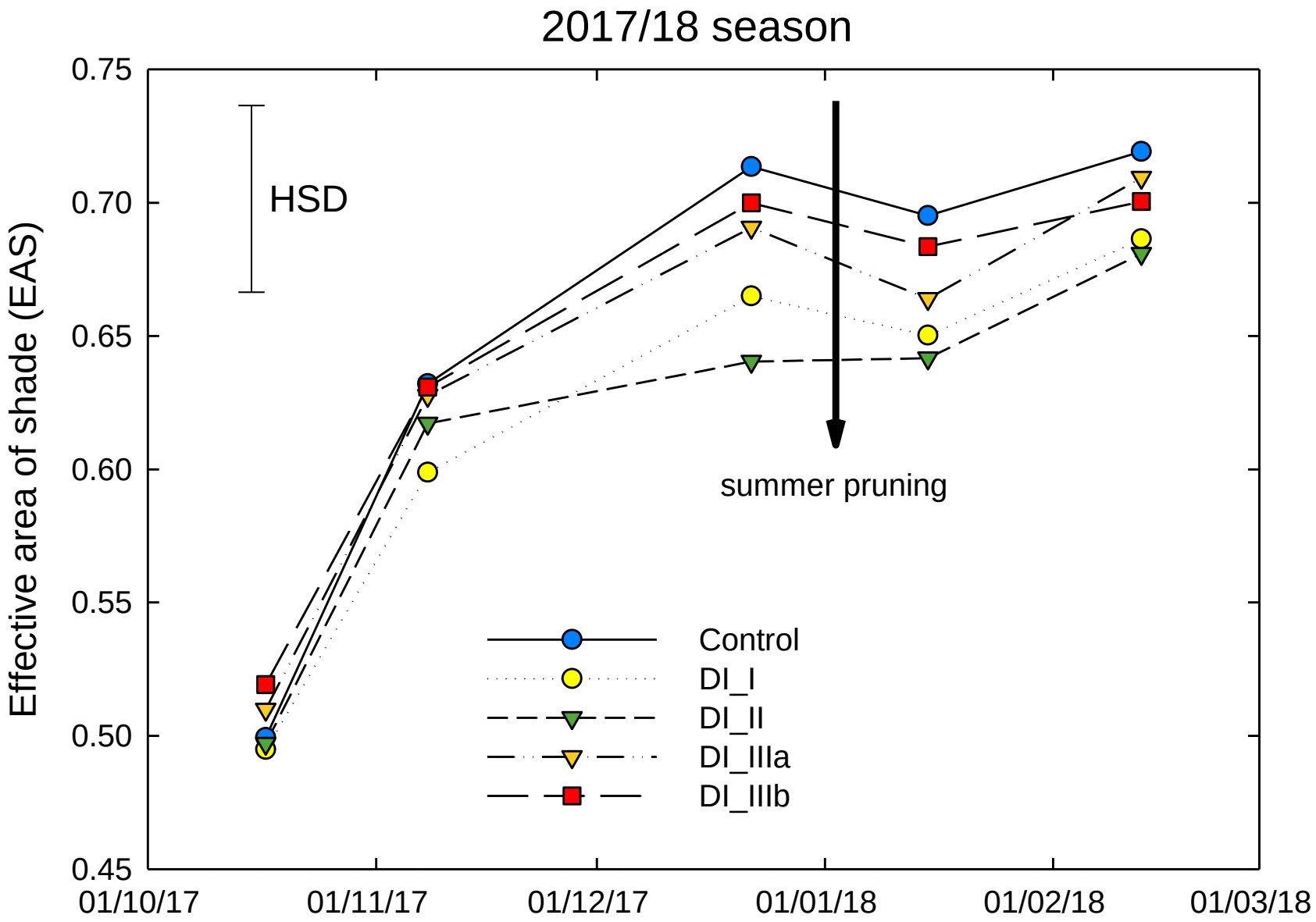
Fruit diameter (irrigation treatments aggregated by stage)



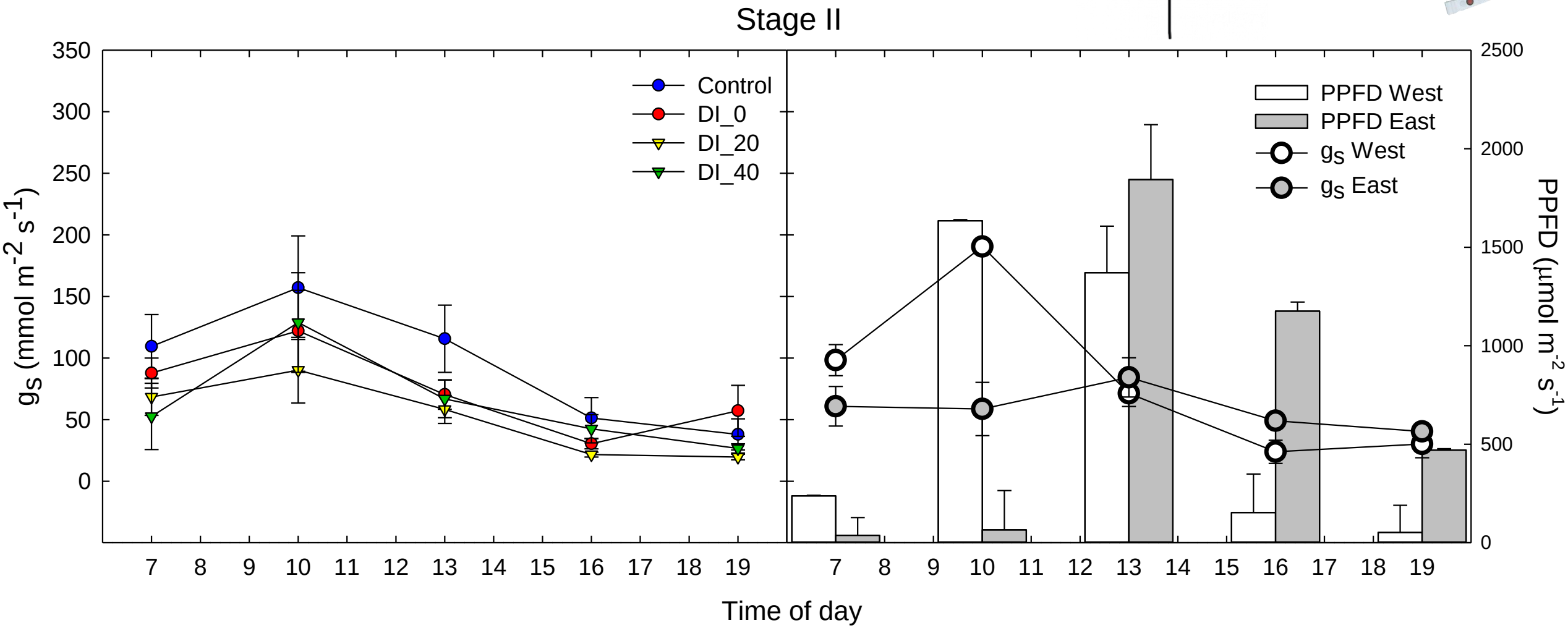
Fruit diameter (in-stage weekly trends)



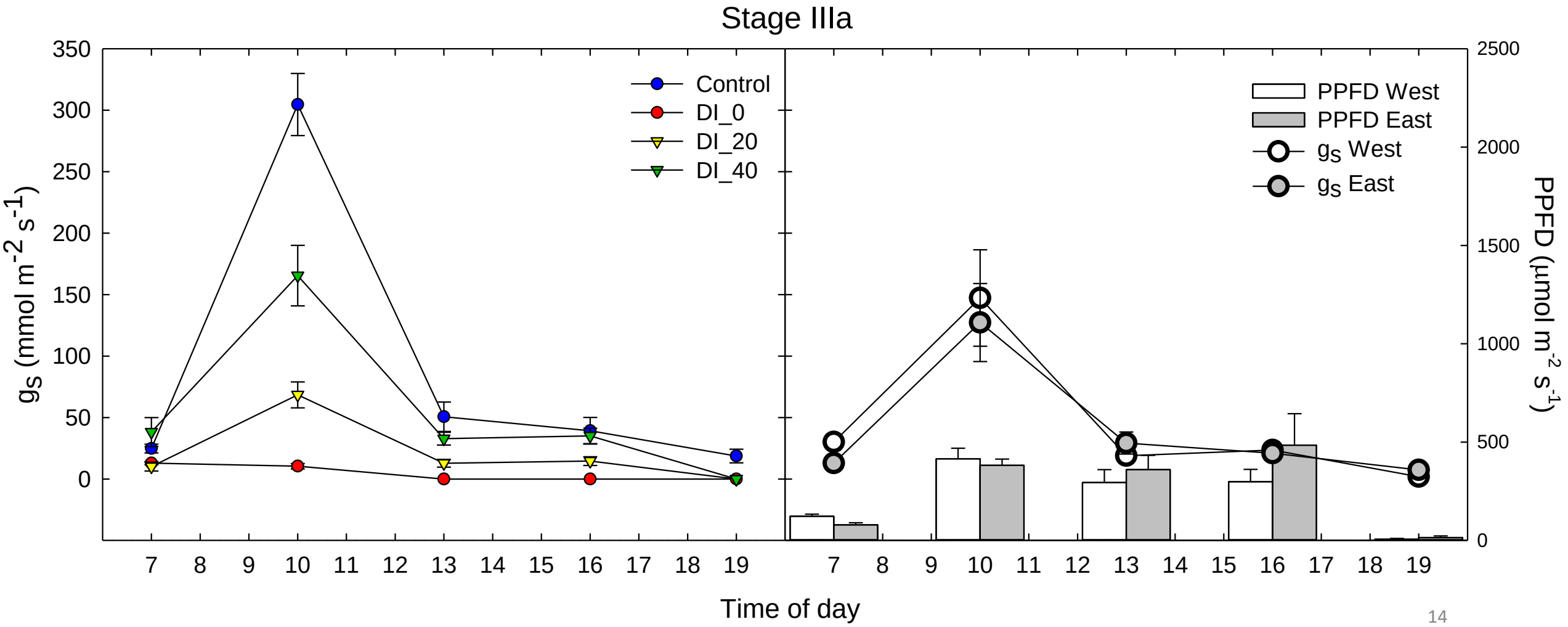
Tree vigour and light interception (Effective area of shade, EAS)



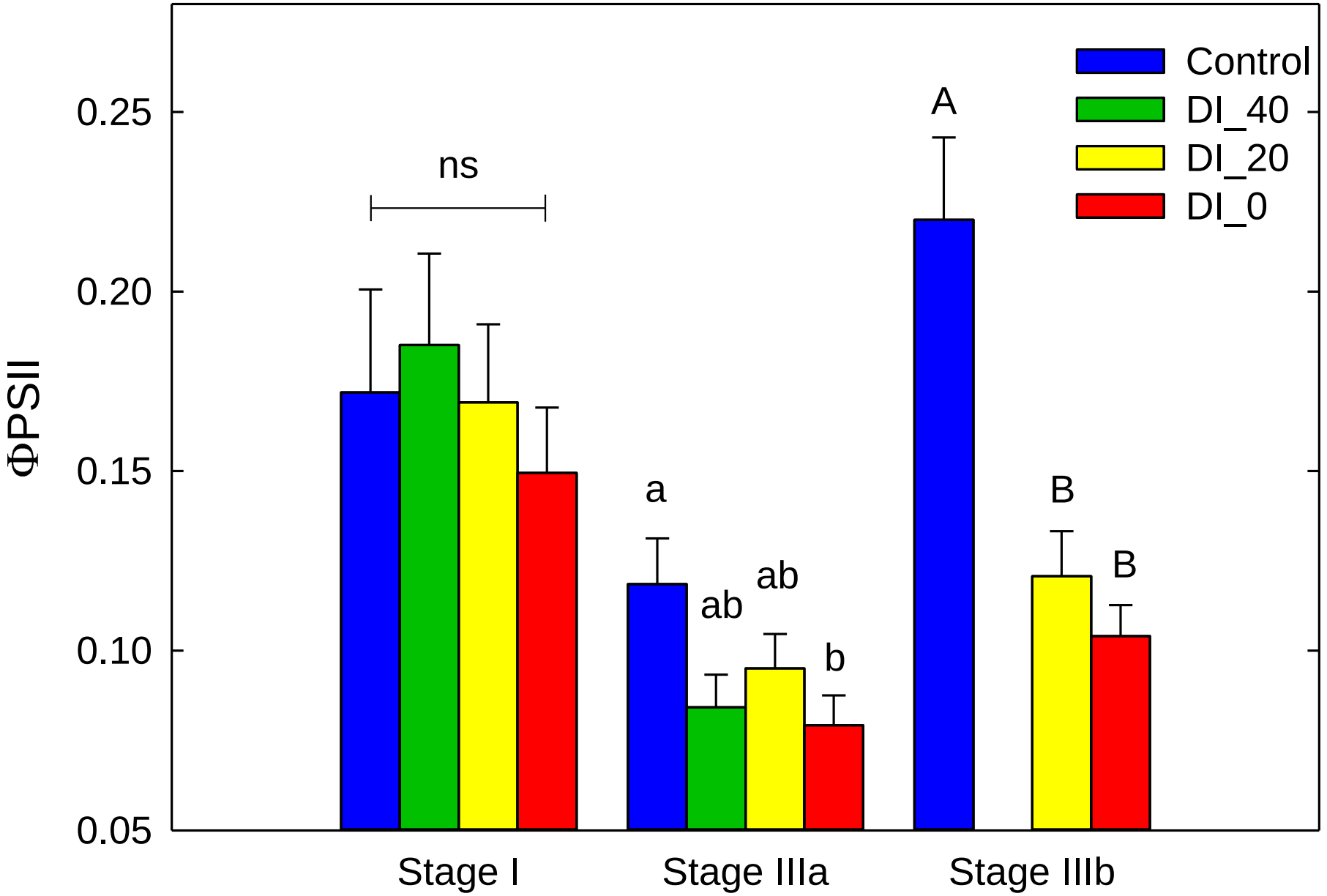
Diurnal stomatal conductance (g_s)



Diurnal stomatal conductance (g_s)

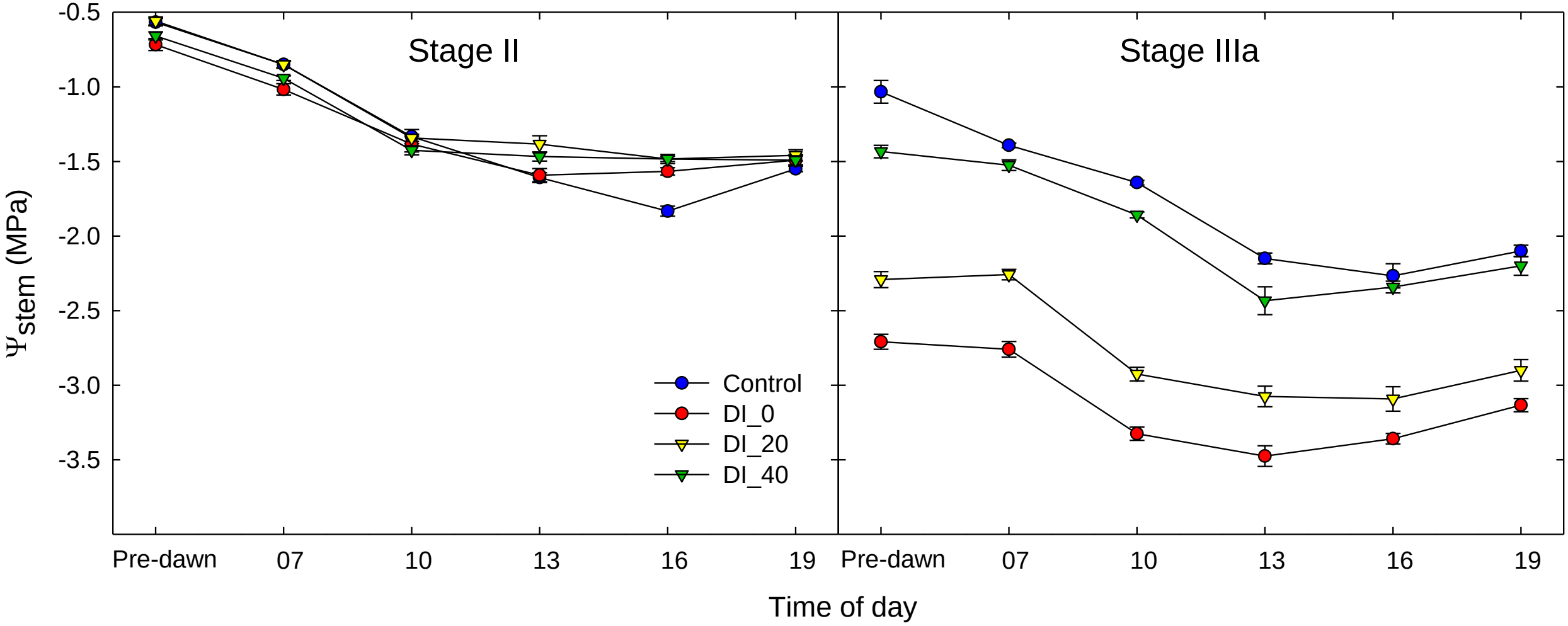


Efficiency of PSII (ΦPSII)



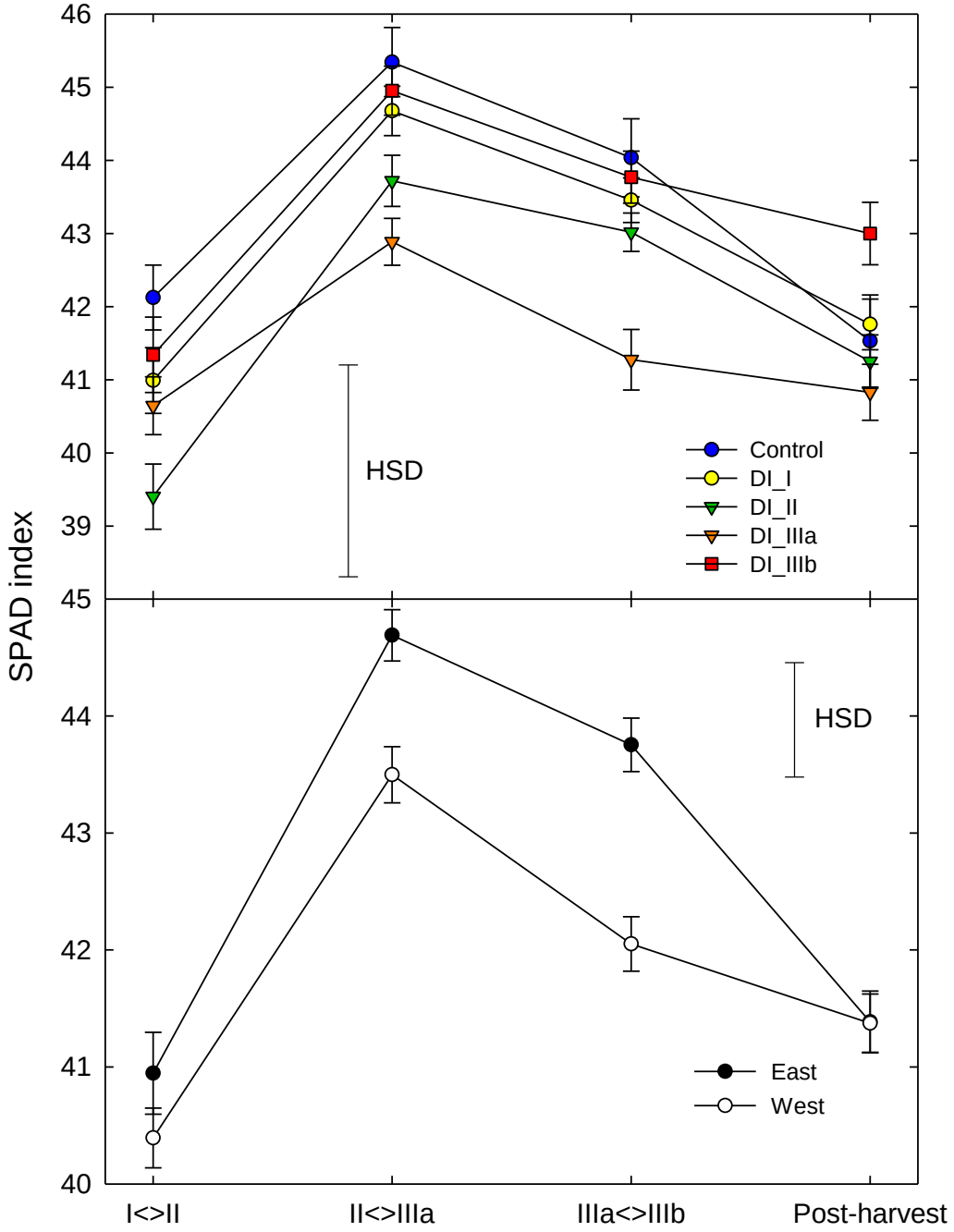
ANOVA and mean separation by Tukey's multiple comparison test
Different letter represent significant differences for $p<0.05$

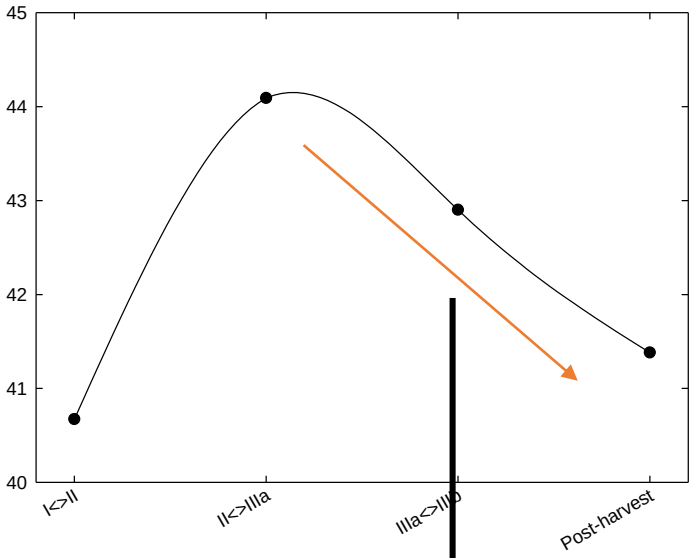
Daily stem water potential (Ψ_{stem}) curve



Error bars represent standard errors.
N of replicates for treatment = 6

SPAD index (i.e. leaf chlorophyll content)





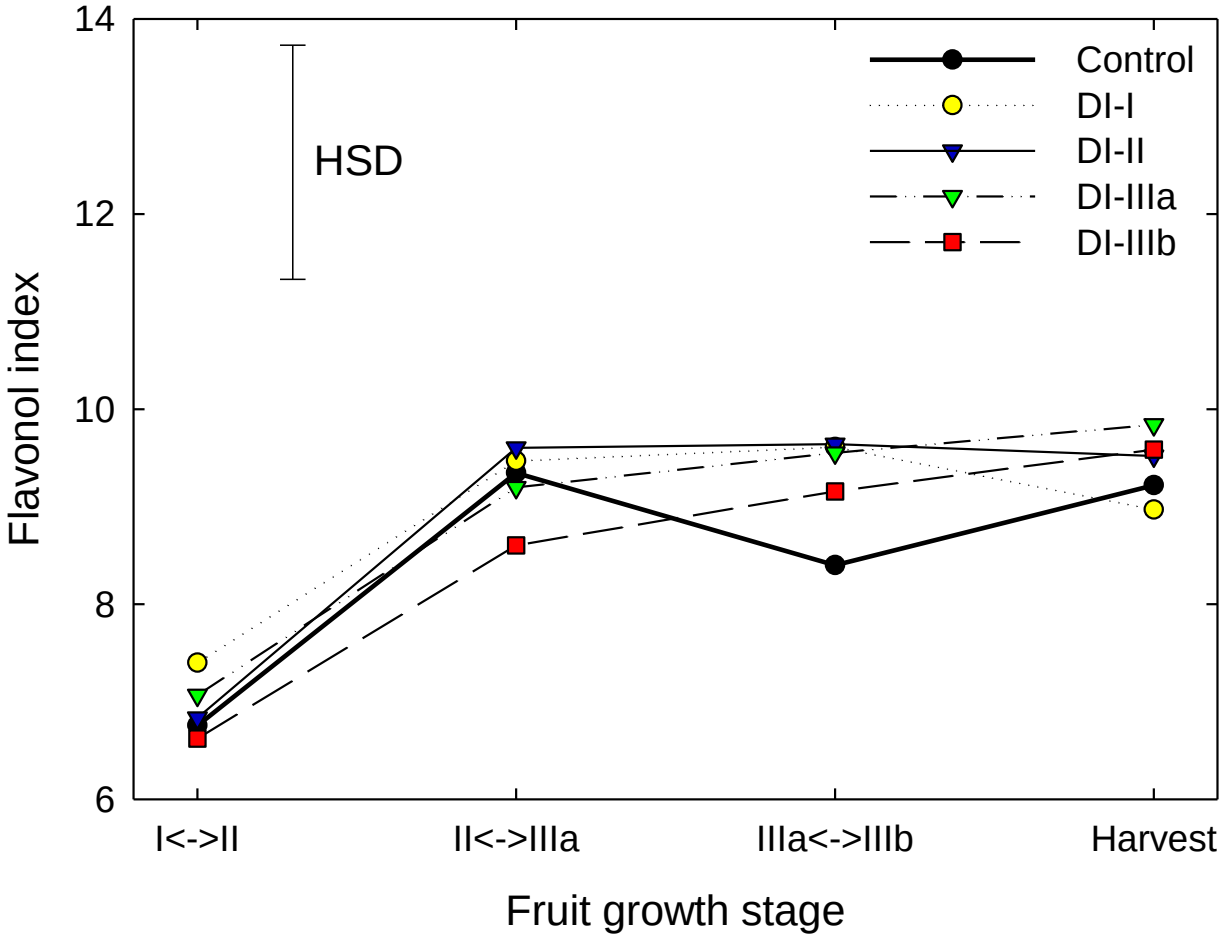
ANOVA:

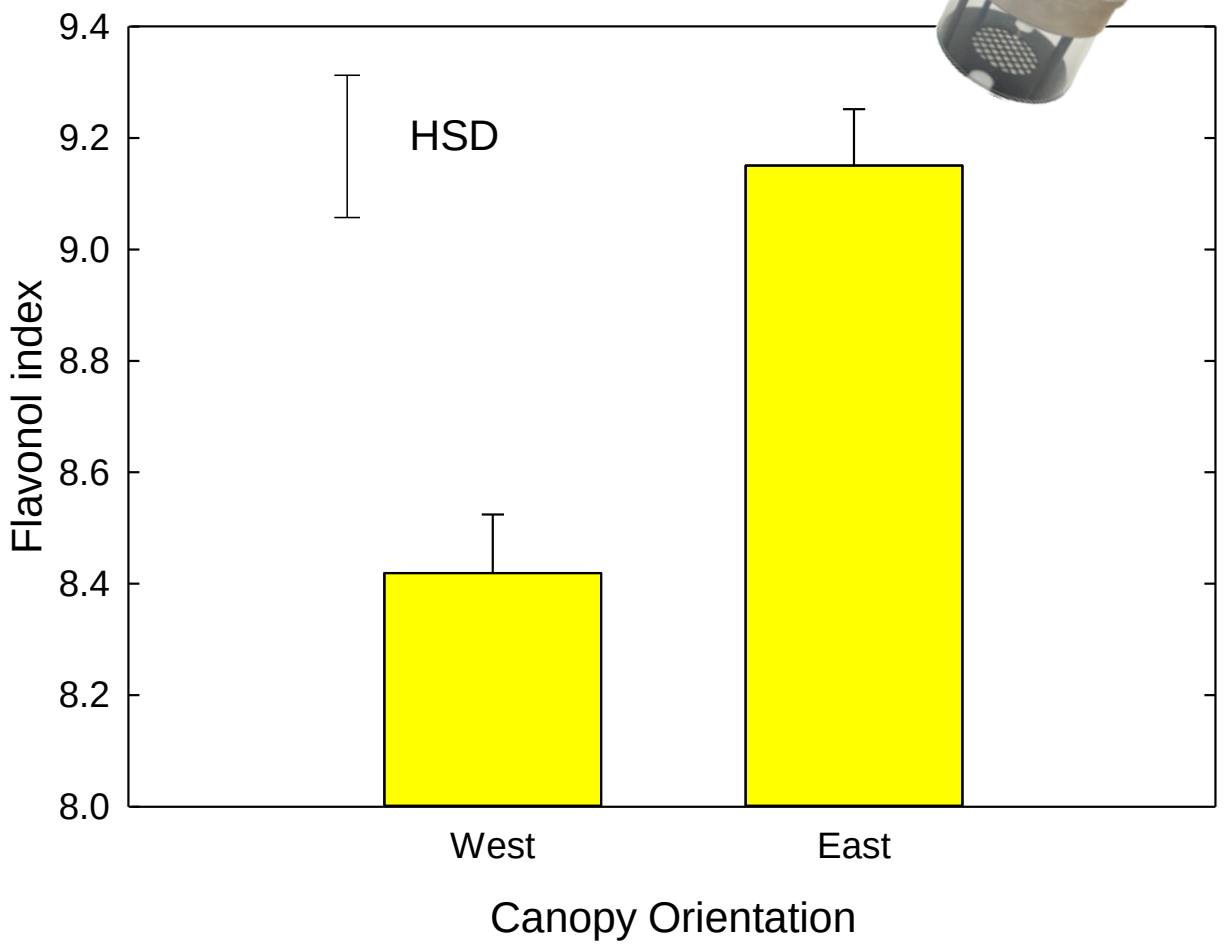
- **Irrigation → p<0.001**
- **Growth stage → p<0.001**
- **Canopy Orientation → p<0.001**
- **Irr Treat * Growth Stage → ns**
- **Canopy orientation * growth stage→ p<0.05**

Error bars represent standard errors.

Chlorophyll likely to be converted into fruit secondary metabolites (i.e. anthocyanins, flavonols, etc)

Fluorometer Multiplex 3 Force A on leaves → flavonol index



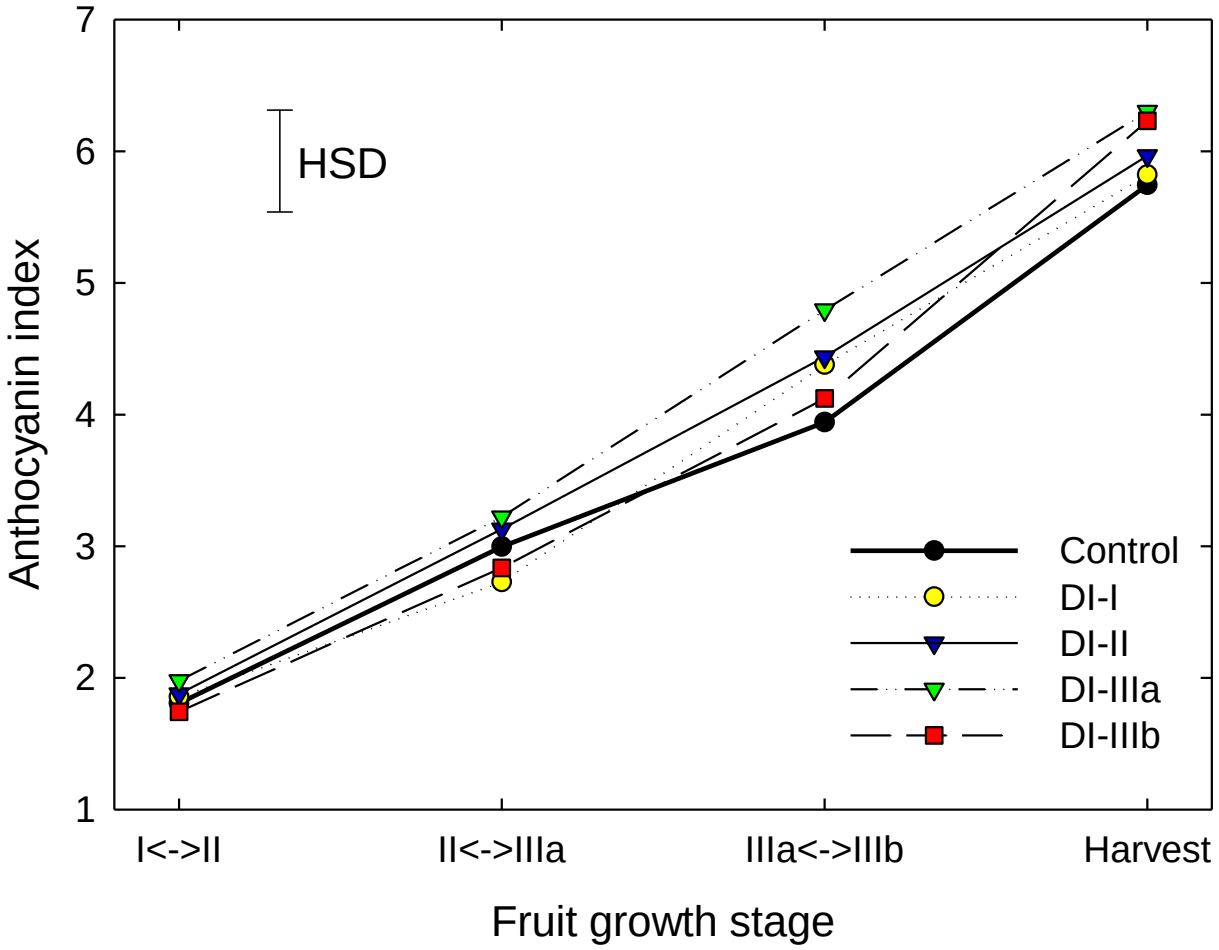


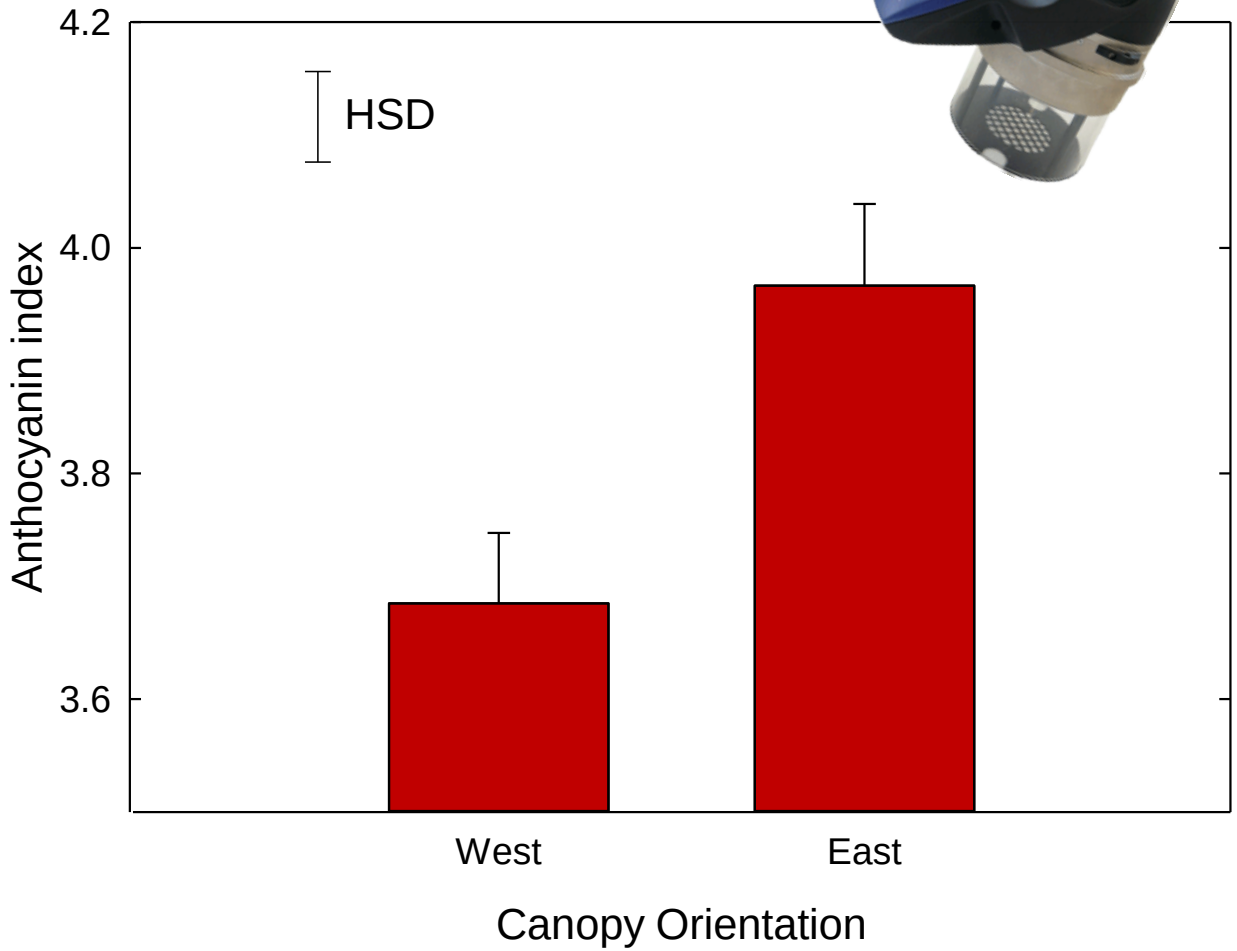
ANOVA:

- **Irrigation Treatment → p<0.001**
- **Growth stage → p<0.001**
- **Irr Treat * Growth Stage → p<0.01**

- **Canopy orientation → p<0.001**
- **Error bars represent standard errors.**

Fluorometer Multiplex 3 Force A on leaves → anthocyanin index



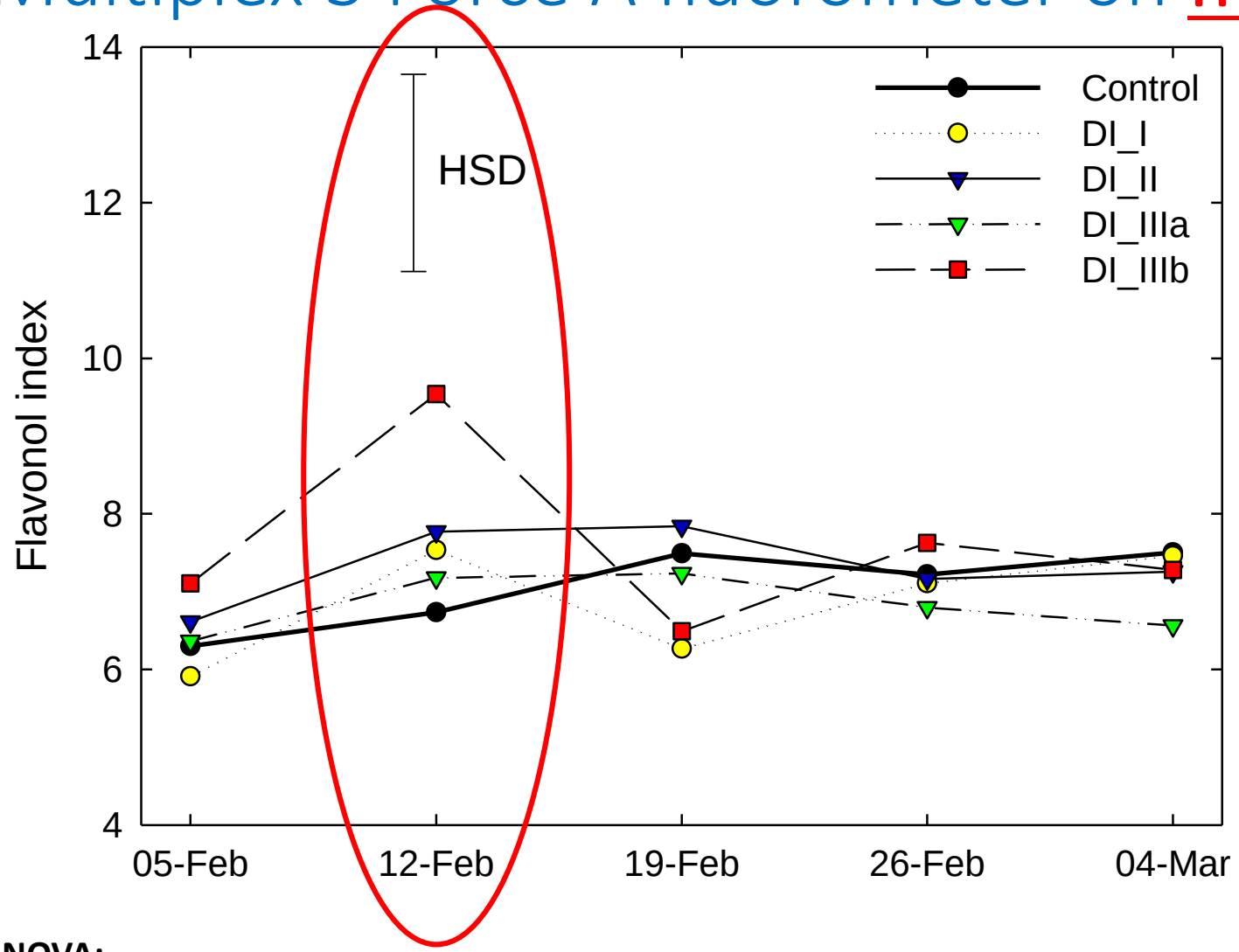


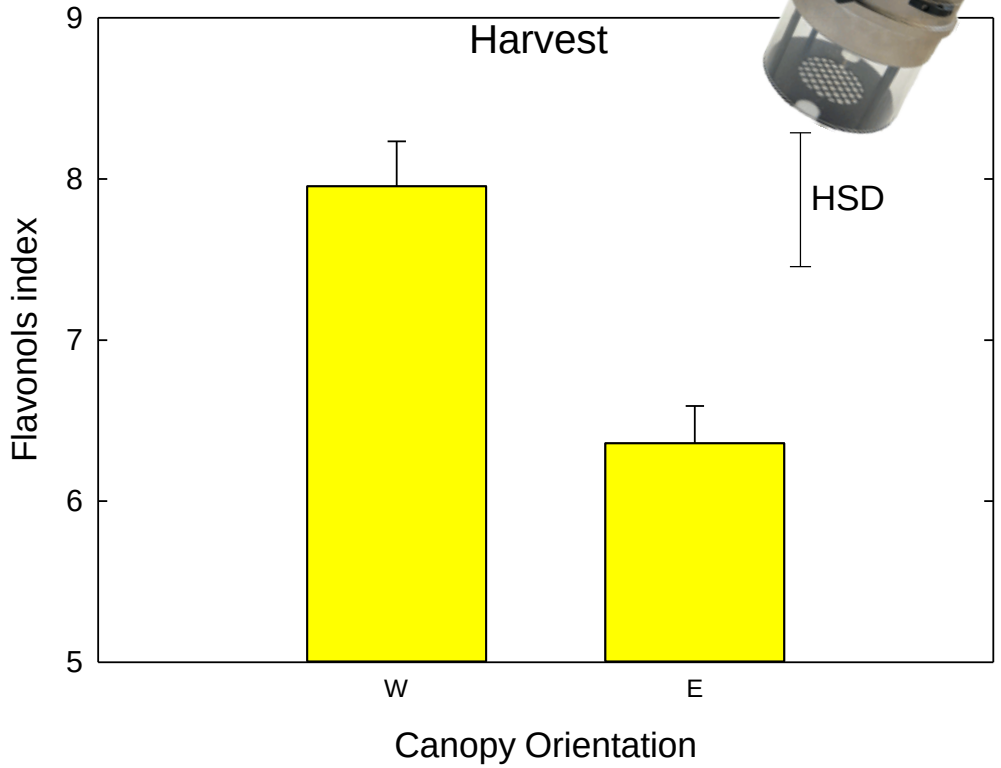
ANOVA:

- **Irrigation Treatment → p<0.001**
- **Growth stage → p<0.001**
- **Irr Treat * Growth Stage → p<0.001**

- **Canopy orientation → p<0.001**
- **Error bars represent standard errors.**

Multiplex 3 Force A fluorometer on fruit → Flavonol index

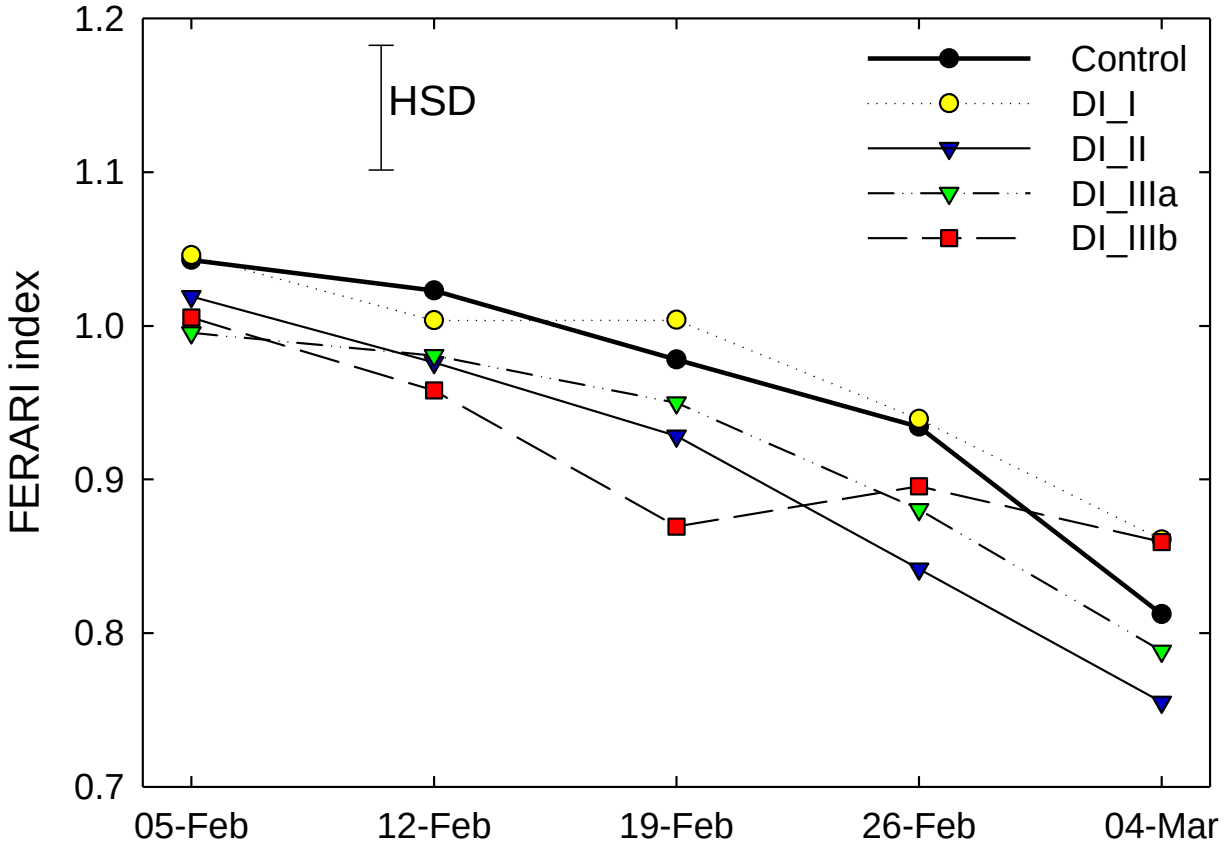


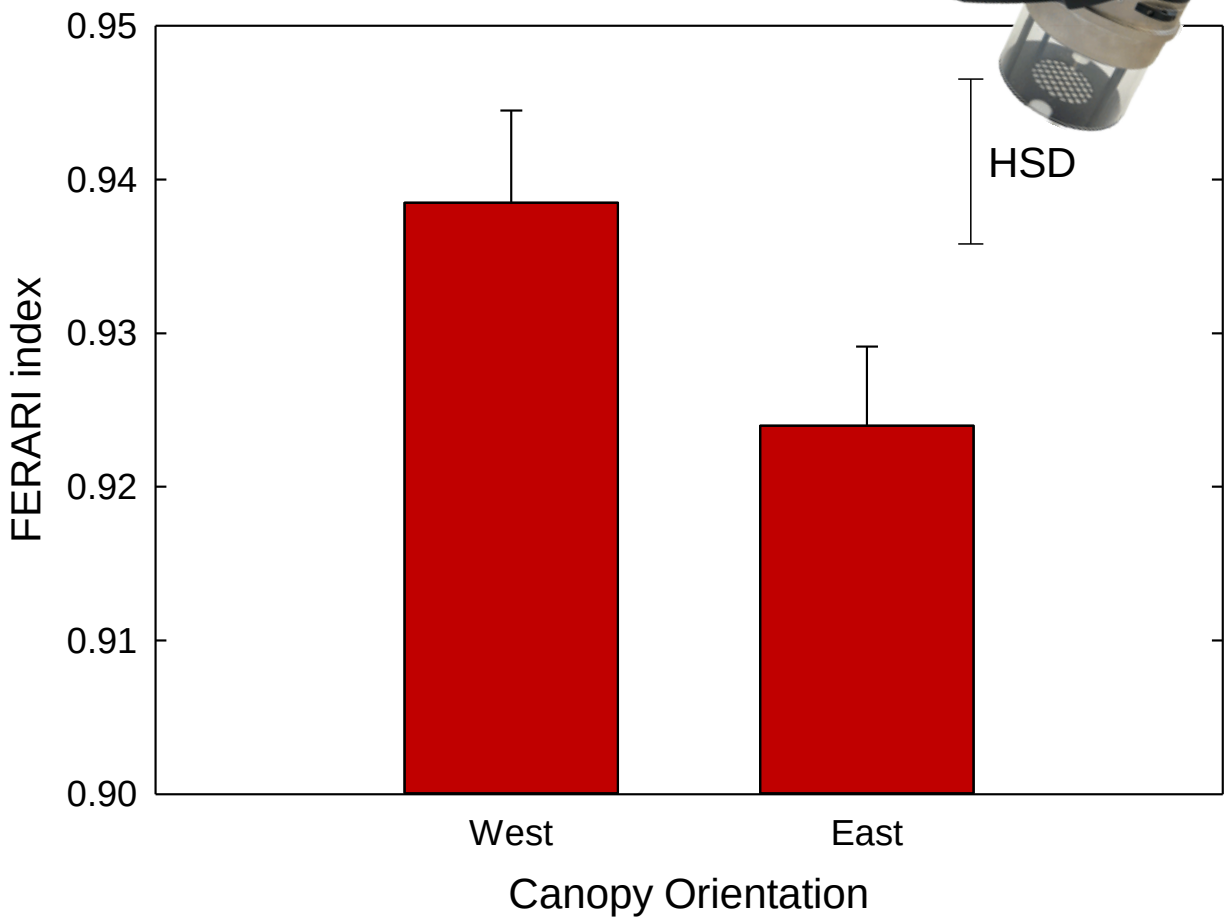


ANOVA:

- **Merged Irrigation Treatment (by fruit growth stage) → p<0.01**
- **Date → p<0.001**
- **Irrigation Treatment * Date→ p<0.05**
- **Canopy orientation → p<0.001**

Fluorometer Multiplex 3 Force A on fruit → fluorescence excitation ratio anthocyanin relative index (FERARI)





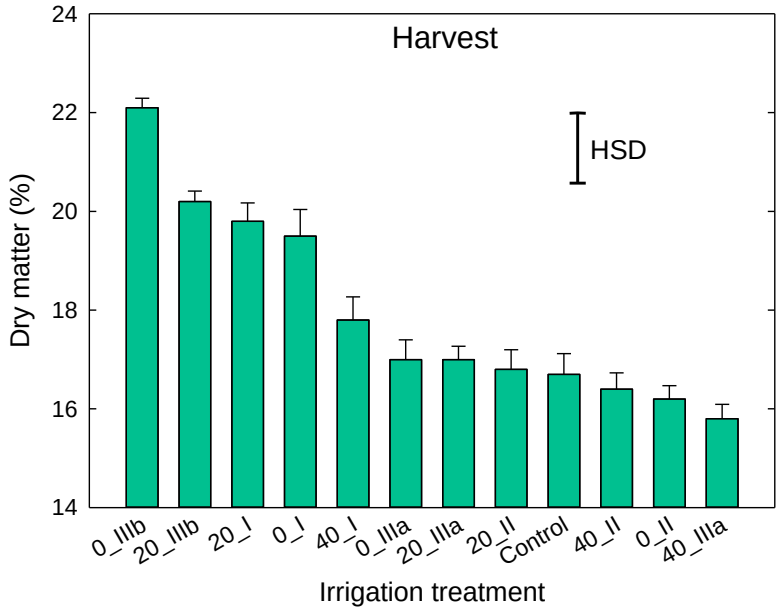
ANOVA:

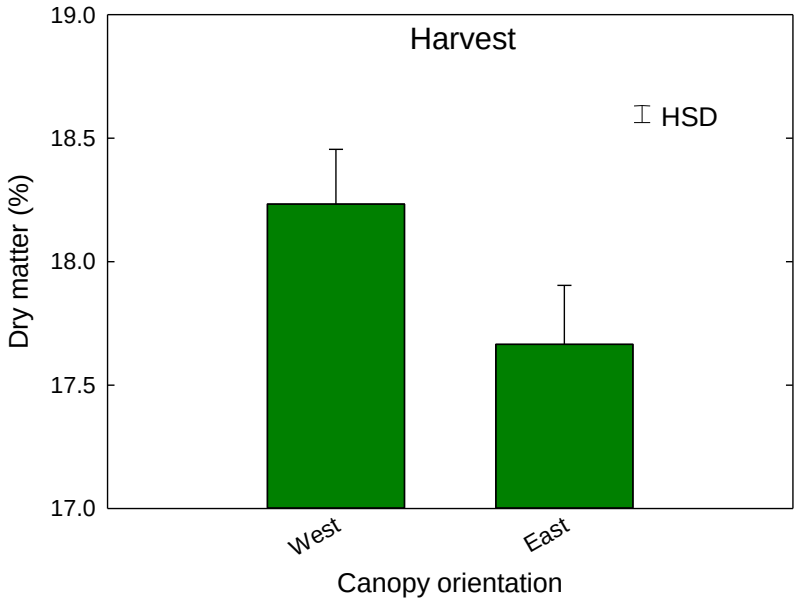
- **Date → p<0.001**
- **Irrigation Treatment → p<0.001**
- **Canopy orientation → p<0.001**
- **Irrigation Treatment * Date→ p<0.001**

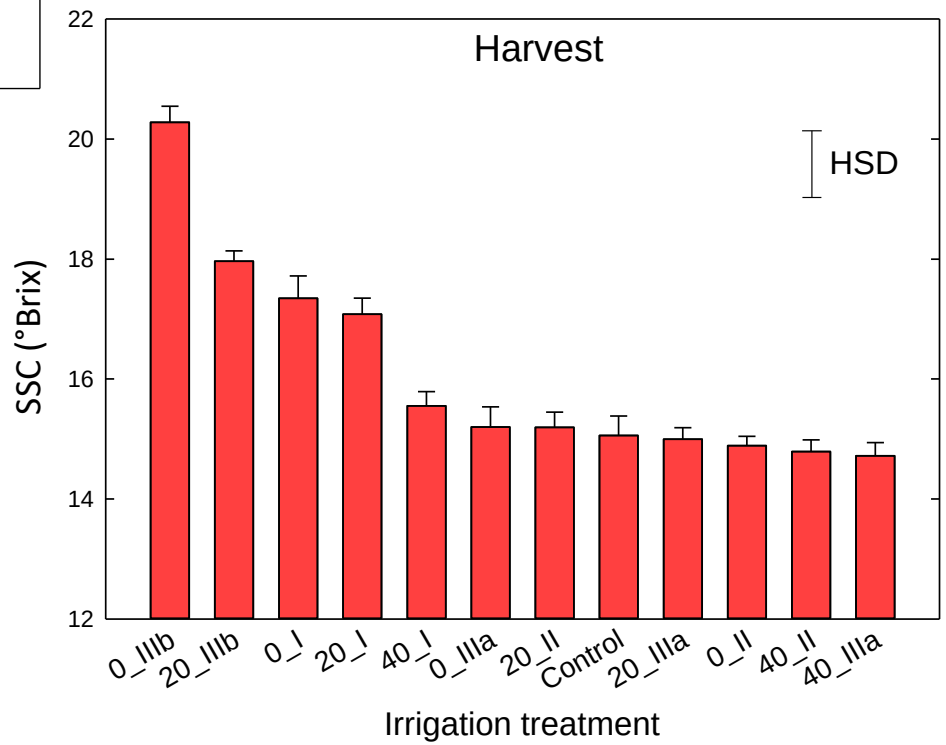
- **Canopy orientation → p<0.001**

Despite at harvest no significant differences

Felix F-750 → Dry matter and SSC







Error bars represent standard errors.

Fruit growth and leaf turgor pressure indices

FRUIT

Fruit gauge output is a signal in mV

1. **Fruit diameter z-scores**:

   $z = (x - \mu) / \sigma$

2. **Fruit relative growth rate (RGR, µm mm^{-1} min^{-1}):**

   $RGR = (\ln Diameter_2 - \ln Diameter_1) / (t_2 - t_1)$

LEAVES

LPCP probe output is an inverted value of leaf turgor pressure (p_p)

1. **p_p z-scores:**

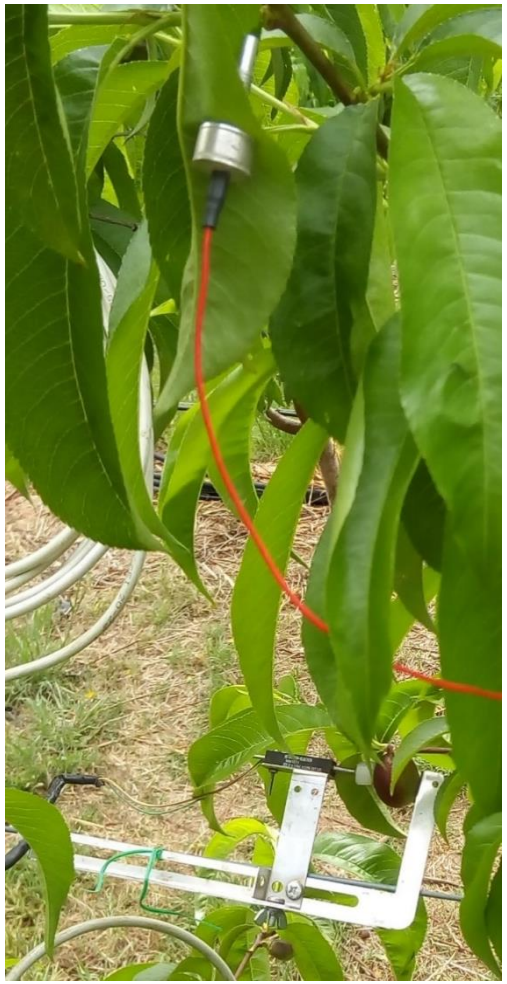
   $z = (x - \mu) / \sigma$

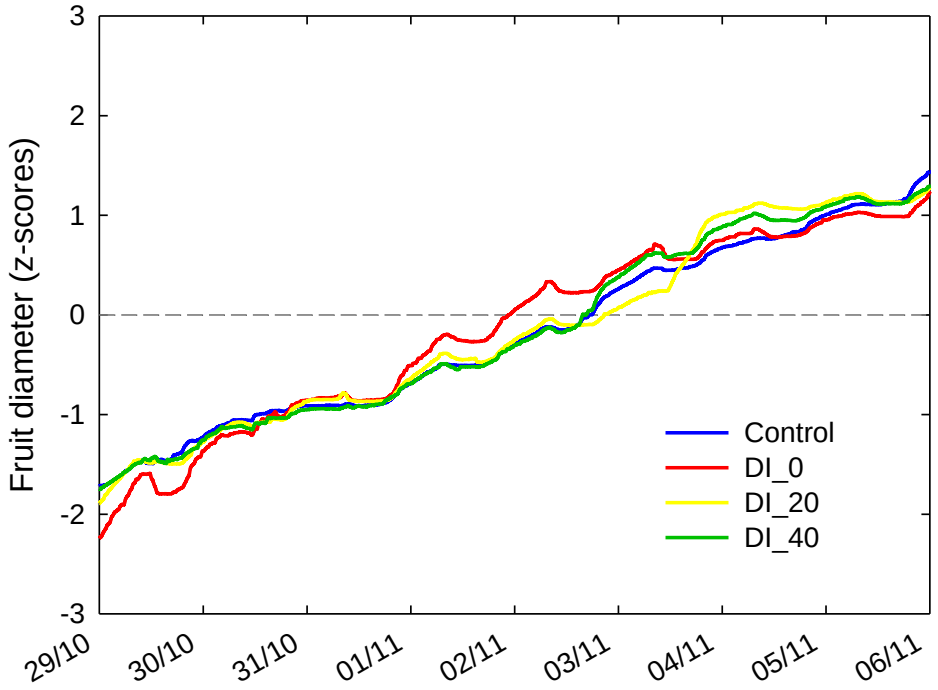
2. **Leaf relative pressure change rate (RPCR, kPa kPa^{-1} min^{-1})**

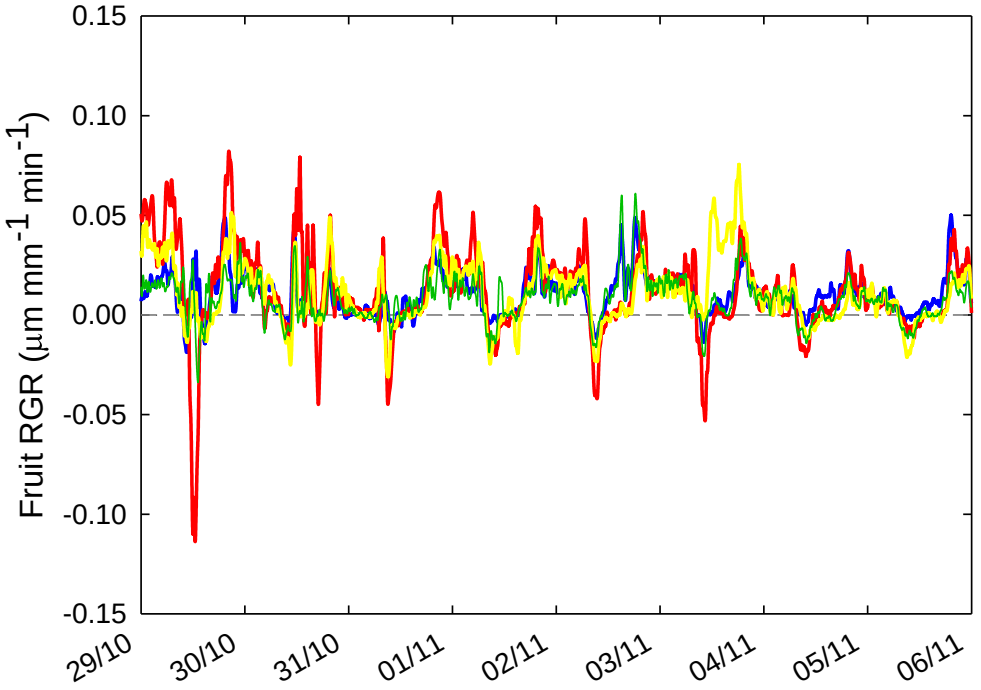
   $RPCR = (\ln p_{p\,2} - \ln p_{p\,1}) / (t_2 - t_1)$

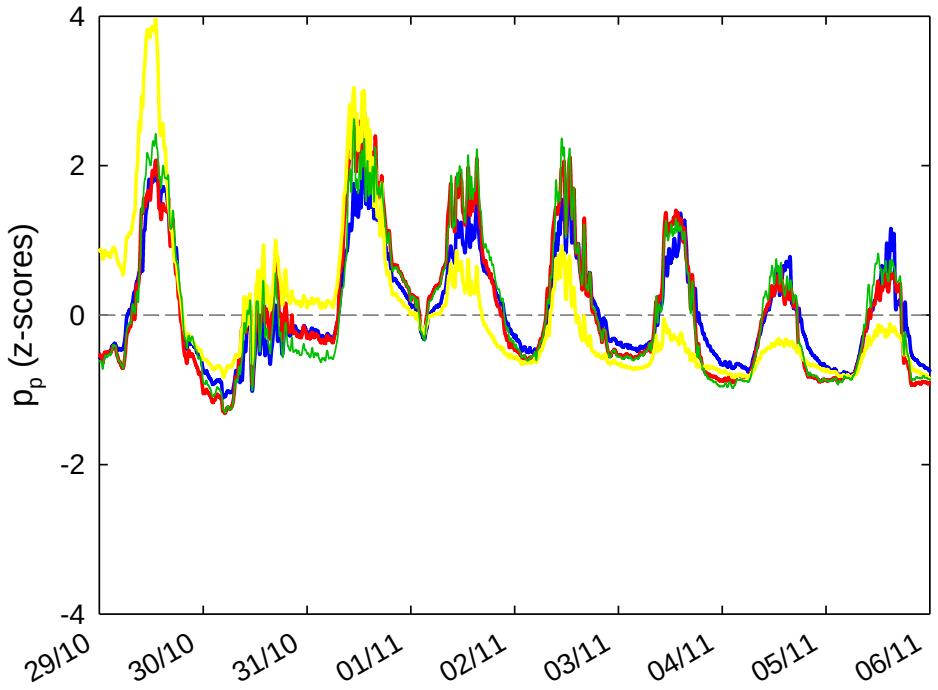
RGR and RPCR are 2nd derivatives of fruit diameter and p_p, respectively.

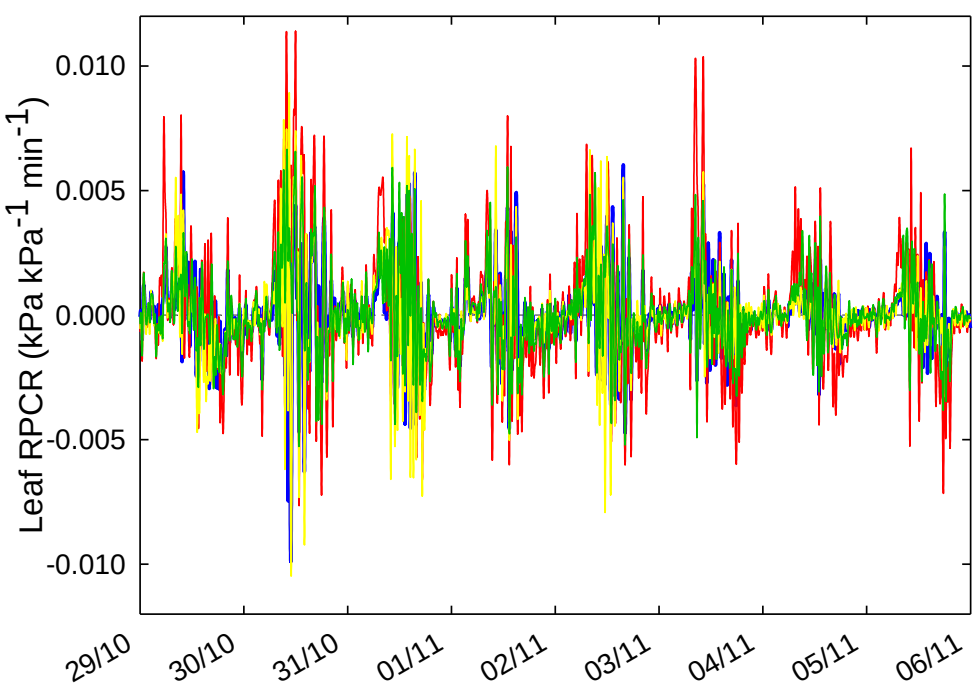
Stage I



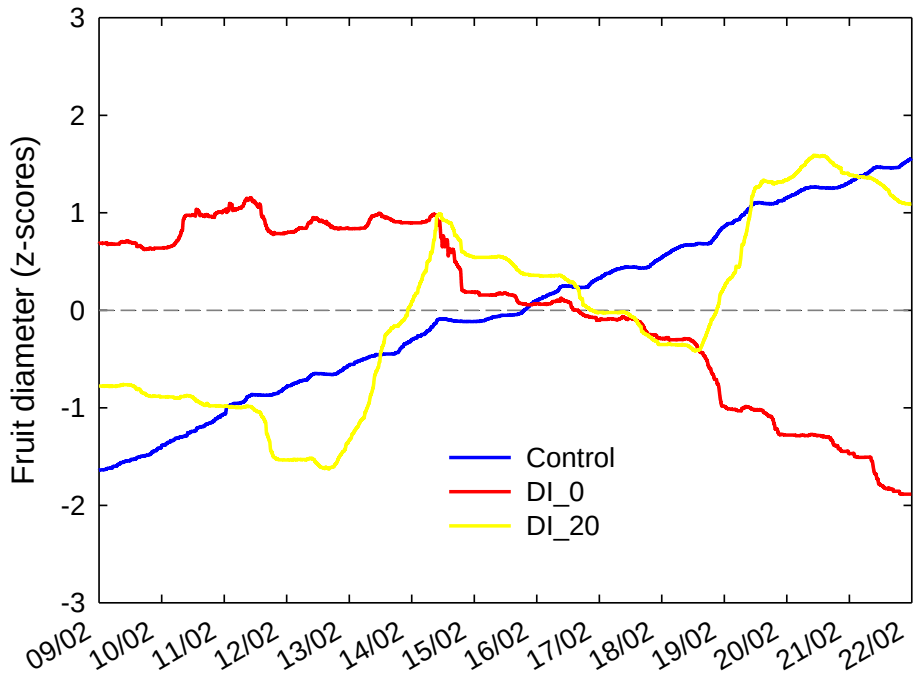

Fruit diameter (z-scores)
3
2
1
0
-1
-2
-3
29/10
30/10
31/10
01/11
02/11
03/11
04/11
05/11
06/11
Control
DI_0
DI_20
DI_40

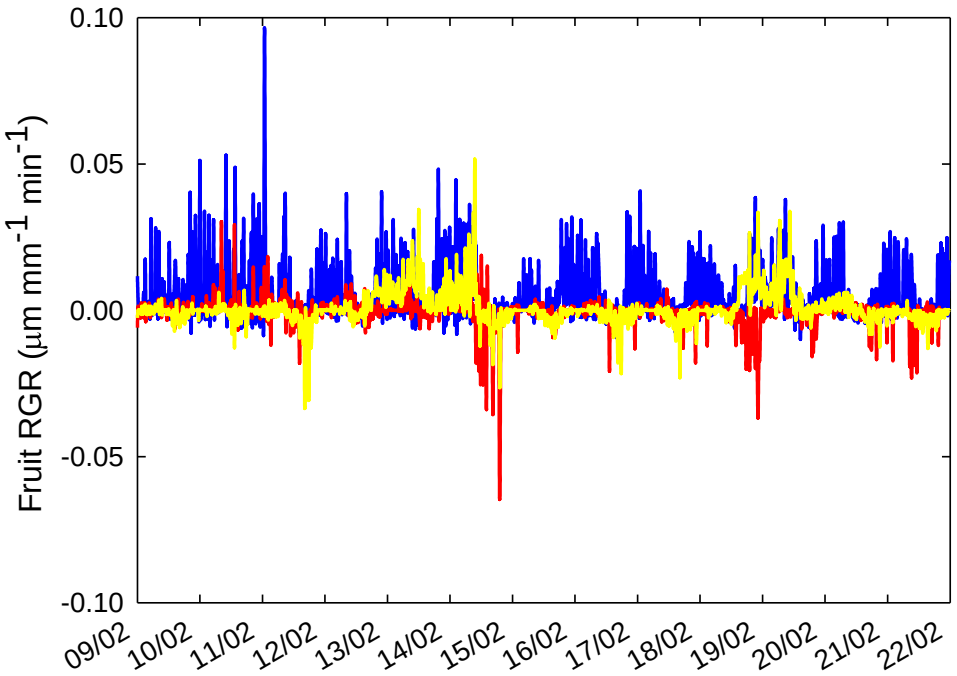

Fruit RGR (μm mm-1 min-1)
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
29/10
30/10
31/10
01/11
02/11
03/11
04/11
05/11
06/11

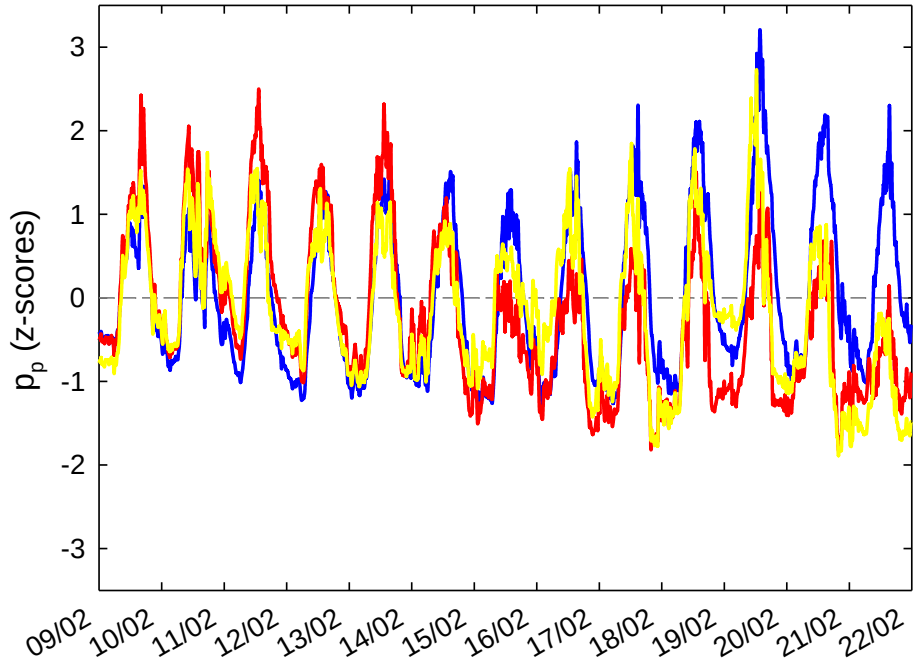

pp (z-scores)
4
2
0
-2
-4
29/10
30/10
31/10
01/11
02/11
03/11
04/11
05/11
06/11

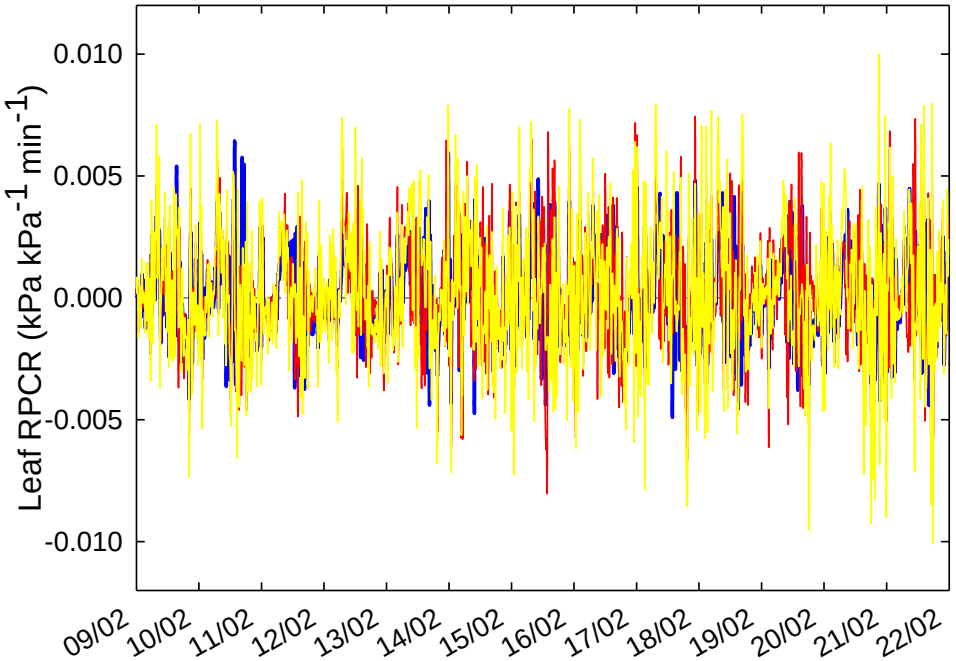

Leaf RPCR (kPa kPa-1 min-1)
0.010
0.005
0.000
-0.005
-0.010
29/10
30/10
31/10
01/11
02/11
03/11
04/11
05/11
06/11

Stage IIIb


Fruit diameter (z-scores)
3
2
1
0
-1
-2
-3
Control
DI_0
DI_20
09/02
10/02
11/02
12/02
13/02
14/02
15/02
16/02
17/02
18/02
19/02
20/02
21/02
22/02

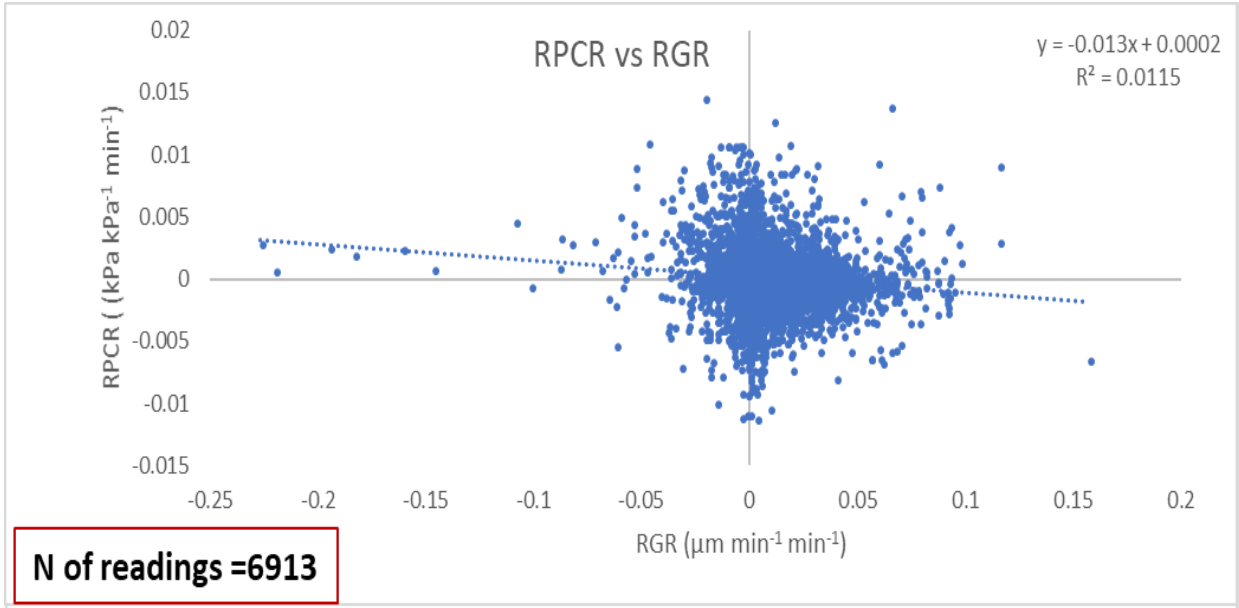

Fruit RGR (µm mm-1 min-1)
0.10
0.05
0.00
-0.05
-0.10
09/02
10/02
11/02
12/02
13/02
14/02
15/02
16/02
17/02
18/02
19/02
20/02
21/02
22/02


pp (z-scores)
3
2
1
0
-1
-2
-3
09/02
10/02
11/02
12/02
13/02
14/02
15/02
16/02
17/02
18/02
19/02
20/02
21/02
22/02

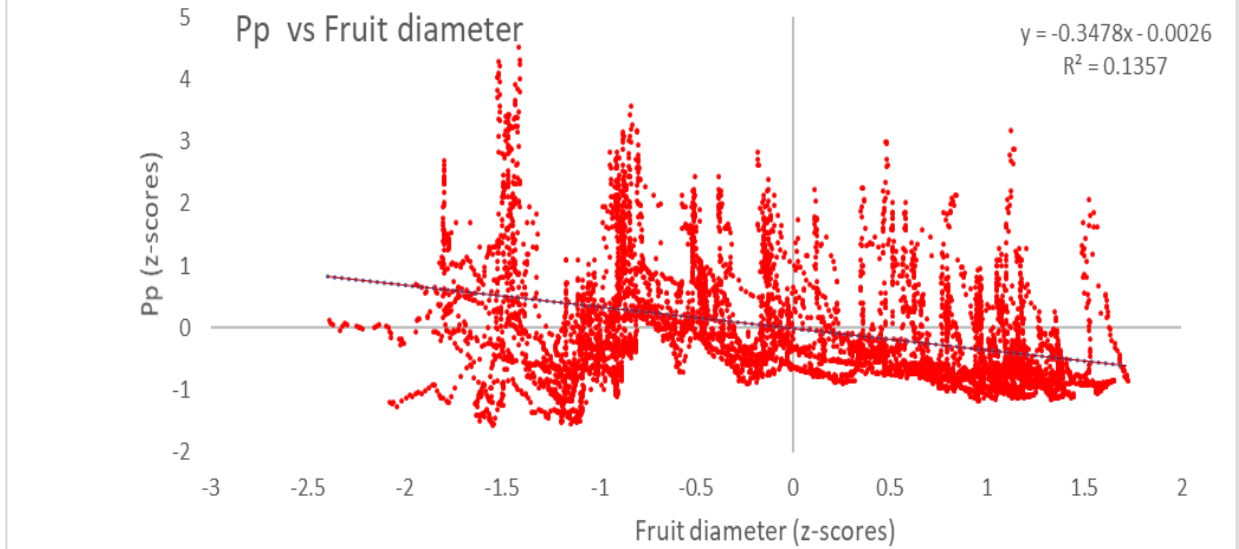

Leaf RPCR (kPa kPa-1 min-1)
0.010
0.005
0.000
-0.005
-0.010
09/02
10/02
11/02
12/02
13/02
14/02
15/02
16/02
17/02
18/02
19/02
20/02
21/02
22/02

Large regressions (sensor outputs)

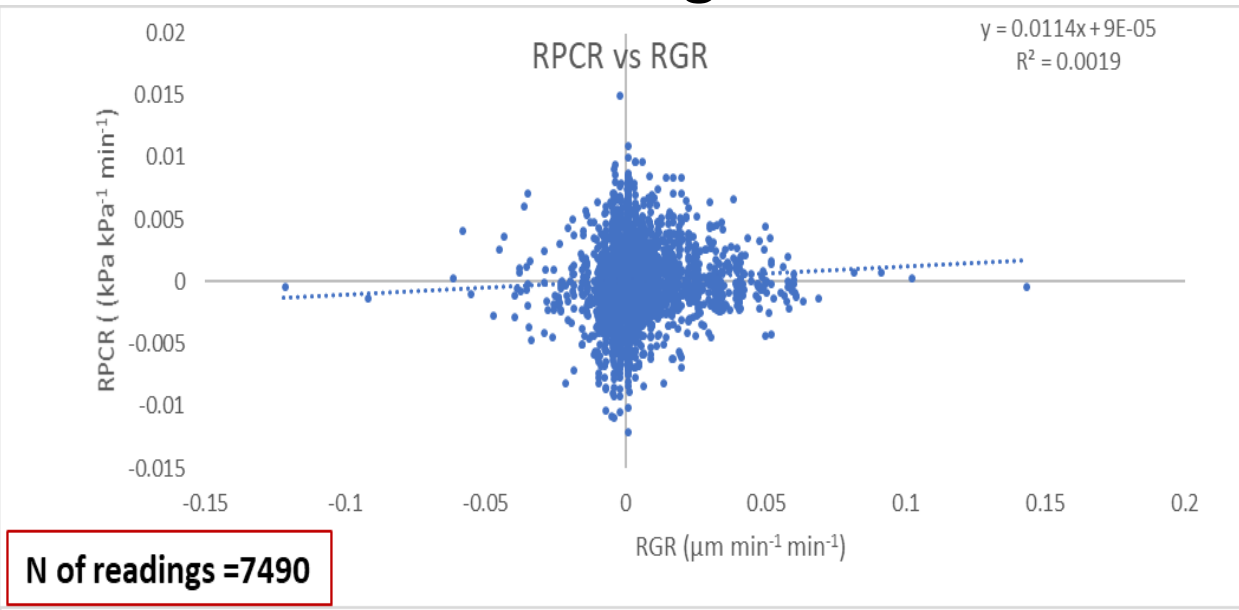
Stage I



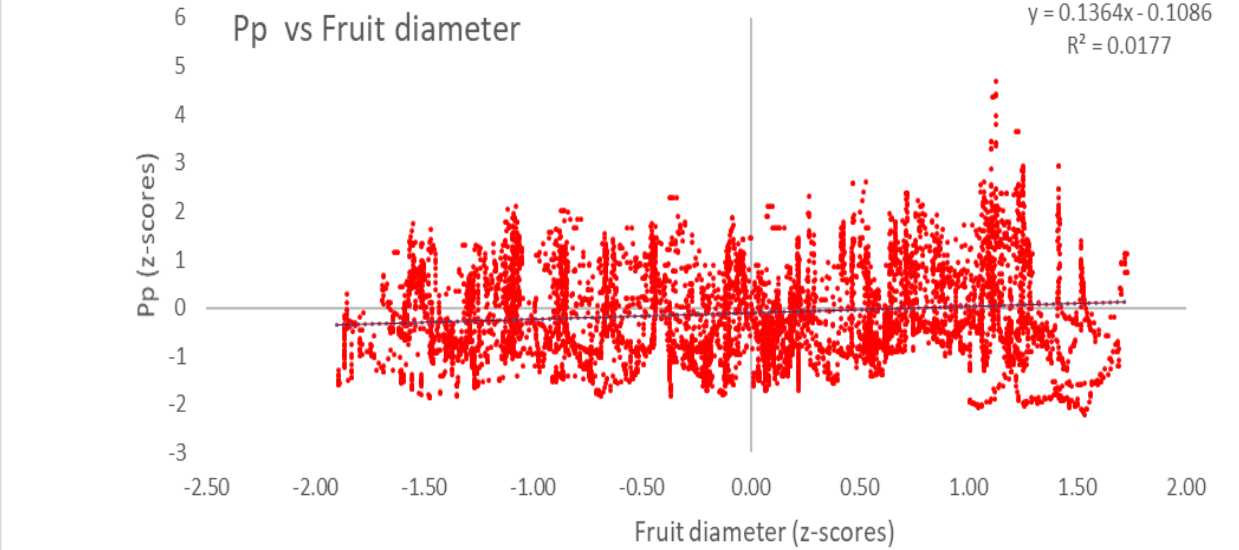
N of readings =6913



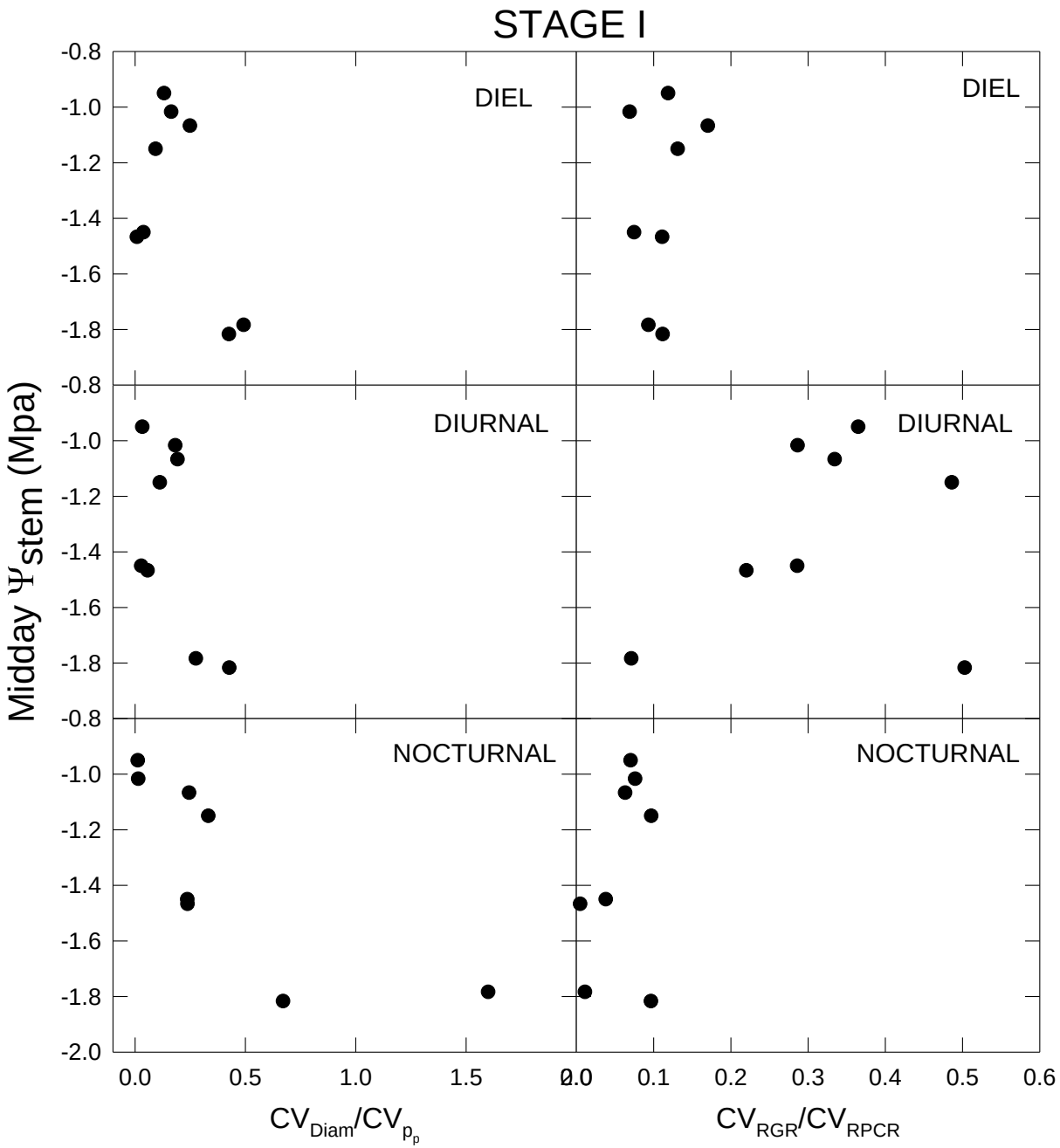
Stage IIIb

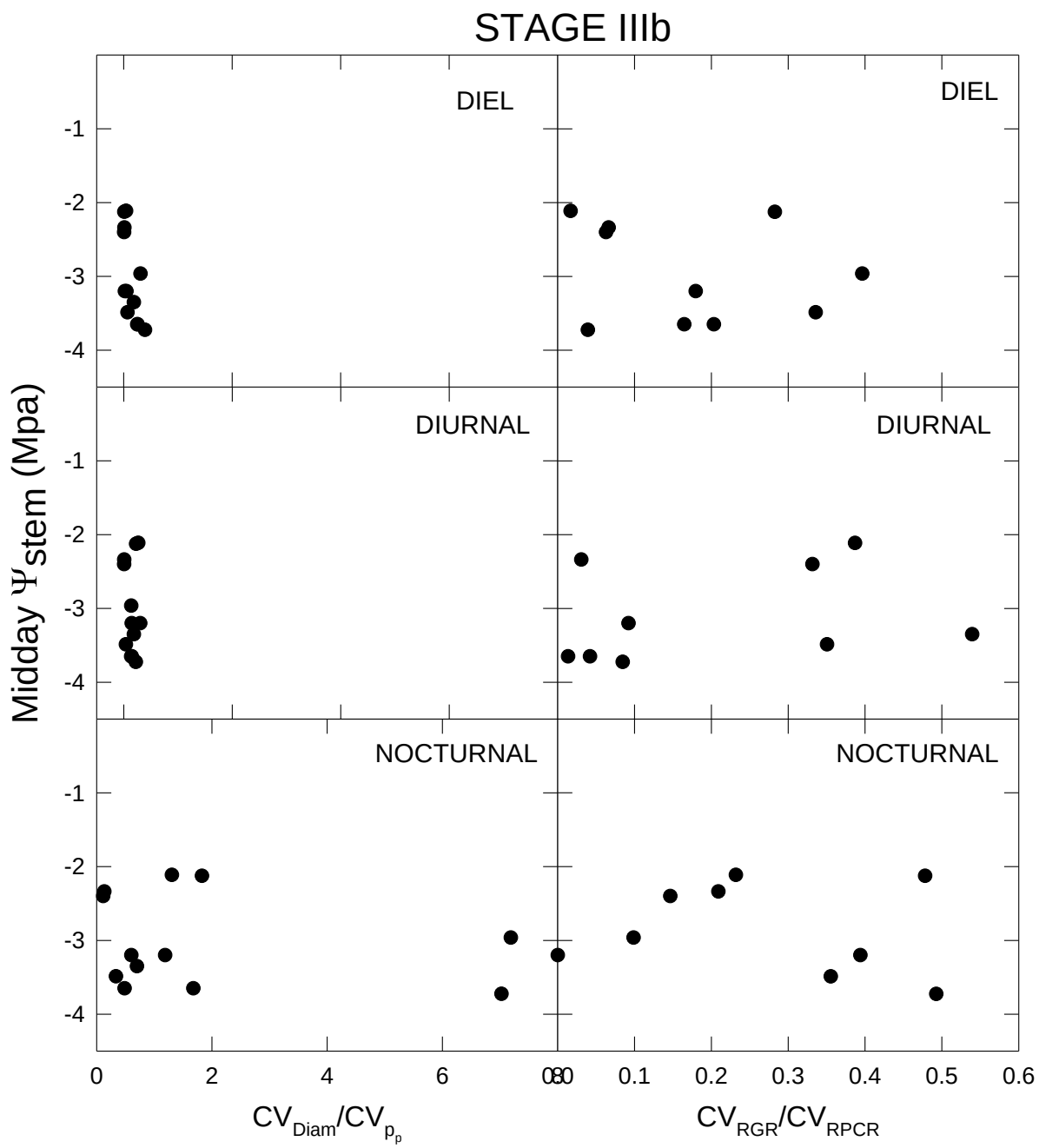


N of readings =7490



Midday Ψ_{stem} Vs CV_{Diam}/CV_{p_p} & Midday Ψ_{stem} Vs CV_{RGR}/CV_{RPCR}

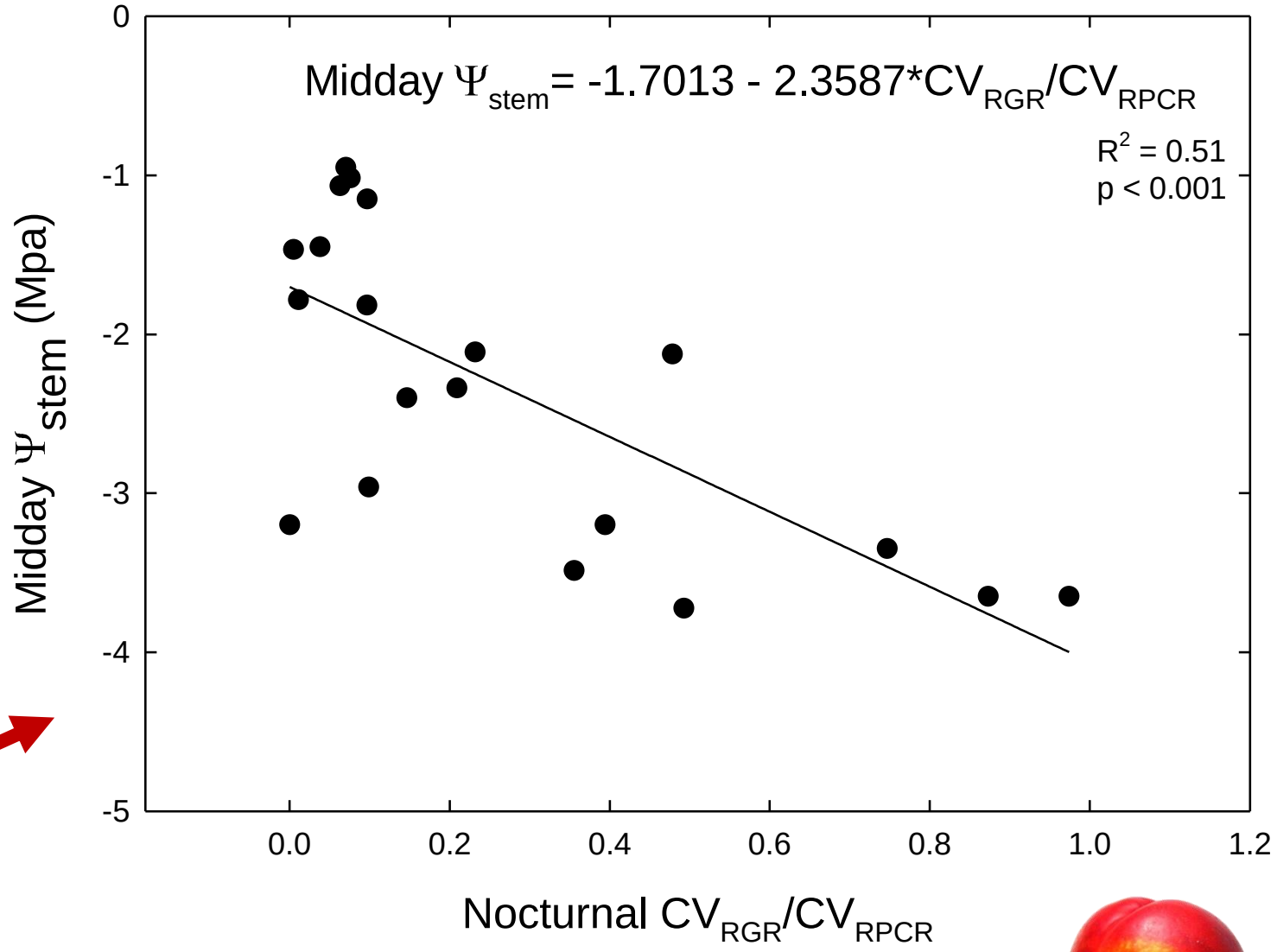




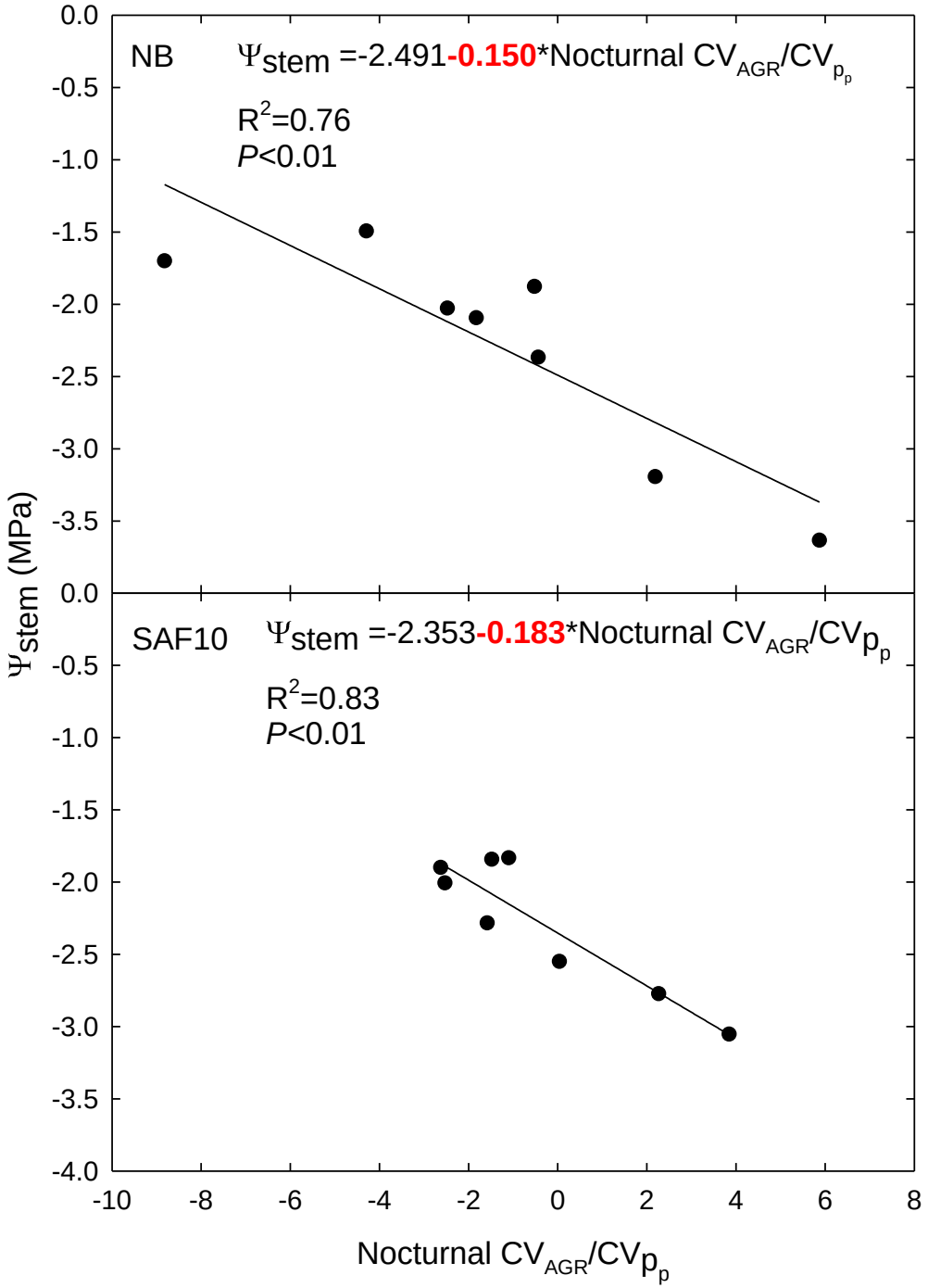
Stage I and IIIb merged

Several regressions tested:

- Diel
  - Midday Ψ_{stem} Vs CV_{Diam}/CV_{p_p}
  - Midday Ψ_{stem} Vs CV_{RGR}/CV_{RPCR}
- Diurnal
  - Midday Ψ_{stem} Vs CV_{Diam}/CV_{p_p}
  - Midday Ψ_{stem} Vs CV_{RGR}/CV_{RPCR}
- Nocturnal
  - Midday Ψ_{stem} Vs CV_{Diam}/CV_{p_p}
  - **Midday Ψ_{stem} Vs CV_{RGR}/CV_{RPCR}**



What's going on in olive?



t-test show no significant differences between the slope of the two regressions, implying a genotype-independent relationship

Conclusions

- A combined index of fruit growth and leaf turgor pressure is a more powerful tool for continuous Ψ_{stem} estimation, compared to considering them individually.

- An integrated approach for continuous monitoring of water status in plant organs (e.g. fruit, leaves, trunk, etc.) can be used for remote, automated irrigation management when trees reach well defined Ψ_{stem} thresholds (e.g. via I/O Arduino board).

- Fruit quality parameters may be determined by non-destructive field measurements by NIR spectroscopy and fluorescence spectroscopy. These technologies might potentially be automated and installed on trees for regular and real-time determination of desired parameters.

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&

my family in Italy…

GRAZIE!

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Continuous determination of fruit tree water-status by plant-based sensors

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