Analysis of field data and modeling with the faq aquacrop model, in the framework of a study on the resistance of two rice cultivars to irrigation deficiency in Cambodia

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ANNEXES

- <u>Complete protocols</u>

  - Calibration of moisture sensors, adapted from Sodham Adla *et al.* (2019) and Matula *et al.* (2016).

Material:

- 2 x Teros 12 moisture sensors (form METER Group)
- 1L container
- Soil samples from our experimental plots
- Em50 datalogger (from Decagon Devices Inc.)
- Computer

Method:

1. We went to the experimental plots in the different sites and collected a sufficient amount of samples to proceed with the calibration.
2. We dried the samples in the oven for 24h at 105°C.
3. We then crushed the samples and removed the secondary soil structures (rocks, roots, etc.)
4. We put the dry samples in the container, with the sensor, and plugged in the datalogger.
5. We first measured the value that the sensor indicated for the dry soil.
6. Secondly, we added water in the container until we reached 15% volumetric water content. We mixed the soil to homogenize the moisture and repeated the measure.
7. We repeated this manipulation with 30% volumetric water content and pure water.
8. We repeated this process 3 times per sensor and per soil type to have an average value.
9. With this data, we were able to fit a 4-points regression curve on the data and get the equation that corrects the Teros 12 measurements.

- Pressure plates measurement

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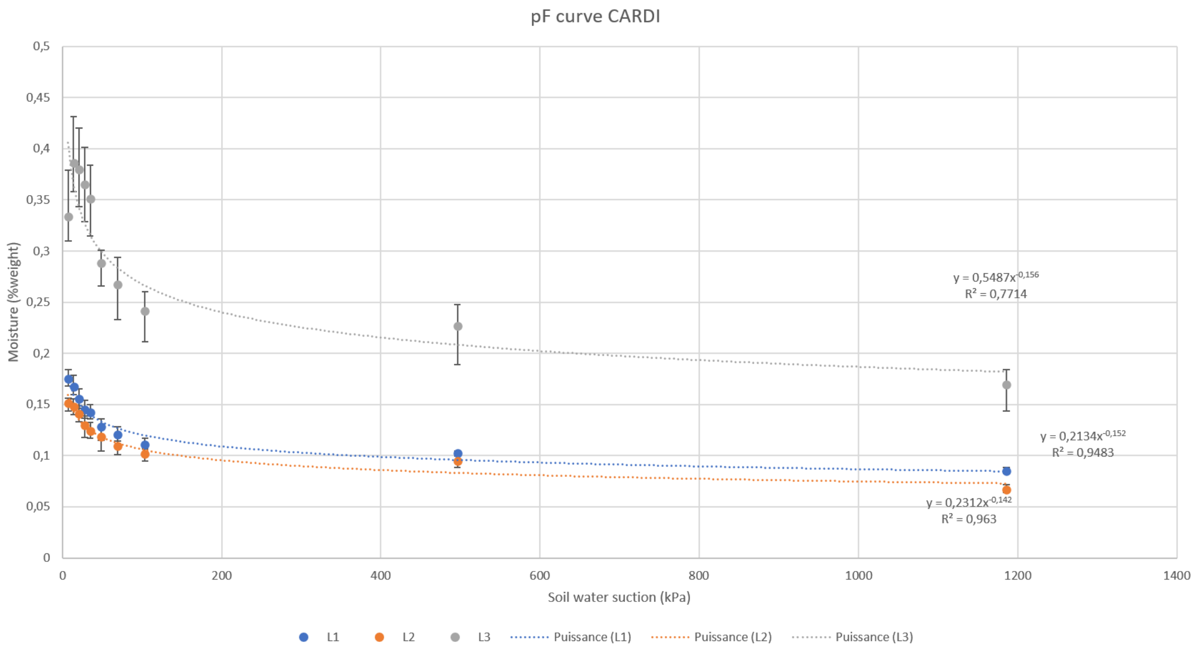
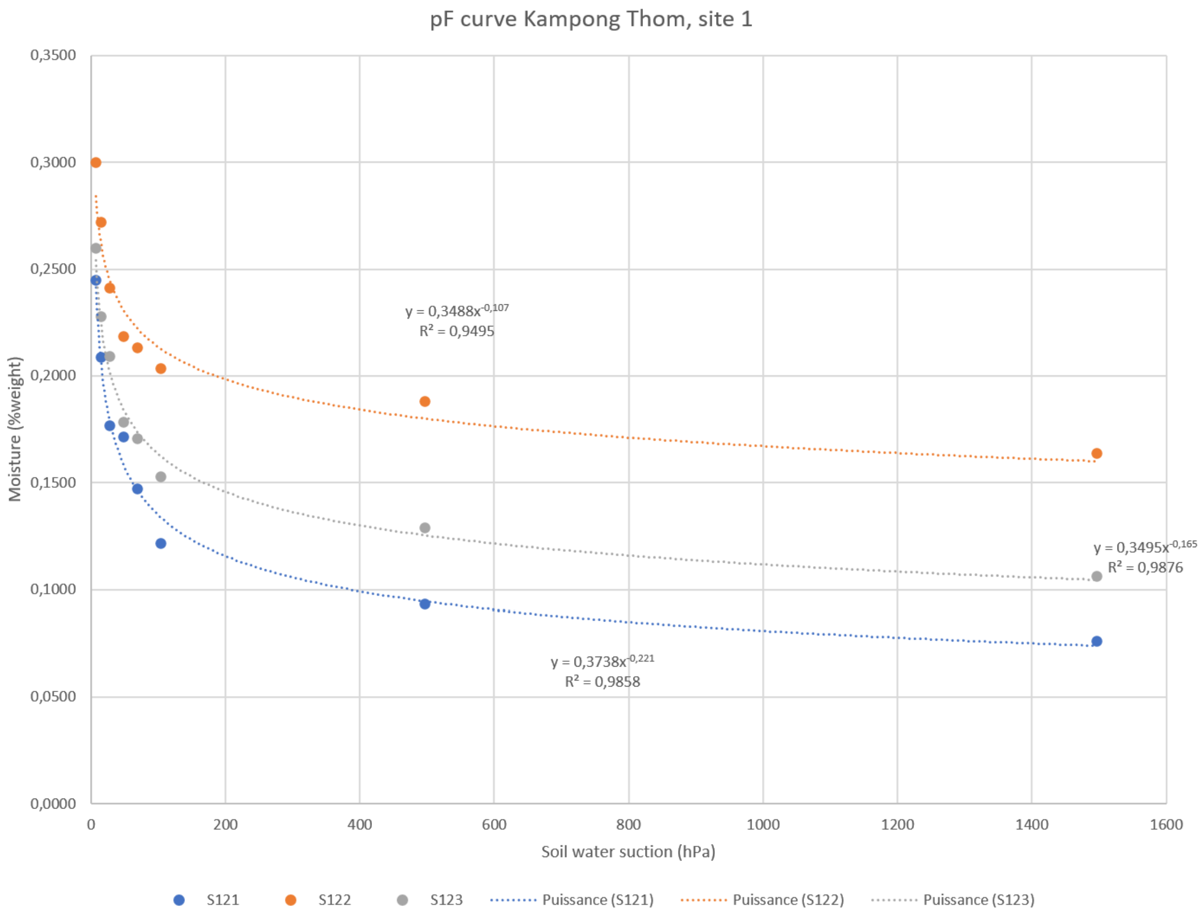
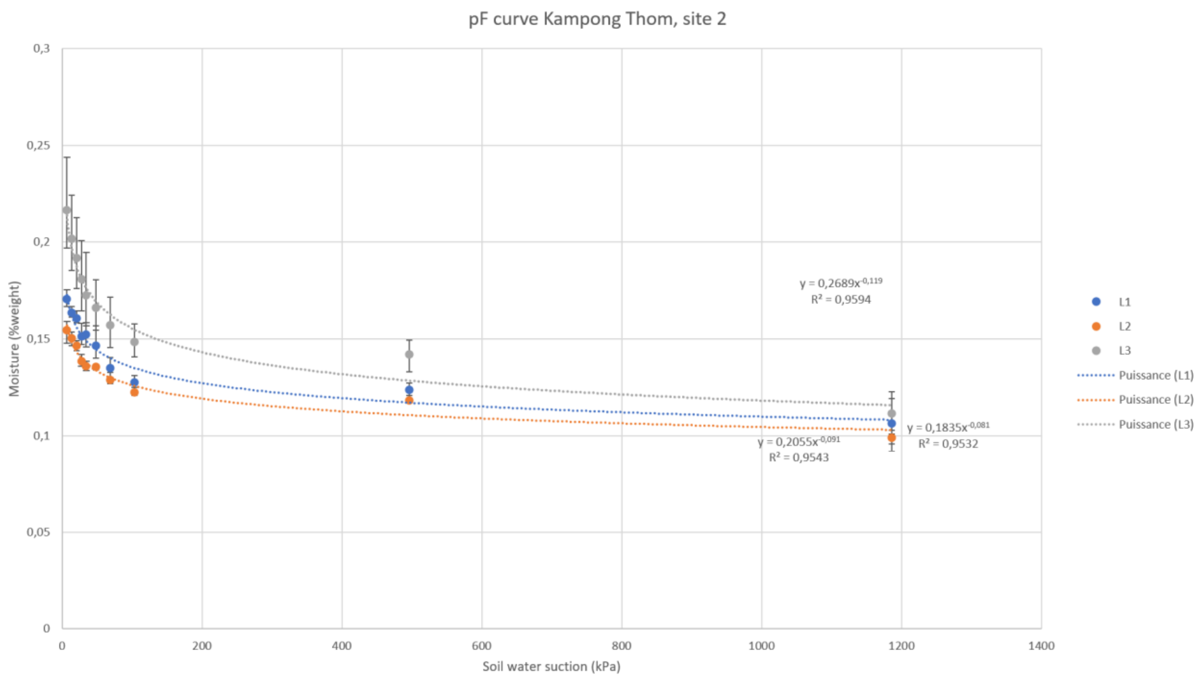






- Measurement of bulk density

Material:

- Soil samples from our experimental plots
- Scientific balance

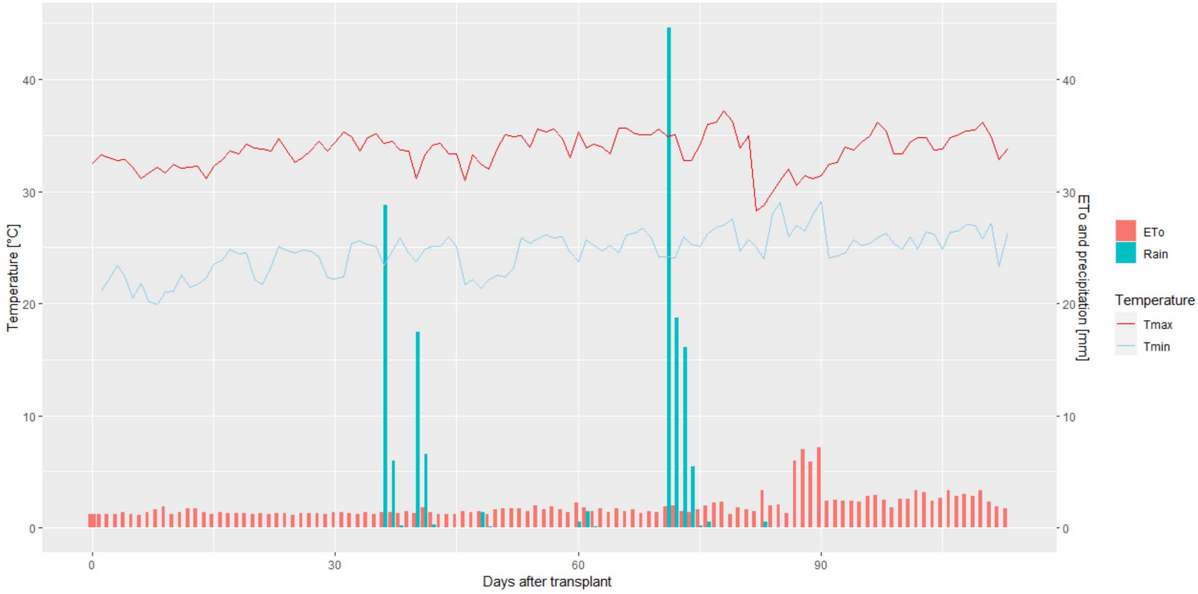
- Oven
- Metal rings

Method:

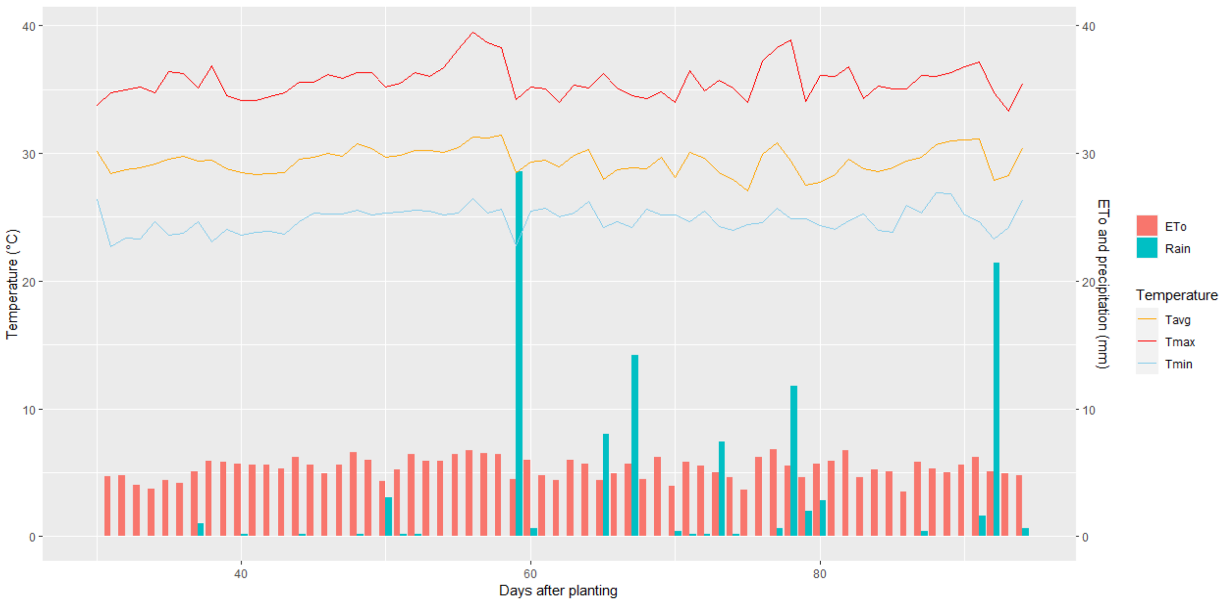
1. We went to the experimental plots in the different sites and collected a three samples per layer of soil to proceed with the measurement.
2. We placed the samples in metal rings.
3. We dried the samples in the oven for 24h at 105°C.
4. We then weighted the dry samples, removed them from the rings and also weighted the rings.
5. We measured the volume of each ring.
6. We calculated the bulk density with the following equation: $\rho_b = \frac{m}{v}$
   With m being the dry mass of the sample in g and v being its volume in cm^3.

- <u>Weather data</u>

The soil dynamics (water level, soil moisture and soil potential) are closely related to the weather. Indeed, the temperature, precipitation and evapotranspiration are the main causes of change.



Daily weather in Kampong Thom



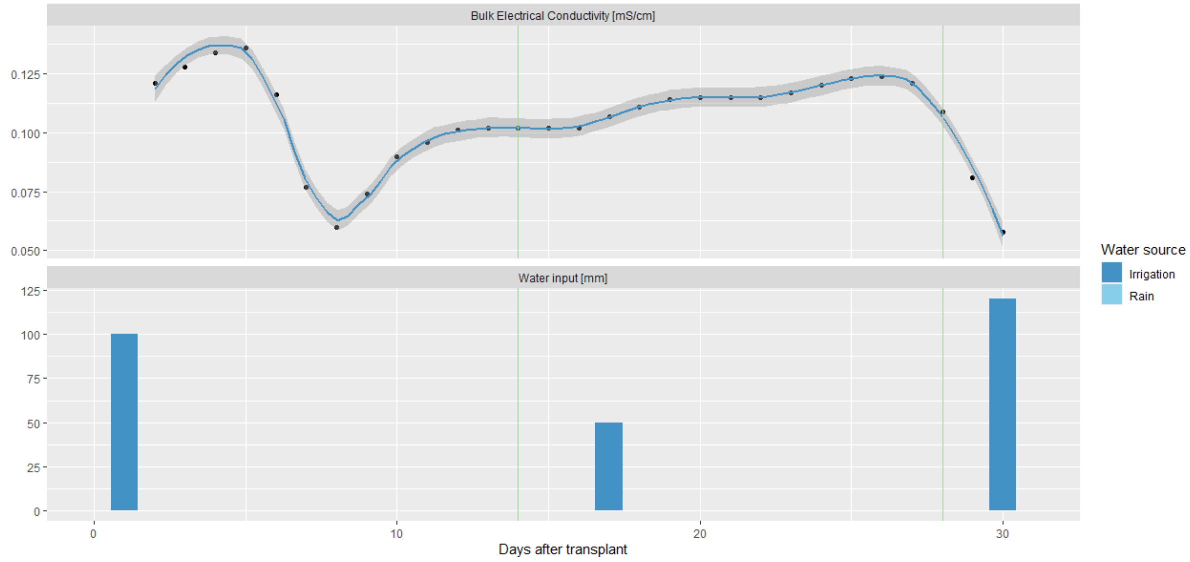
Daily weather in CARDI during the experiment of 2021

Daily weather in CARDI during the experiment

- <u>Bulk electrical conductivity</u>

We can look into the bulk electrical conductivity to understand more about the water dynamics in the soil.

- In Kampong Thom



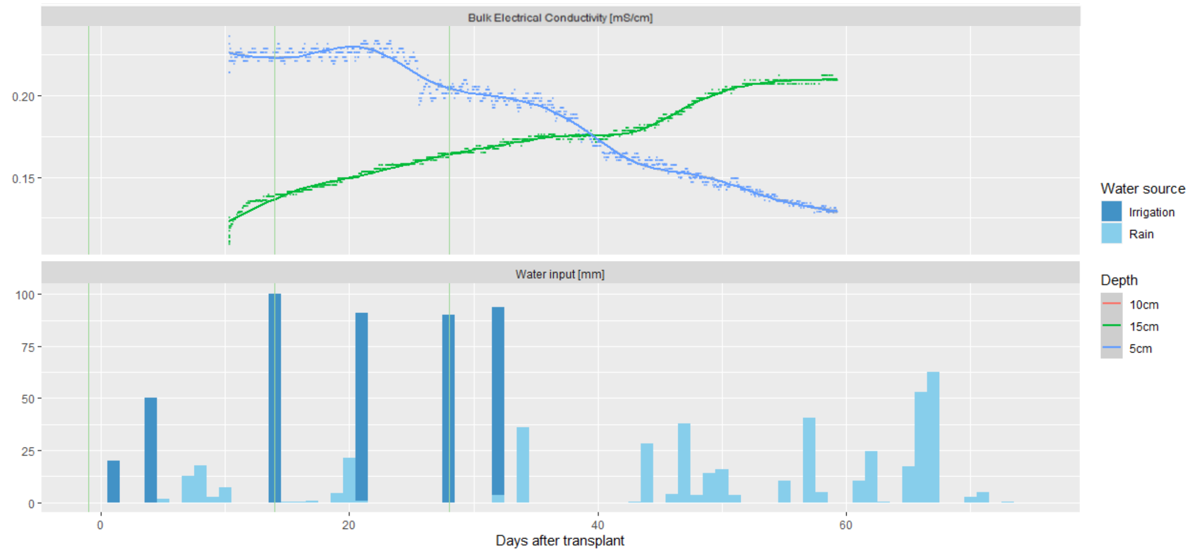
Measures of bulk electrical conductivity in Kampong Thom, depth of 10cm – Site 2

On figure X, we can see the evolution of the electrical conductivity. It is depending on the concentration of ions, their type and the temperature. Thus, it does not react to the quantity of water, but the presence of ions: it should react to the application of fertilizer (the green lines on the graph) and if it reacts to the application of irrigation that would mean that the water is charged in ions, maybe salt.

Indeed, we do not have any information concerning the composition of the water of irrigation, so the electrical conductivity can be a clue.

From what we can see on the figure, we can assume that some input of ions was made before the start of the rice culture, even though no fertilization is listed prior to the transplant. We can see that the first fertilization leads to a slow increase in bulk electrical conductivity, but it is hard to interpret the effect of the irrigation events.

- In CARDI



Measures of bulk electrical conductivity in CARDI

We can see here that over time, the EC_b decreases at 5cm, and increases at 15cm. This figure could then illustrate the penetration of the fertilizer from the top layer of the soil, and its accumulation deeper in the soil. Indeed, the plateaus that we can see in the 5cm layer correspond to the application of fertilizer (represented by the vertical green lines).

- <u>Parameters entered in the model</u>

Parameters of the different cultivars in AquaCrop

	CAR15	Sen Pidor
Days to reach maximum root	65	65
WP (g/m²)	17	16
HI	39	42
Tolerance to water stress	Extremely tolerant	Extremely tolerant
CCo	0,75	0,75
Maximum CC	56	43
Canopy decline	12	12
Recovery	7	7
Days to reach max. canopy	52	52
Senescence	69	73
Maturity	83	95
Days to flowering	53	66
Duration of flowering	7	7
Min-max effective root depth	10-15 cm	10-15 cm

The weed management is very good. Concerning the field management, there were bunds between the plots, with a depth varying between 0.3 and 0.4m, but in CARDI the size of the bunds was reduced to translate the drainage of the plots after intense rains.

The salinity stress was not taken into account, because we did not have any information on the composition of the water. Moreover, the measures bulk electrical conductivities (shown in the annex) were relatively low and could be attributed to the fertilizer inputs.

We considered the temperature stress, and set-up the base temperature at 10°C and the upper temperature at 40°C.

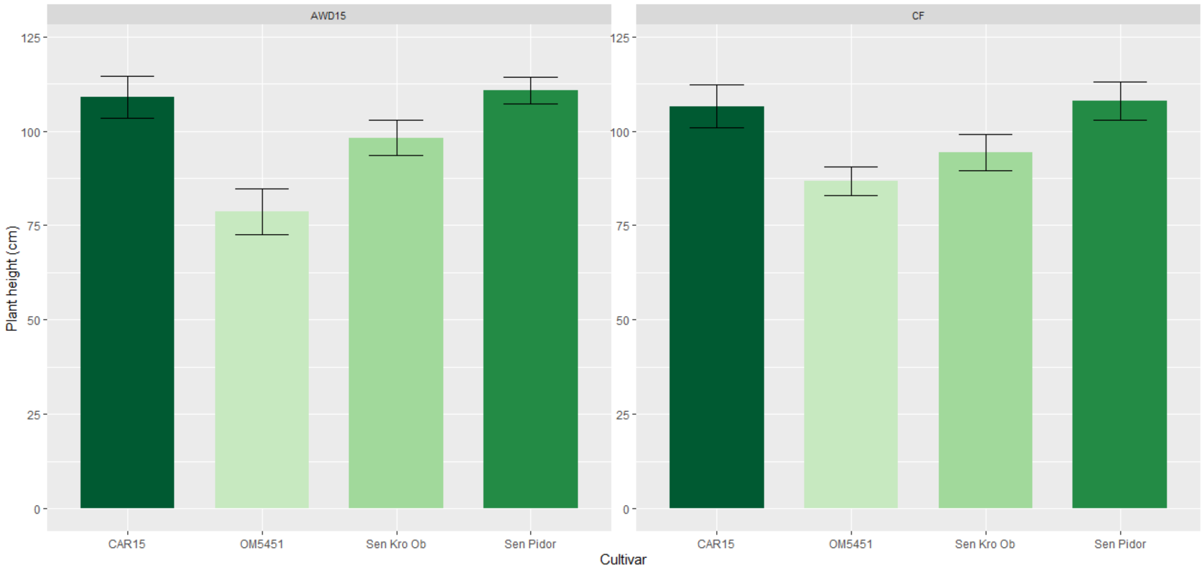
As there were several inputs of fertilizer in all the sites, we assumed that there was no major fertility stress. Moreover we did not have the data necessary to calibrate the reaction of the cultivars to the absence of fertilizer so we did not consider this stress either.

Values of the cultivars after calibration

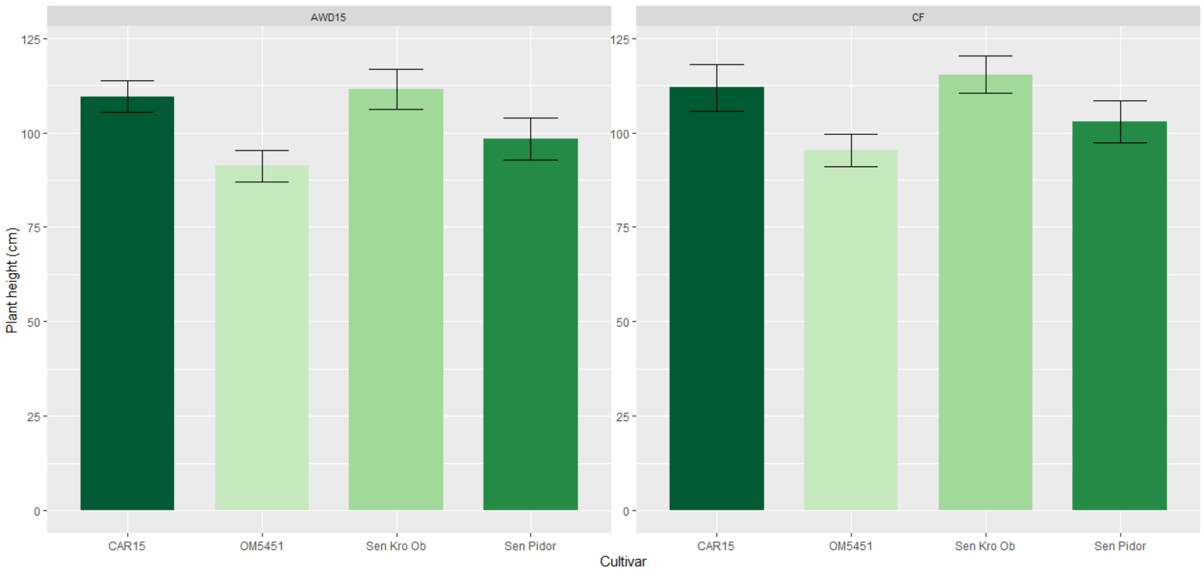
	CAR15	Sen Pidor
WP (g/m²)	17	16
HI	48	42
Tolerance to water stress	Extremely tolerant	Extremely tolerant
CCo	0,75	0,75
CC_x	60	63
Canopy decline	16	25
Recovery	7	6

Days to reach CC_x	69	42
Senescence	70	66
Maturity	90	95
Days to flowering	60	66
Duration of flowering	8	8
Min-max effective root depth	15cm	10cm
$K_{c\,Tr}$	1.10	0.95

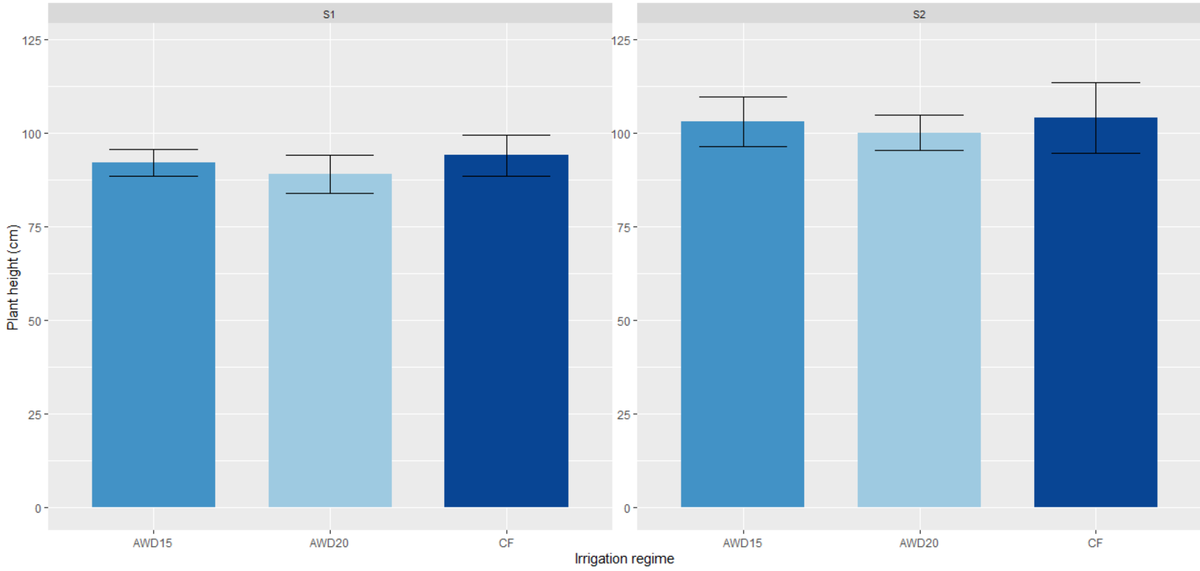
- <u>Plant height</u>



Plant height at harvest in CARDI, 2021



Plant height at harvest in CARDI, 2022



Plant height at harvest in Kampong Thom

- <u>Yield and WUE data</u>

Grain yield and harvest index in CARDI

	CARDI 2021							
	AWD15				CF			
	OM5451	Sen Pidor	Sen Kro Ob	CAR15	OM5451	Sen Pidor	Sen Kro Ob	CAR15
Grain yield (ton/ha) at 14% moisture	2,419 ± 0,245	2,203 ± 0,099	2,499 ± 0,165	2,947 ± 0,245	3,280 ± 0,226	2,216 ± 0,098	3,052 ± 0,156	2,757 ± 0,204
Harvest index (%)	40,245 ± 1,841	33,818 ± 1,735	35,067 ± 4,273	34,719 ± 1,586	40,878 ± 2,501	34,698 ± 2,292	39,227 ± 3,584	38,835 ±1,802
	CARDI 2022							
	AWD15				CF			
	OM5451	Sen Pidor	Sen Kro Ob	CAR15	OM5451	Sen Pidor	Sen Kro Ob	CAR15
Grain yield (ton/ha) at 14% moisture	3,379 ± 0,150	2,817 ± 0,153	2,677 ± 0,415	3,015 ± 0,416	3,116 ± 0,530	3,206 ± 0,203	3,131 ± 0,141	3,311 ± 0,105

Harvest index (%)	34,537 ± 2,487	28,891 ± 2,390	28,561 ± 3,348	29,440 ± 1,840	32,077 ± 2,825	29,476 ± 1,095	28,328 ± 0,762	30,400 ± 1,921

Grain yield and harvest index in Kampong Thom

	Kampong Thom (CAR15)					
	Site 1			**Site 2**		
	AWD20	**AWD15**	**CF**	**AWD20**	**AWD15**	**CF**
Grain yield (ton/ha) at 14% moisture	3,233 ± 0,291	3,736 ± 0,172	3,564 ± 0,435	3,054 ± 0,742	3,601 ± 0,531	4,060 ± 0,986
Harvest index (%)	45,312 ± 0,015	44,964 ± 0,003	42,547 ± 0,016	43,200 ± 3,424	46,529 ± 1,725	36,938 ± 14,665

Water-Use Efficiency and Economic efficiency in all the experimental sites

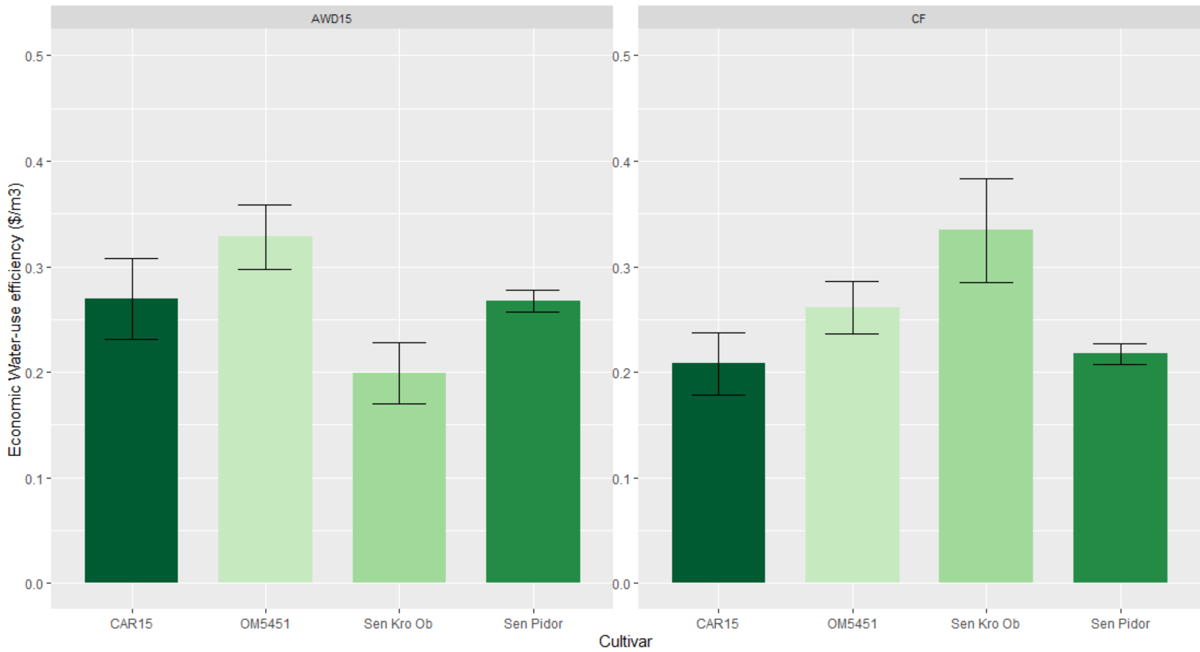
	CARDI 2021							
	AWD15				**CF**			
	OM5451	**Sen Pidor**	**Sen Kro Ob**	**CAR15**	**OM5451**	**Sen Pidor**	**Sen Kro Ob**	**CAR15**
WUE (kg/m^3)	0,625 ± 0,052	0,411 ± 0,097	0,274 ± 0,055	0,540 ± 0,067	0,407 ± 0,023	0,274 ± 0,009	0,377 ± 0,016	0,341 ± 0,021
Economic efficiency (USD/m^3)	0,328 ± 0,031	0,267 ± 0,01	0,200 ± 0,029	0,270 ± 0,038	0,261 ± 0,025	0,217 ± 0,01	0,334 ± 0,049	0,208 ± 0,029
	CARDI 2022							
	AWD15				**CF**			
	OM5451	**Sen Pidor**	**Sen Kro Ob**	**CAR15**	**OM5451**	**Sen Pidor**	**Sen Kro Ob**	**CAR15**
WUE (kg/m^3)	0,352 ± 0,017	0,289 ± 0,010	0,284 ± 0,006	0,308 ± 0,009	0,382 ± 0,053	0,397 ± 0,021	0,374 ± 0,015	0,401 ± 0,010
Economic efficiency (USD/m^3)	0,175 ± 0,017	0,181 ± 0,010	0,192 ± 0,028	0,149 ± 0,021	0,162 ± 0,015	0,206 ± 0,01	0,224 ± 0,033	0,164 ± 0,023

	Kampong Thom (CAR15)					
	Site 1			**Site 2**		
	AWD20	**AWD15**	**CF**	**AWD20**	**AWD15**	**CF**

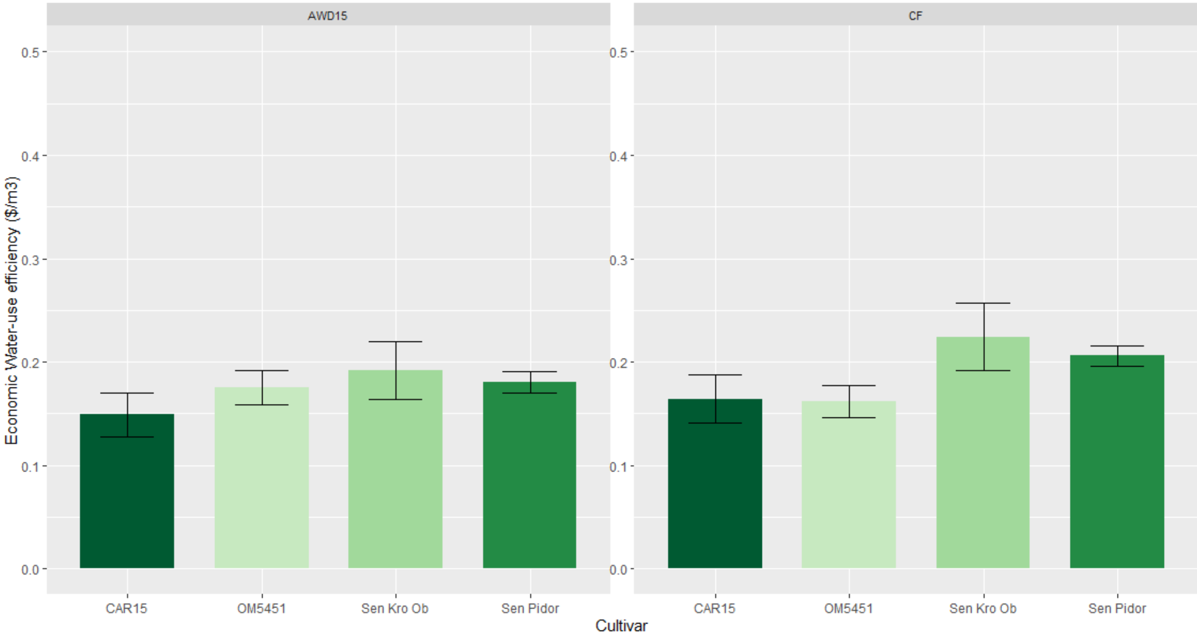
WUE (kg/m^3)	0,351 ± 0,039	0,352 ± 0,027	0,358 ± 0,013	0,548 ± 0,023	0,578 ± 0,034	0,650 ± 0,012
Economic efficiency (USD/m^3)	0,175 ± 0,025	0,176 ± 0,025	0,179 ± 0,025	0,274 ± 0,038	0,289 ± 0,041	0,325 ± 0,046

- Economic Water-Use Efficiency

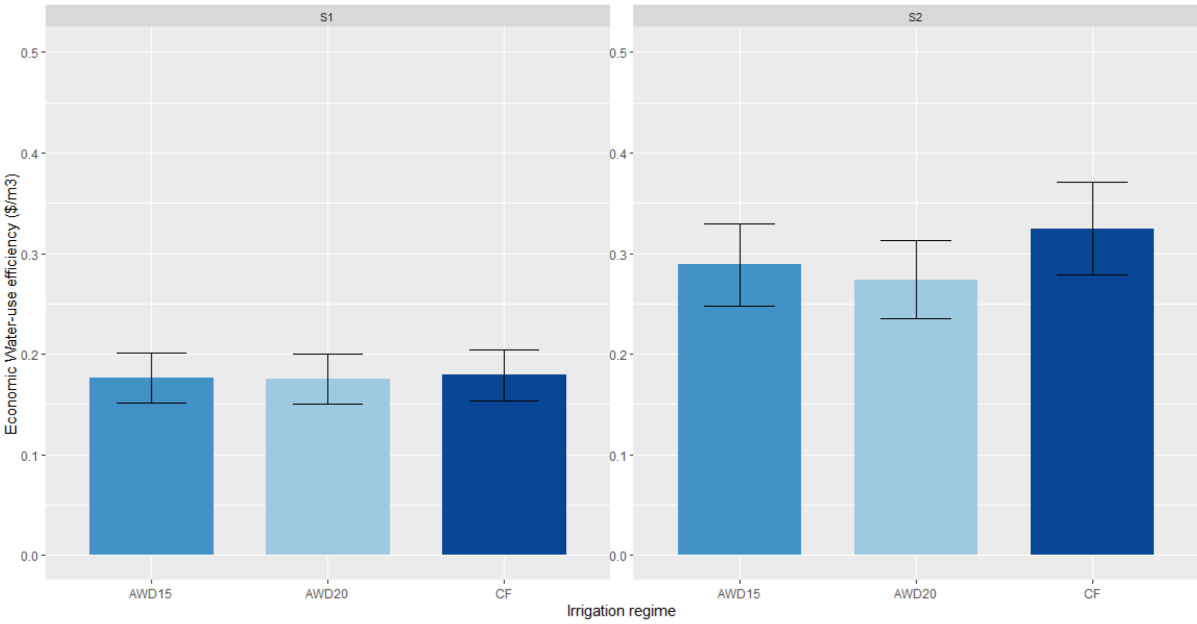
According the most recent selling prices of the different varieties, we also calculated the economic income that farmers can earn with 1 m^3 of water. Indeed, in 2022 the Sen Pidor variety is sold for 650$ per ton, the OM5451 cultivar is sold from 490$ to 560$ per ton. The CAR15 variety is sold from 450$ to 550$ per ton and finally the Sen Kro Ob variety is sold from 650$ to 800$ per ton.



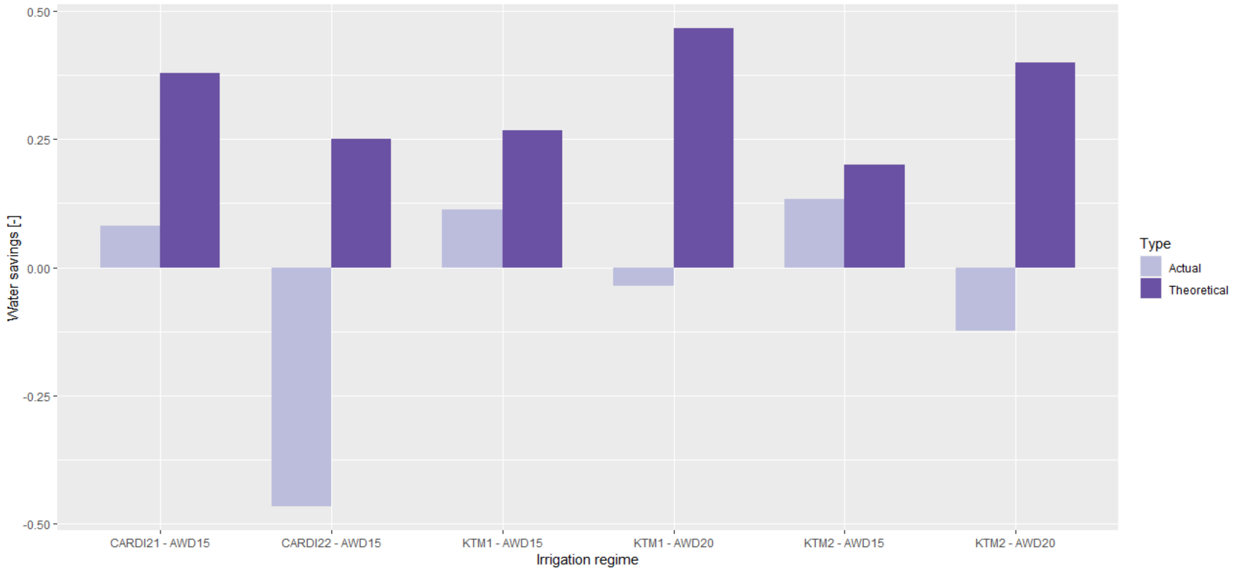
Economic Water-Use Efficiency in CARDI, 2021



Economic Water-Use Efficiency in CARDI, 2022



Economic Water-Use Efficiency in Kampong Thom



Quantity of water saved in all the AWD scenarios (compared to CF)

In figure 50 are presented the percentage of water saved compared to CF in the AWD scenarios in all sites, according to the theoretical irrigation schedule, and the measured water levels.

We need to take a lot of precaution interpreting this graph because it is based on measures of water level that may not be accurate. We did not have any data of volume or discharge so the actual percentage of water saved may not be exact. In all the experiments including AWD in the literature, the AWD saves water, so here we probably have a combination of bad management and bad data collection.

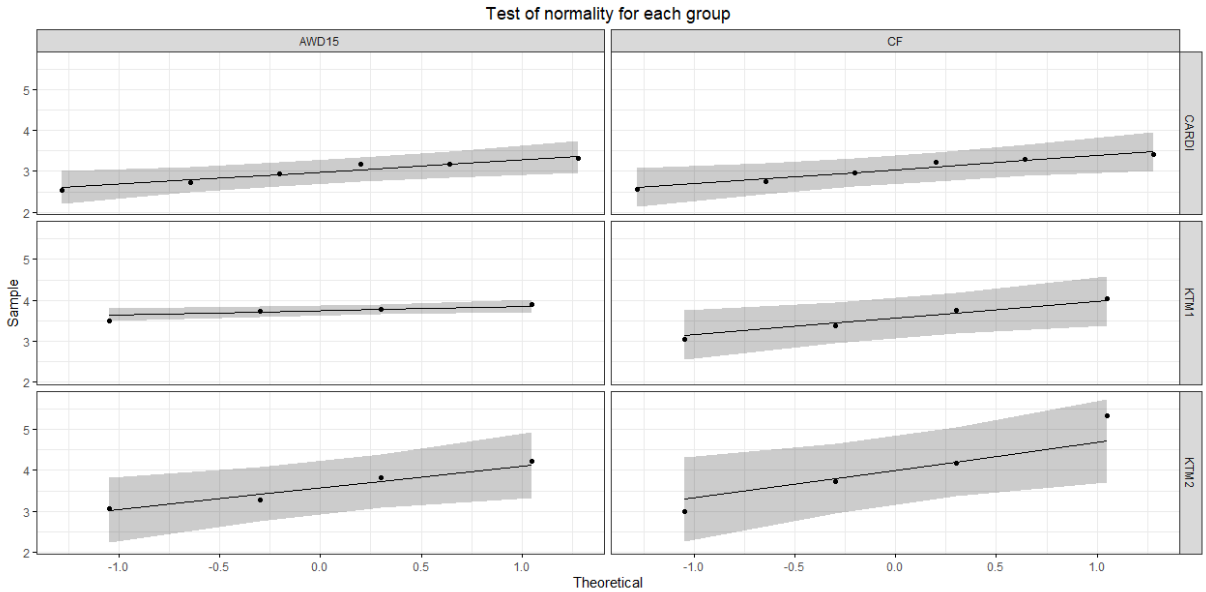
- <u>Qualitative observations</u>

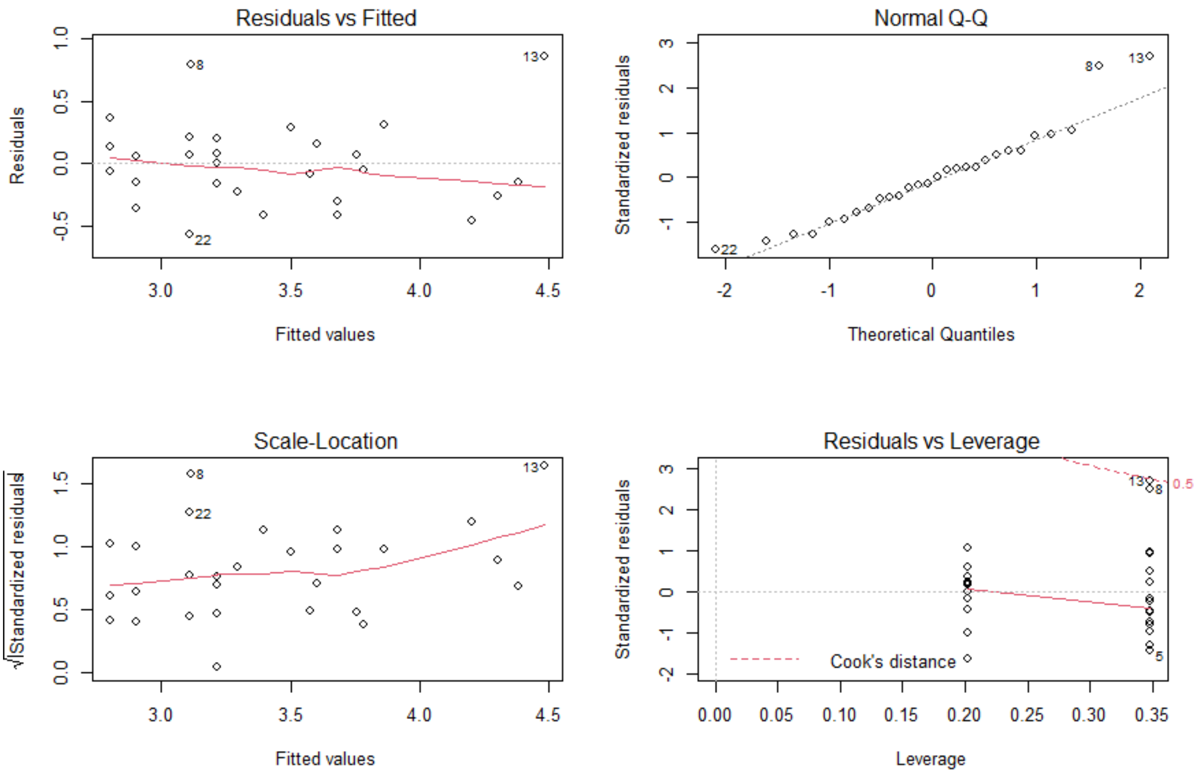
During the harvest in the Site 2 of Kampong Thom, we observed that a lot of rice grains were unripe. This was not quantified because the grains were dried and then it was impossible to determine the ripe from the unripe grains. This phenomenon could be due to the very poor stand that the number of tillers and grains had to compensate, but the quality of the grains was lessened.

Also, during the harvest in Site 2, we observed some lodging in the AWD20 plots. This was not a problem because the harvest was made manually but this could be in the case of a harvest that uses tractors.

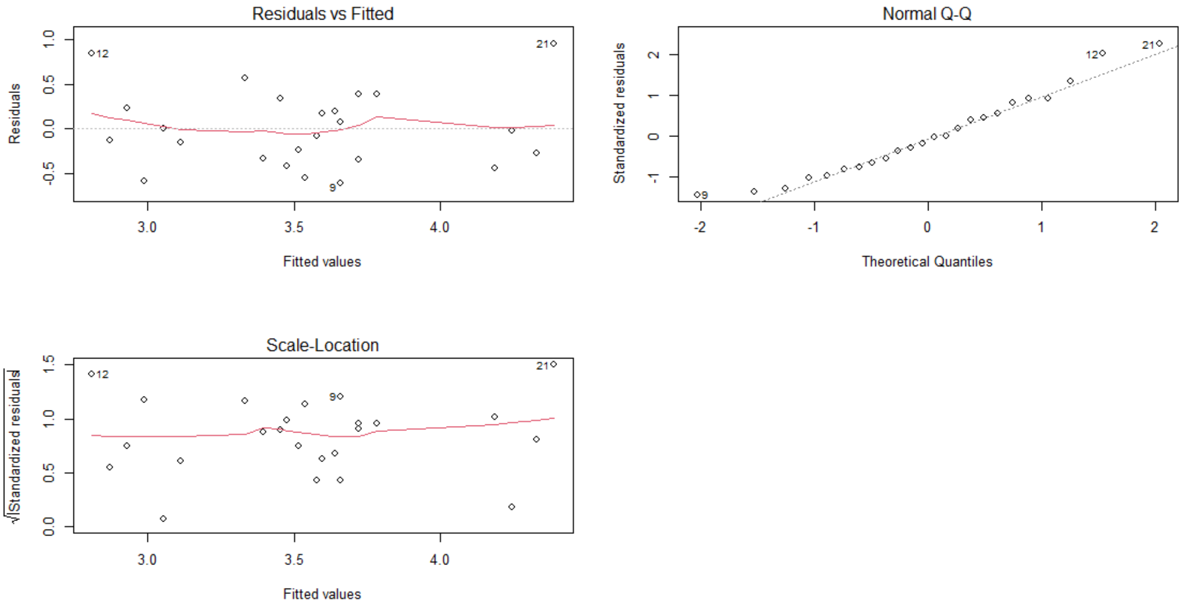
We also observed eggs of the golden apple snails in all the sites at several times of the culture. Even though there was a pesticide that was applied, some snails were still present.

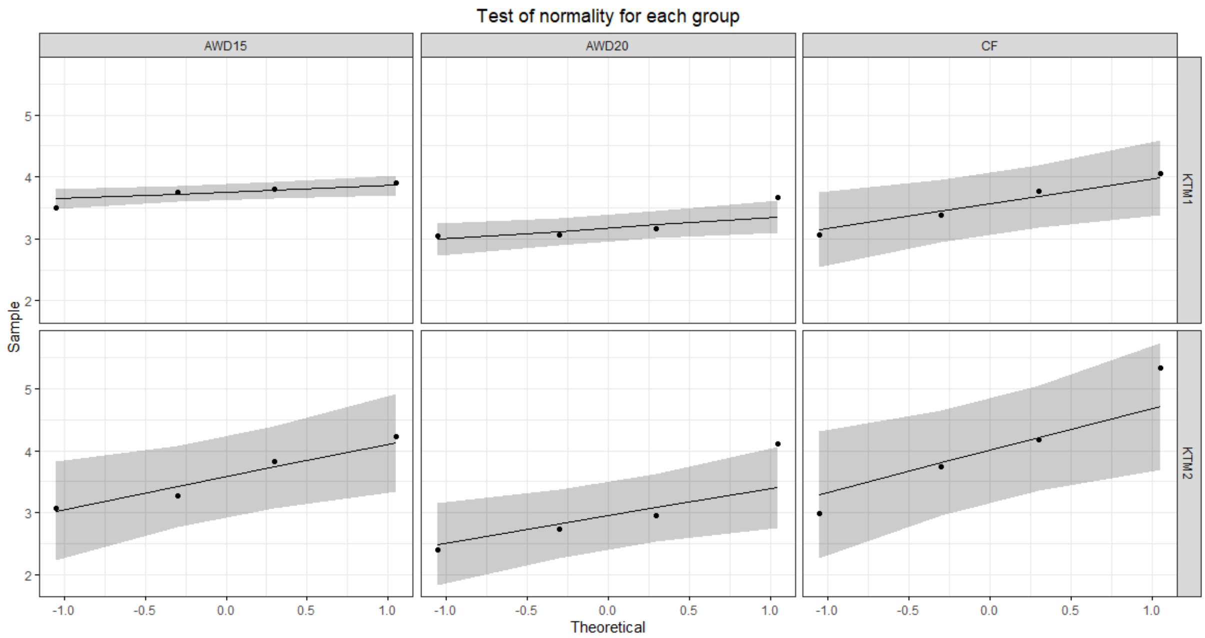
- <u>Statistical analysis – detailed results</u>
    - Validity of the test of the effect of irrigation in the three sites





- Validity of the test of the effect of irrigation in Kampong Thom





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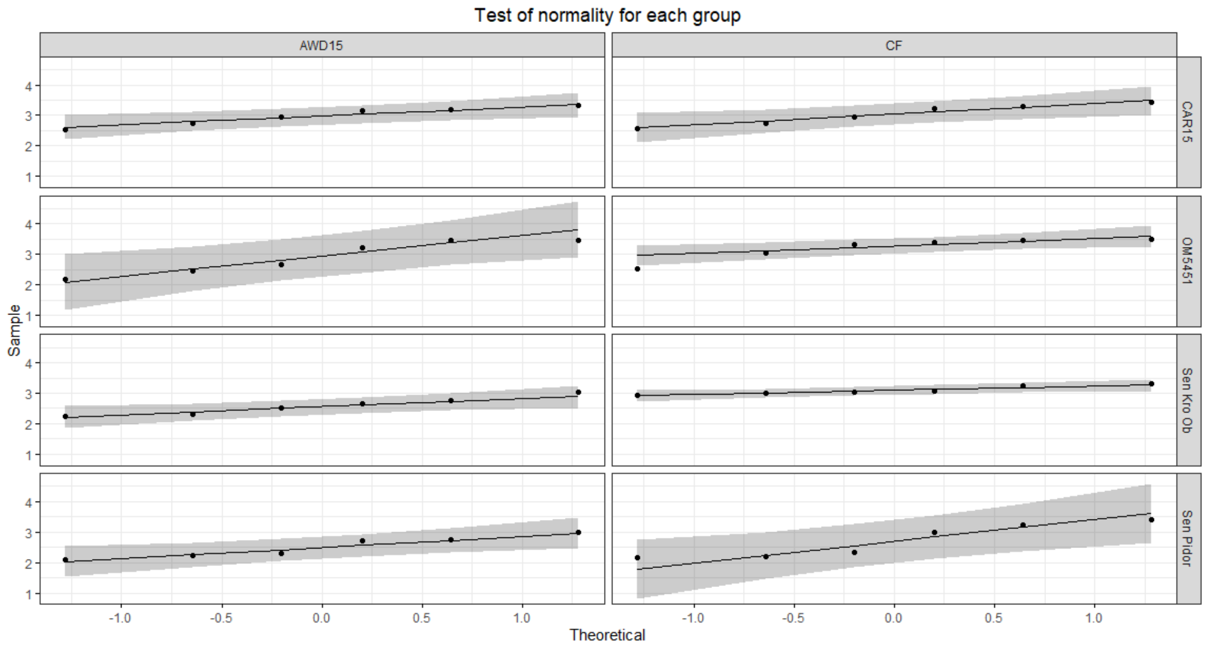

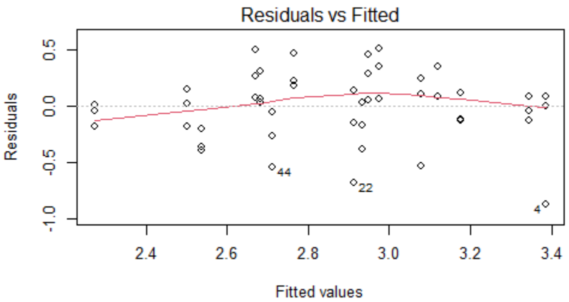

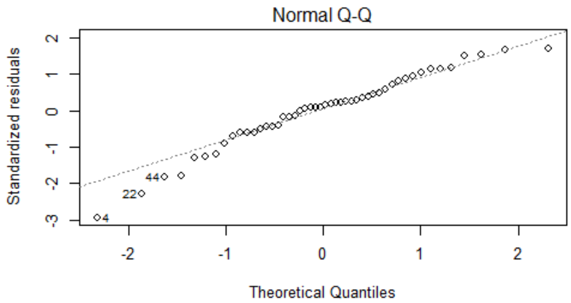

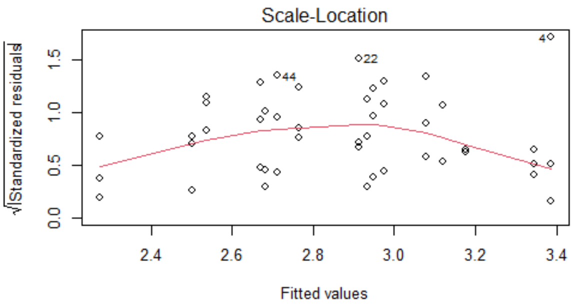

- <u>Phenological development</u>
  - CARDI 2021

	Phenological stage	50% flowering [DAT]	Maturity [DAT]
AWD15	CAR15	53	83
	OM5451	50	80
	Sen Kro Ob	59	89
	Sen Pidor	65	95
CF	CAR15	53	83
	OM5451	50	80
	Sen Kro Ob	60	90
	Sen Pidor	66	96

- CARDI 2022

[DAT]	Phenological stage	50% flowering [DAT]	Maturity [DAT]
AWD15	CAR15	56	86
	OM5451	50	80
	Sen Kro Ob	66	96
	Sen Pidor	70	100
CF	CAR15	55	85
	OM5451	51	81
	Sen Kro Ob	66	96
	Sen Pidor	69	99

- Kampong Thom Site 1

[DAT]	Phenological stage	50% flowering [DAT]	100% flowering [DAT]	End of flowering [DAT]	Maturity [DAT]
AWD20	CAR15	69	81	85	98
AWD15	CAR15	70	80	86	100
CF	CAR15	70	80	86	100

- Kampong Thom Site 2

[DAT]	Phenological stage	50% flowering [DAT]	100% flowering [DAT]	End of flowering [DAT]	Maturity [DAT]
AWD20	CAR15	55	66	70	85
AWD15	CAR15	60	64	71	90
CF	CAR15	57	63	69	87