UNIVERSITÀ DEGLI STUDI DI UDINE

Vine balance and grape quality are modulated by water, nutrients and soil management

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University of Udine,

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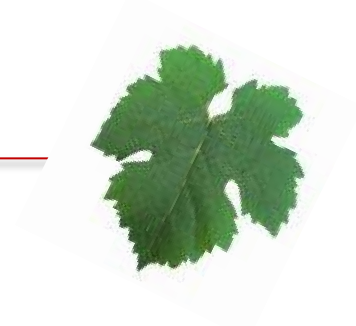
Water, production and grape quality

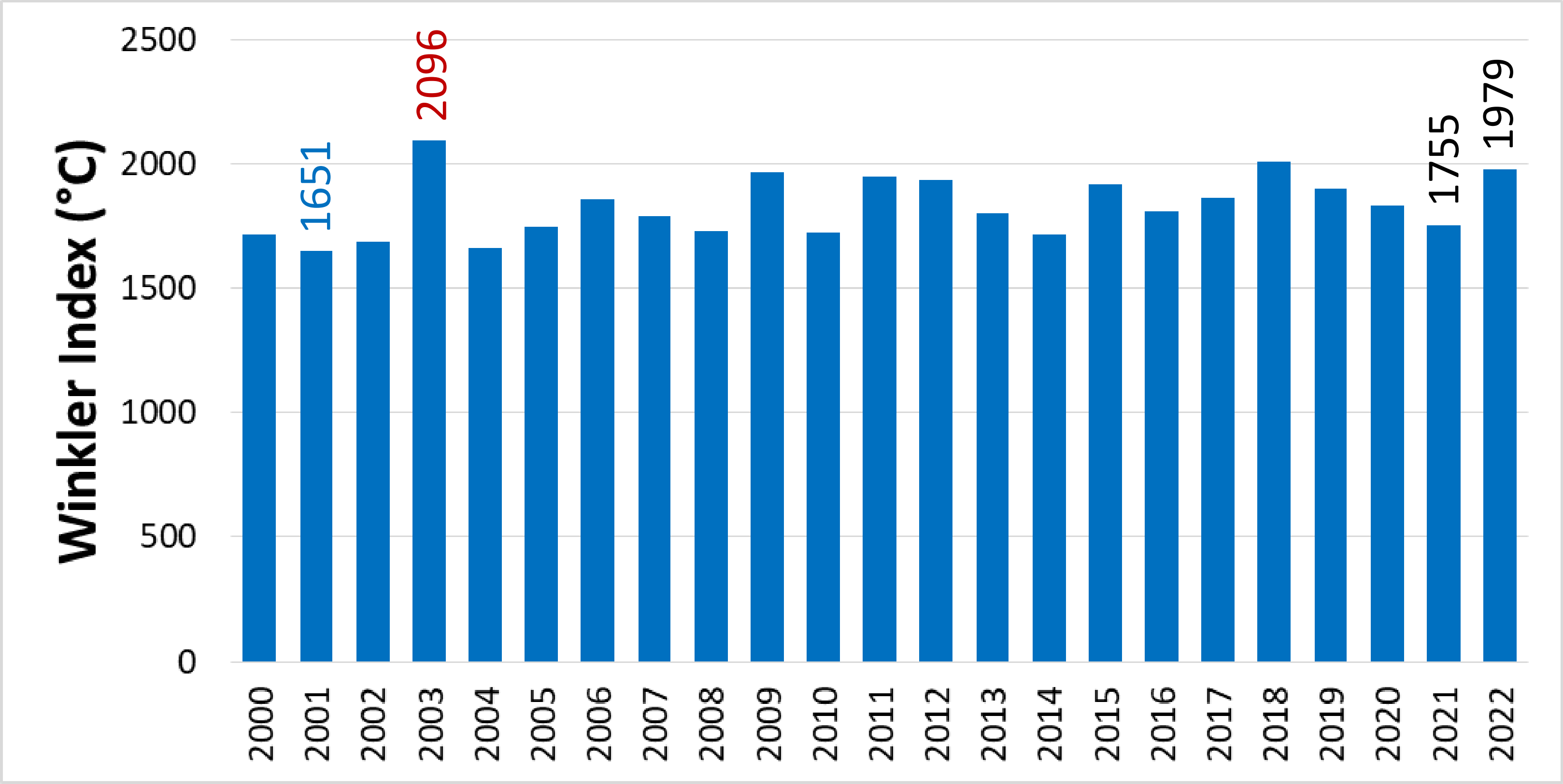


Water is required for the survival of the plants

Water balance determines the **vine requirement** to **fullfil completely** the water lost by evapotranspiration

Optimisation of grape quality is achieved when **moderate water stress** is imposed at certain phenological stages

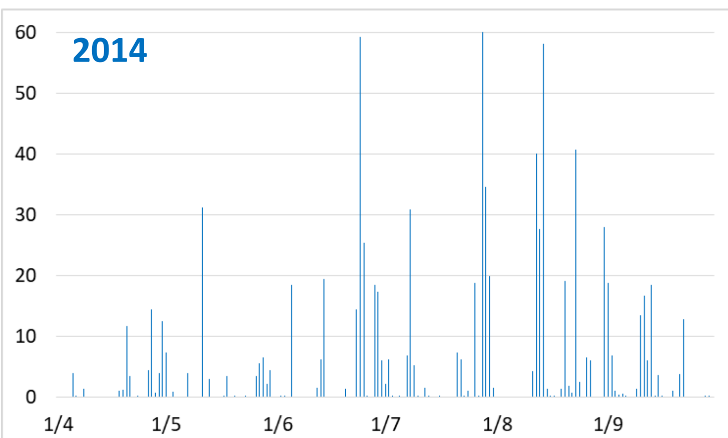
Meteorological conditions in FVG

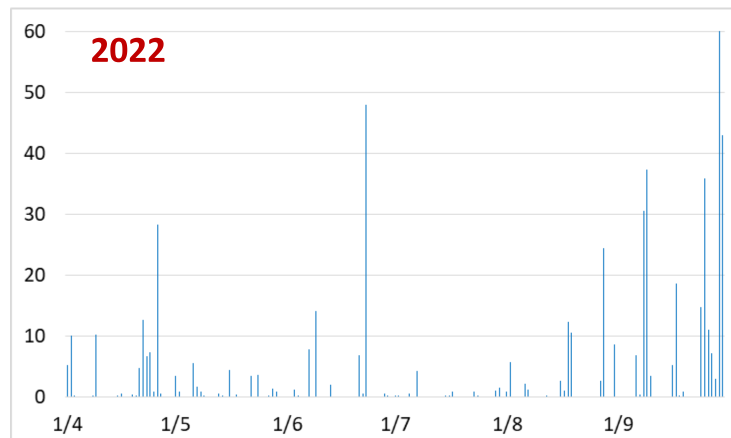


Weather station of Udine (ARPA FVG–OSMER), data accessed from http://www.meteo.fvg.it/

Meteorological conditions in FVG

	2001	2002	2003	2004	2006	2007	2008	2010	2011	2012	2013	2014	2016	2018	2019	2020	2021	2022
january	237	34	63	46	53	65	175	80	99	48	97	463	71	58	24	14	163	50
february	9	83	16	181	34	97	58	224	45	21	112	402	335	70	128	25	107	40
march	251	27	0	54	124	105	101	45	222	7	262	71	107	140	33	151	28	5
april	125	167	160	96	109	25	173	87	18	239	92	59	67	105	143	31	172	113
may	63	125	66	166	88	209	166	230	85	88	299	72	238	125	303	119	282	28
june	98	127	99	131	21	117	130	69	190	114	64	188	122	132	21	247	37	81
july	164	127	47	63	91	128	189	144	148	72	47	209	92	110	73	84	90	10
august	62	274	103	321	204	147	115	122	23	94	95	238	69	72	65	162	71	72
september	249	169	100	97	54	160	102	265	84	201	302	105	114	47	149	145	97	280
october	49	143	110	254	31	113	130	179	198	176	78	62	124	158	46	206	176	43
november	49	224	173	137	82	50	226	252	26	260	186	311	254	181	440	26	149	148
december	11	60	219	128	176	29	325	262	61	84	108	101	0	19	158	345	61	135
	1366	1561	1155	1673	1067	1246	1890	1957	1199	1405	1743	2282	1592	1215	1581	1555	1432	1004





Weather station of Udine (ARPA FVG–OSMER), data accessed from http://www.meteo.fvg.it/

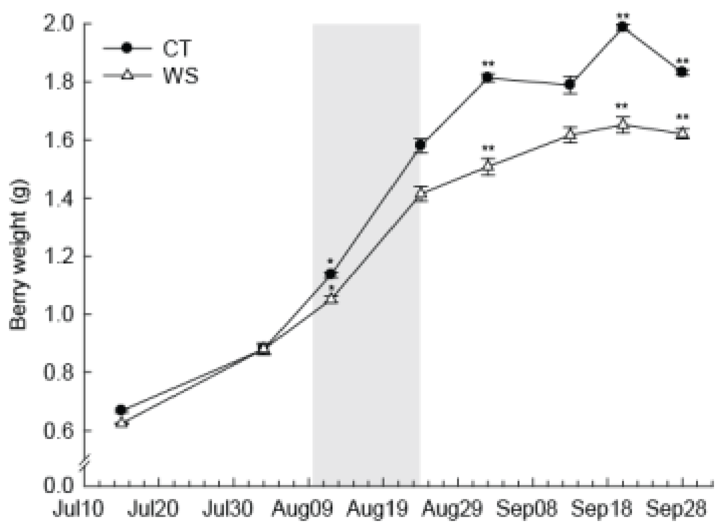
Water, production and grape quality

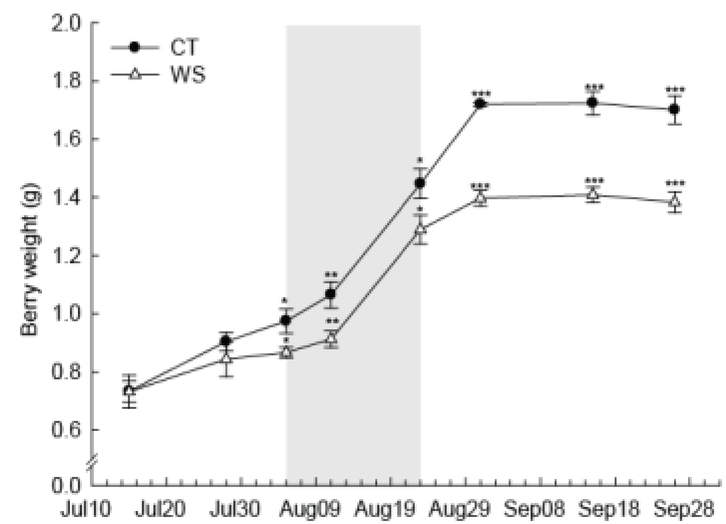
Different effects of water stress on:

- Cluster weight and yield
- Berry weight and skin-to-flesh ratio
- Accumulation of soluble solids
- Degradation of acids
- Biosynthesis of polyphenols
- Biosynthesis of aroma compounds
- Wine chemistry
- Sensory descriptors of wines

Cluster weight, yield and berry weight

	Well-watered	water stress	Sign. F
Yield 2004 (kg / vine)	4.59	3.75	*
Yield 2005 (kg / vine)	4,10	3,22	*





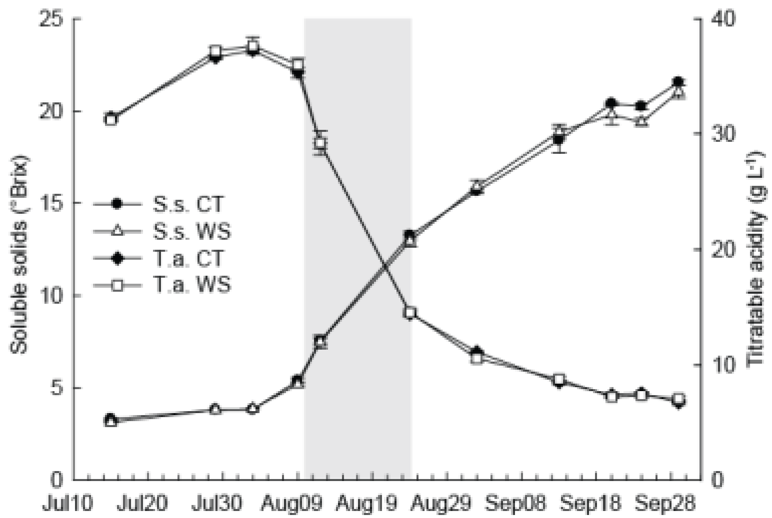
Castellarin S.D., Pfeiffer A., **Sivilotti P.**, Degan M., Peterlunger E. and Di Gaspero G. (2007). *Plant, Cell and Environment* **30**(11):1381-1399.

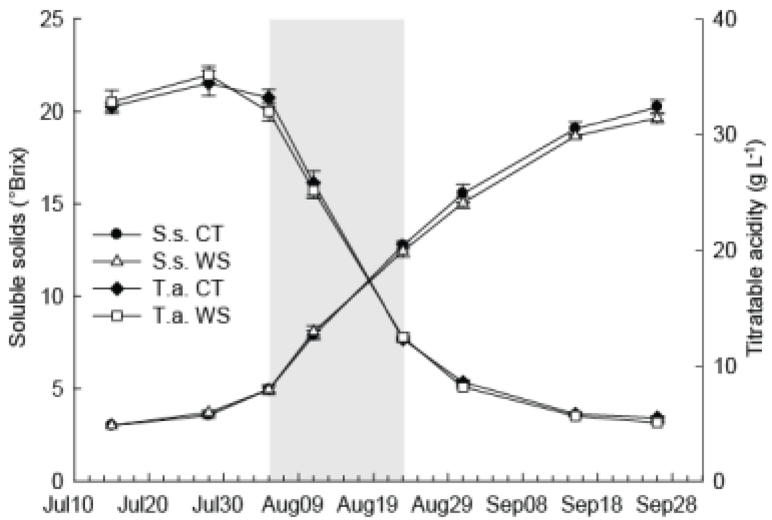
Cluster weight, yield and berry weight

	Mild water deficit	Moderate water deficit	Sign. F
Cluster number	10,7	10,2	n.s.
Yield (kg/vine)	1,81	1,48	**
Cluster weight (g)	164	145	*
Berry weight (g)	2,26	1,86	***
Skin-to flesh weight (%)	8,4	8,6	n.s.
Seeds-to-flesh weight (%)	3,9	3,7	n.s.

Calderan A., **Sivilotti P.**, Braidotti R., Mihelčič A., Lisjak K. and Vanzo A. (2021). *Agricultural Water Management* **246**:106684.

Soluble solids and titratable acidity





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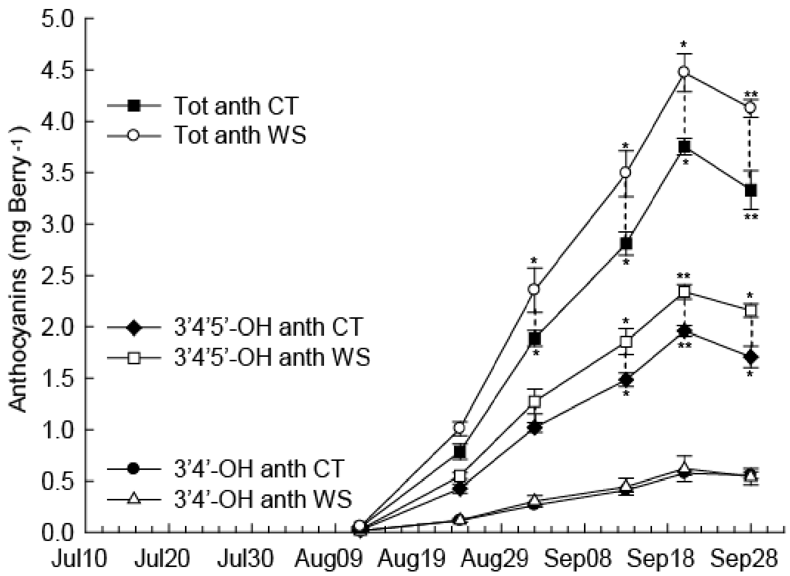
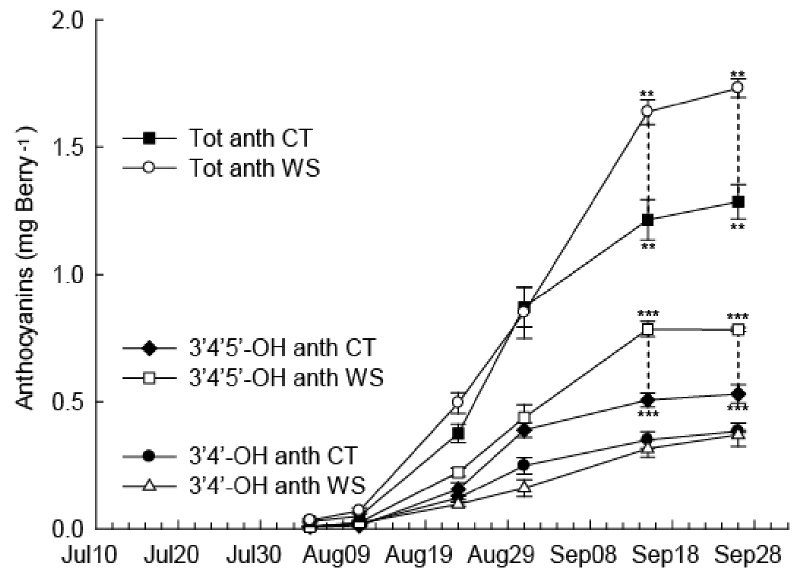
Polyphenols: anthocyanins





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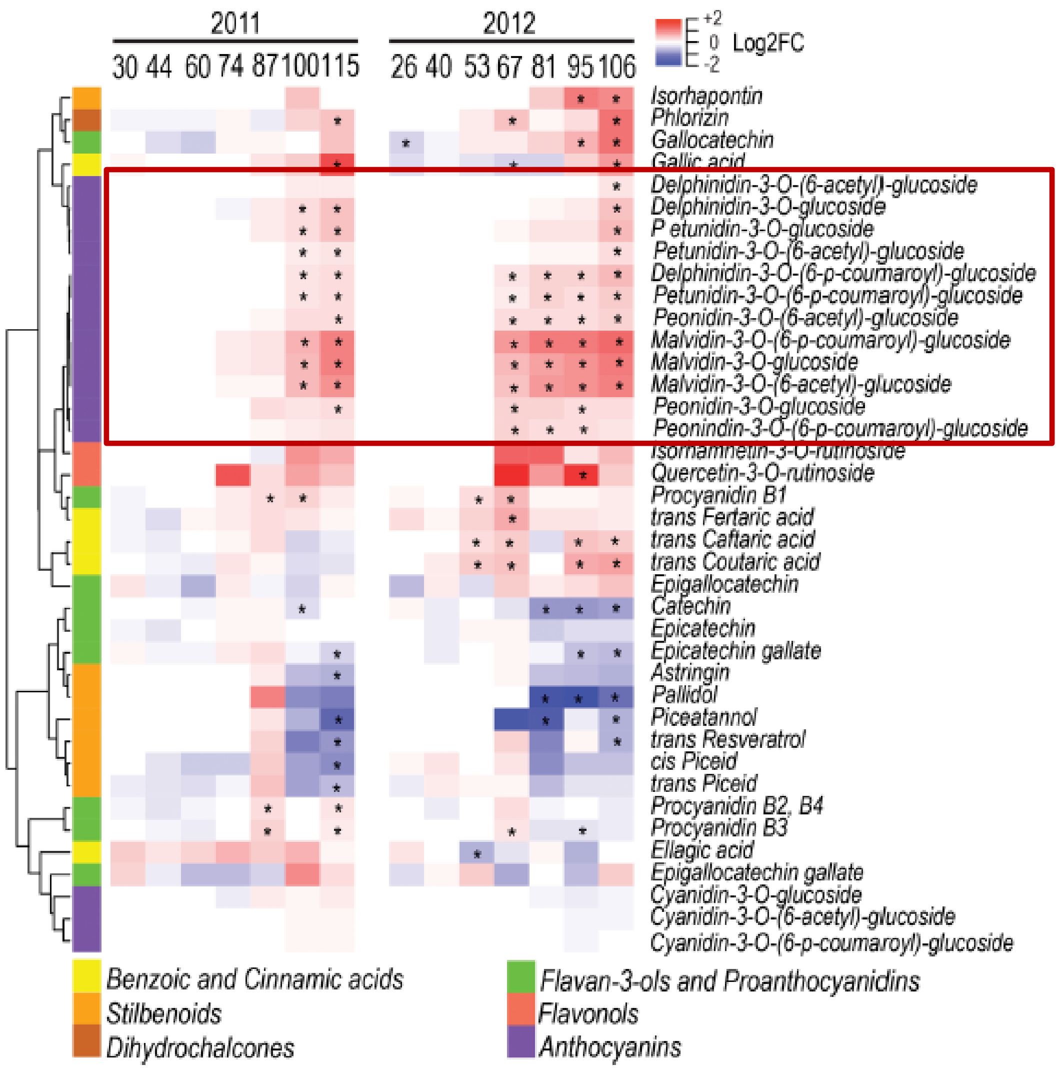
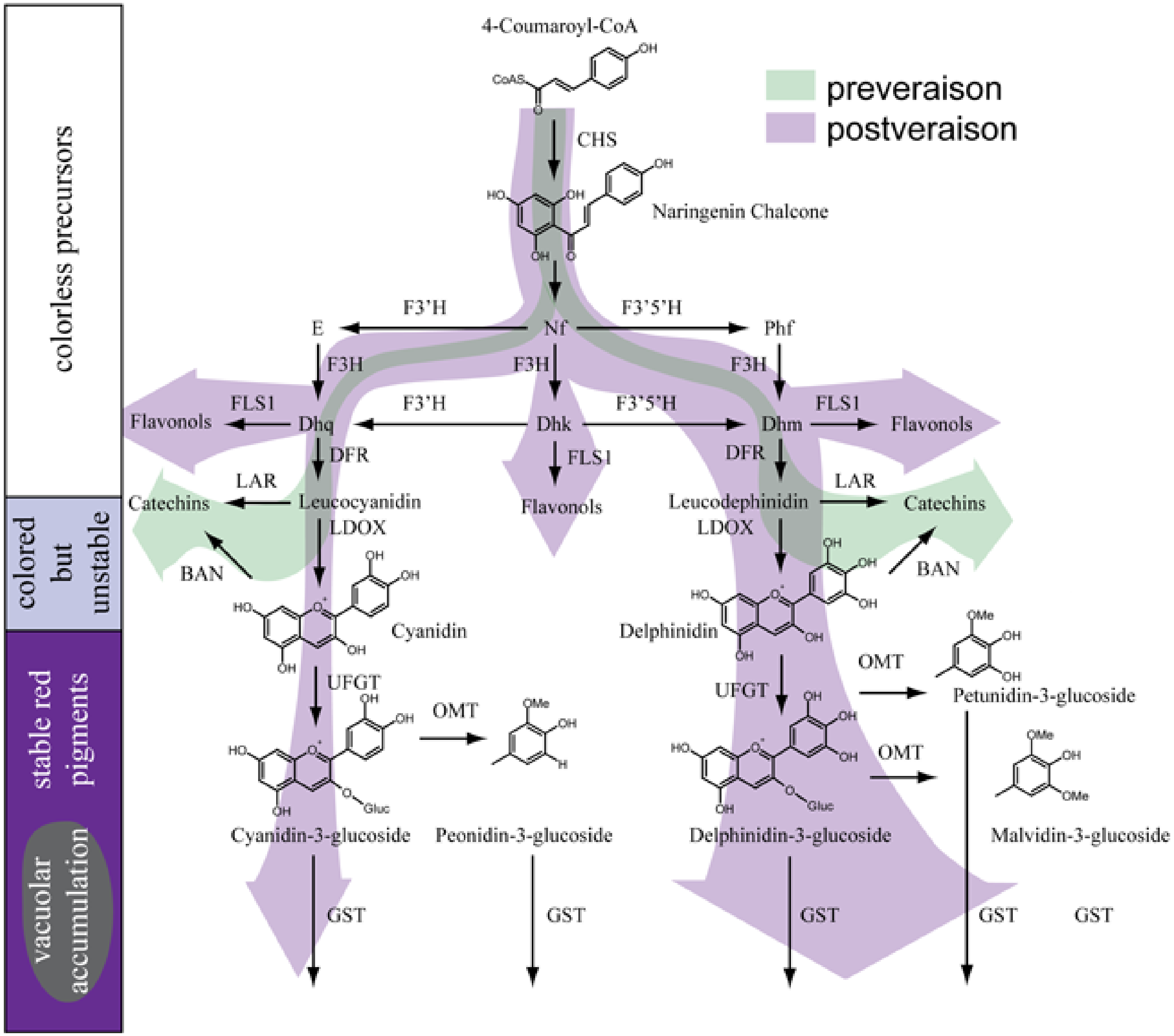


tri-substituted and methoxylated anthos

Savoi S., Wong D.C.J., Degu A., Herrera J.C., Bucchetti B., Peterlunger E., Fait A., Mattivi F. and Castellarin S.D. (2017). *Frontiers in Plant Sciences* **8**:1124.

Polyphenols: anthocyanins

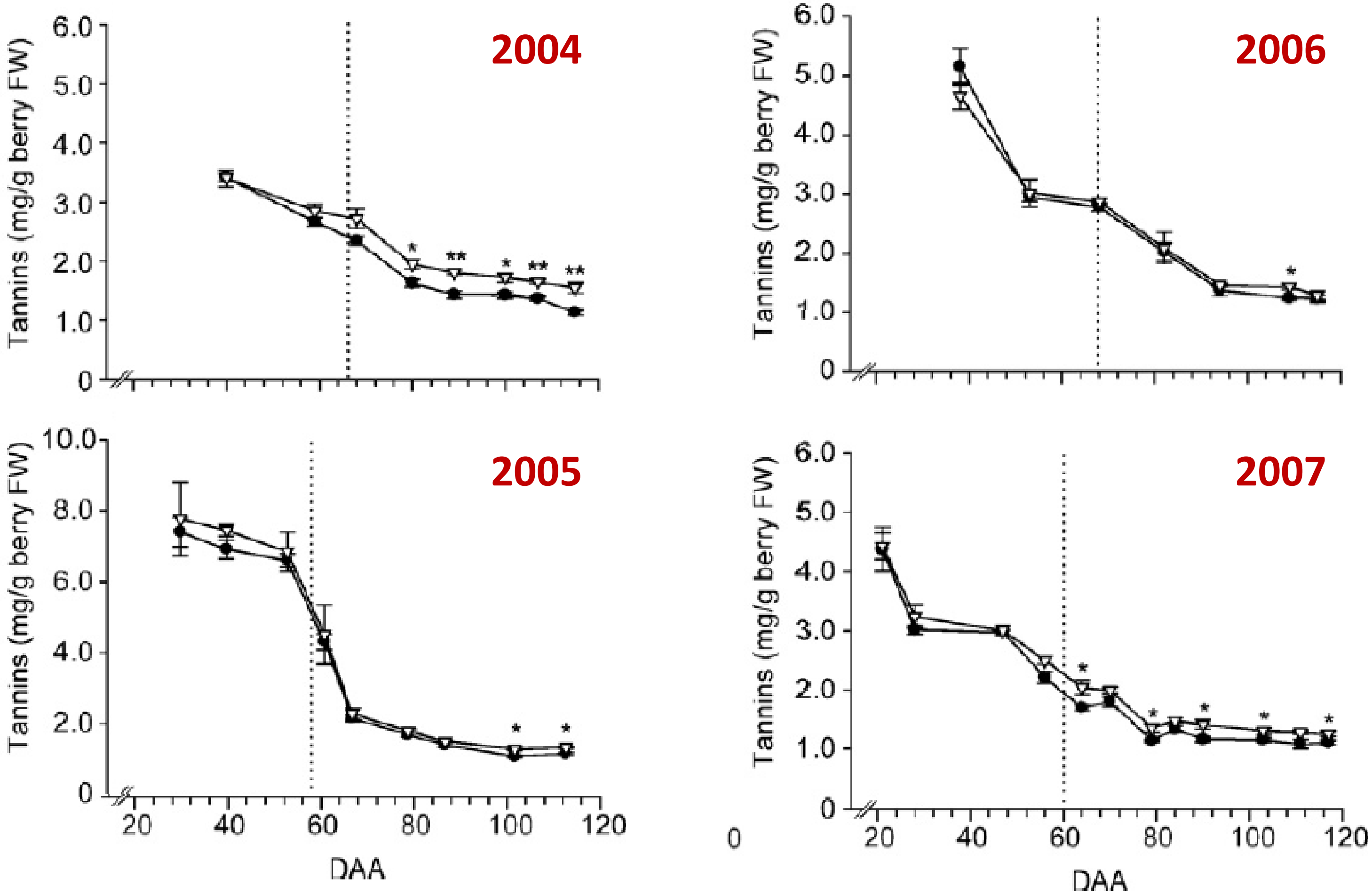


Polyphenols: anthocyanins

Water stress promotes

- higher **biosynthesis** of anthocyanins
- higher proportion a **tri-substituted** monomers
- higher proportion of **methoxyated** monomers

Polyphenols: skins proanthocyanins



Bucchetti B., Matthews, M.A., Falginella L., Peterlunger E., Castellarin S.D. (2011). *Scientia Horticulturae* **128**:297-305.

Polyphenols: skins proanthocyanins

	Mild water deficit	Moderate water deficit	Sign. F
Total extraction			
HMWP (mg/g berry FW)	5,30	5,12	n.s.
LMWP (mg/g berry FW)	1.98	2.22	n.s.
Mean degree of polymerisation	17.68	19.60	n.s.
% galloylation	**12.13**	**14.47**	***
% prodelphinidines	28.22	27.76	n.s.

Calderan A., **Sivilotti P.**, Braidotti R., Mihelčič A., Lisjak K. and Vanzo A. (2021). *Agricultural Water Management* **246**:106684.

Polyphenols: skins proanthocyanins

	Mild water deficit	Moderate water deficit	Sign. F
Wine-like extraction			
HMWP (mg/g berry FW)	1.51	1.35	n.s.
LMWP (mg/g berry FW)	0.56	0.39	n.s.
Mean degree of polymerisation	7.07	6.84	n.s.
% galloylation	**7.80**	**11.20**	***
% prodelphinidines	31.60	33.30	n.s.

Calderan A., **Sivilotti P.**, Braidotti R., Mihelčič A., Lisjak K. and Vanzo A. (2021). *Agricultural Water Management* **246**:106684.

Polyphenols: seeds proanthocyanins

	Mild water deficit	Moderate water deficit	Sign. F
Total extraction			
HMWP (mg/g berry FW)	1.74	1.68	n.s.
LMWP (mg/g berry FW)	1.23	1.23	n.s.
Mean degree of polymerisation	8.29	8.86	n.s.
% galloylation	46.66	48.27	n.s.

Calderan A., **Sivilotti P.**, Braidotti R., Mihelčič A., Lisjak K. and Vanzo A. (2021). *Agricultural Water Management* **246**:106684.

Polyphenols: seeds proanthocyanins

	Mild water deficit	Moderate water deficit	Sign. F
Wine-like extraction			
HMWP (mg/g berry FW)	0.45	0.46	n.s.
LMWP (mg/g berry FW)	0.39	0.37	n.s.
Mean degree of polymerisation	**4.06**	**4,80**	***
% galloylation	**37.60**	**45.20**	***

Calderan A., **Sivilotti P.**, Braidotti R., Mihelčič A., Lisjak K. and Vanzo A. (2021).
Agricultural Water Management **246**:106684.

Cell-wall modification during ripening

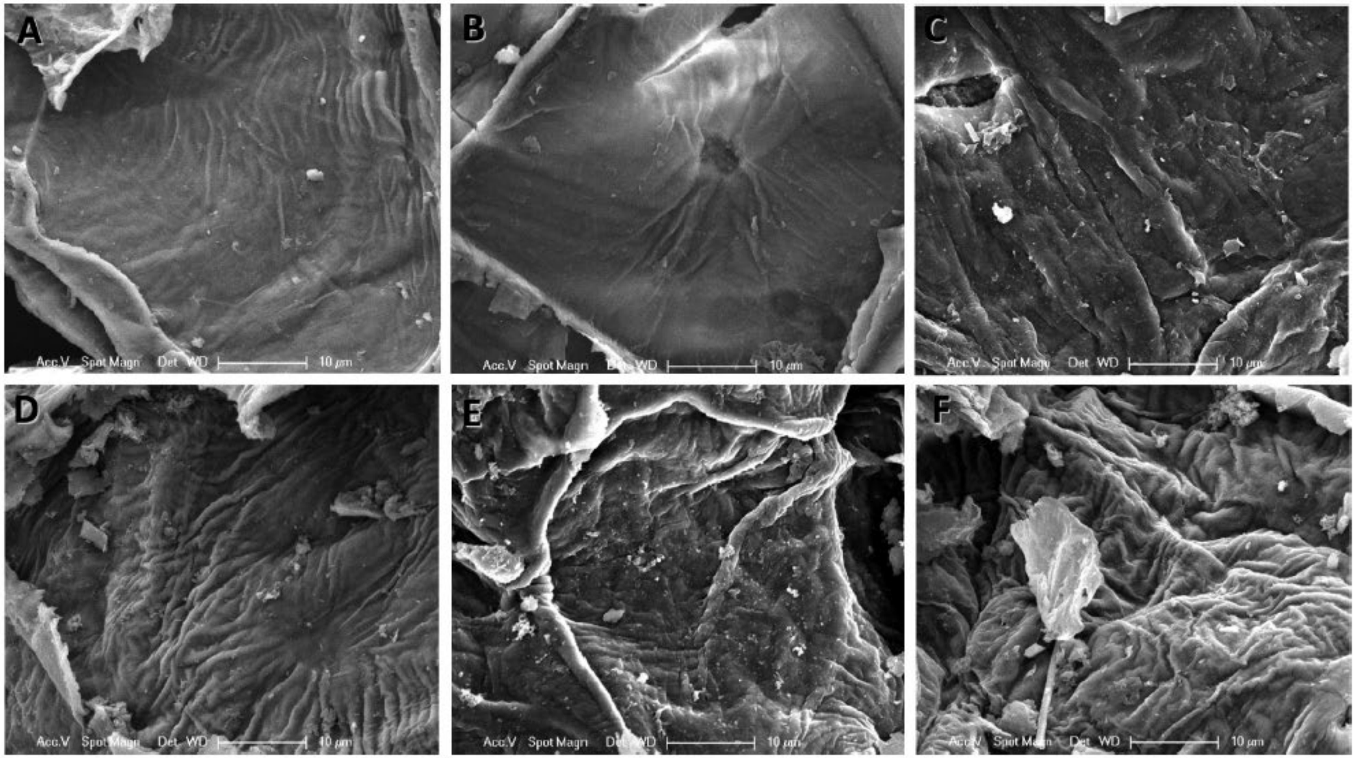


Figure 3. Scanning electron micrographs (5000× magnification) of isolated cell wall material from unripe and ripening Cabernet Sauvignon grape skins: (A, B) January 15, −11 DAV, preveraison; (C) January 26, DAV, veraison; (D) February 23, 28 DAV, 22 °Brix; (E) March 2, 35 DAV, 23 °Brix; (F) March 17, 50 DAV, 26 °Brix (DAV = days after veraison, bars = 10 μm).

Bindon K.A, Hadi Madani S., Pendleton P, Smith P.A., Kennedy J.A (2014).
Journal of Agricultural and Food Chemistry **62**:1130–1141.

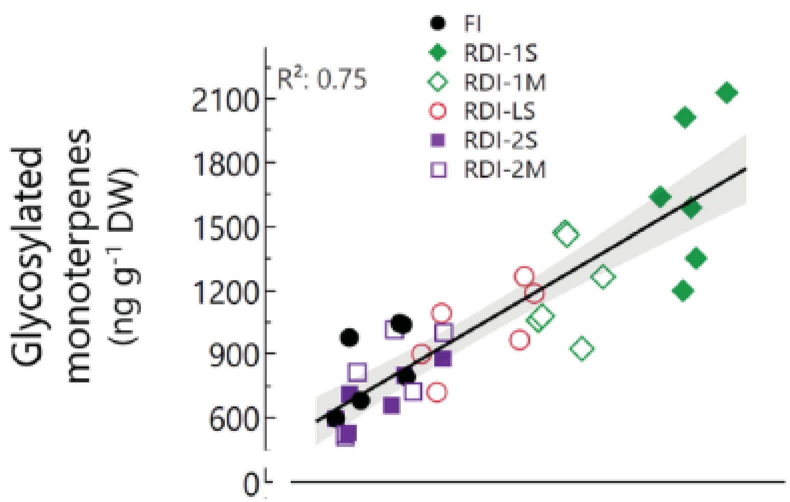
Polyphenols: proanthocyanins

Water stress promotes

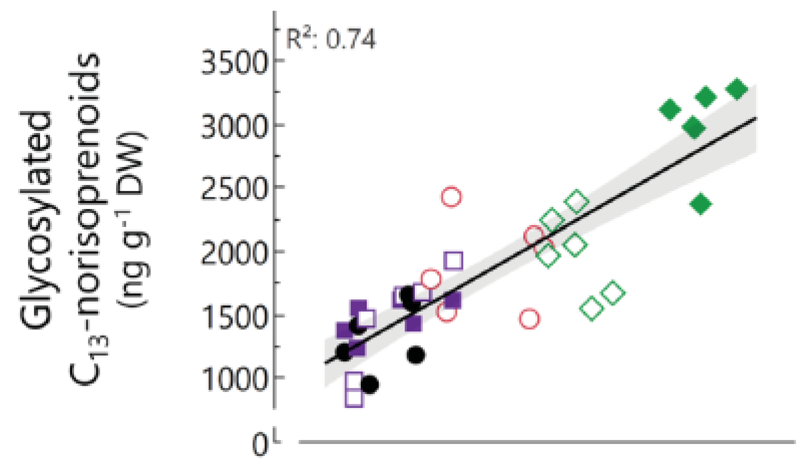
- higher **biosynthesis** and polymerisation of flavan-3-ols
- higher proportion a **galloylated** monomers
- higher adsorption on cell-walls

Aroma compounds: terpenes & norisoprenoids

Water stress **before veraison** affect the biosynthesis of varietal aroma compounds



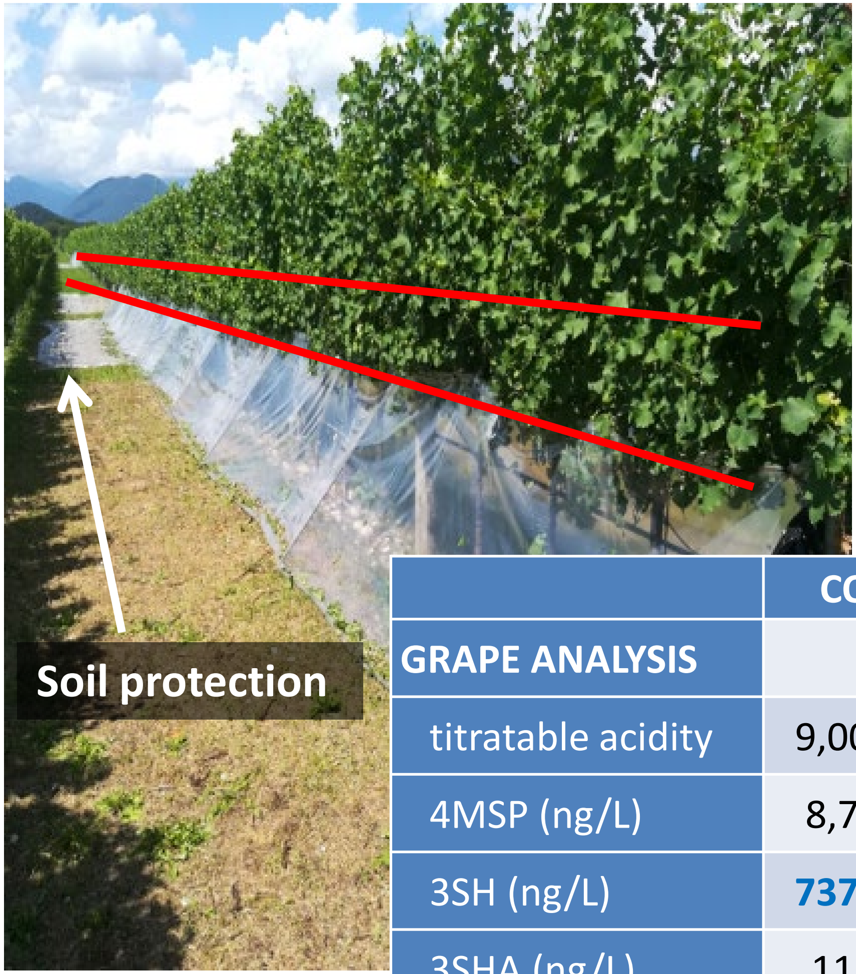
Water stress integral pea-size to veraison



Water stress integral pea-size to veraison

Palai G., Caruso G., Gucci R. and D'Onofrio C. 2023. *Frontiers in Plant Sciences* **14**:1117572

Aroma compounds: thiols in wines



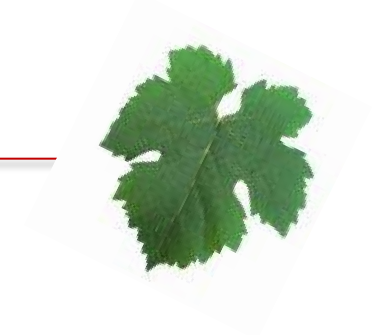
Undisturbed canopy

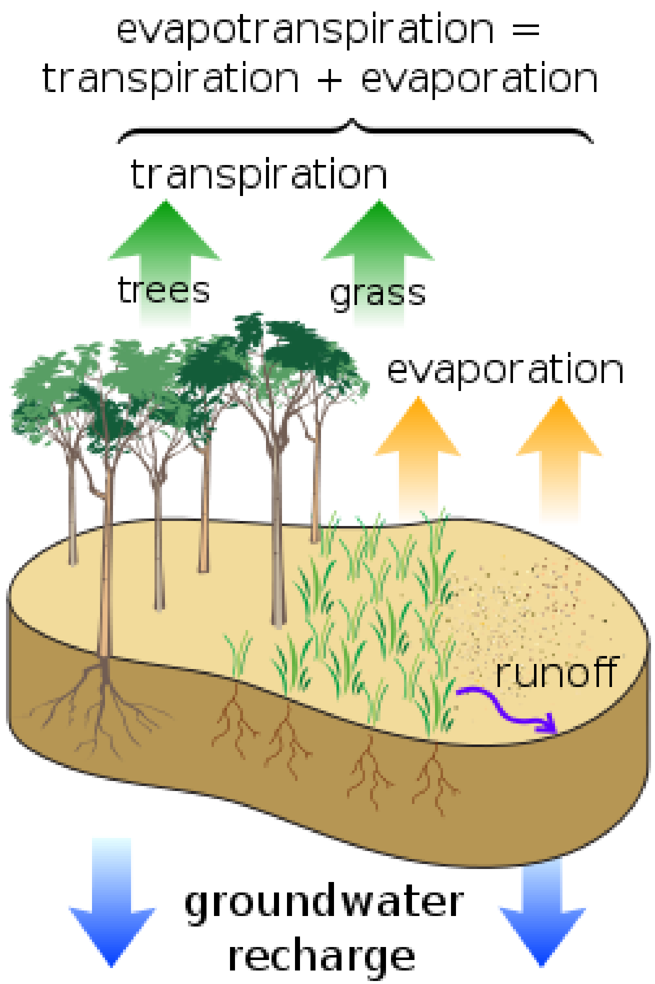
Heated cluster area

	CON	HS	WS	WS/HS	sign. F
GRAPE ANALYSIS					
titratable acidity	9,00 ab	**9,31 a**	**8,68 b**	**8,68 b**	**
4MSP (ng/L)	8,70 b	**11,07 a**	**5,50 c**	**7,60 bc**	**
3SH (ng/L)	**737,1 b**	839,8 ab	**896,0 a**	**879,3 a**	*
3SHA (ng/L)	11,91	8,09	13,78	10,99	ns

Calderan A., Falchi R., Braidotti R., Lisiak K., Vanzo A., Meggio F. and **Sivilotti P.** In litteris

How much to irrigate ?





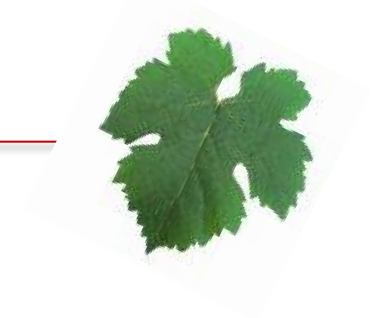
evapotranspiration

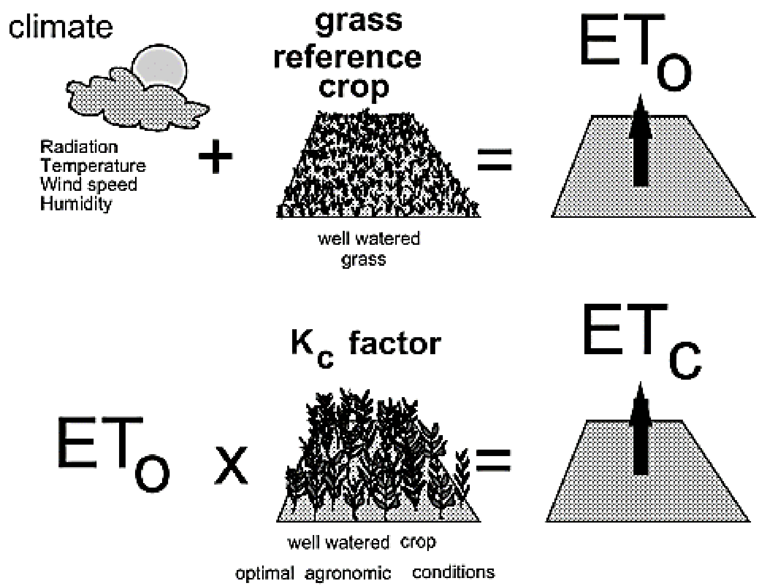
available water content

http://en.wikipedia.org/wiki/Evapotranspiration#mediaviewer/File:Surface_water_cycle.svg

Evapotranspiration

Evapotranspiration





Reference crop:
uniform grass or alfa-alfa field

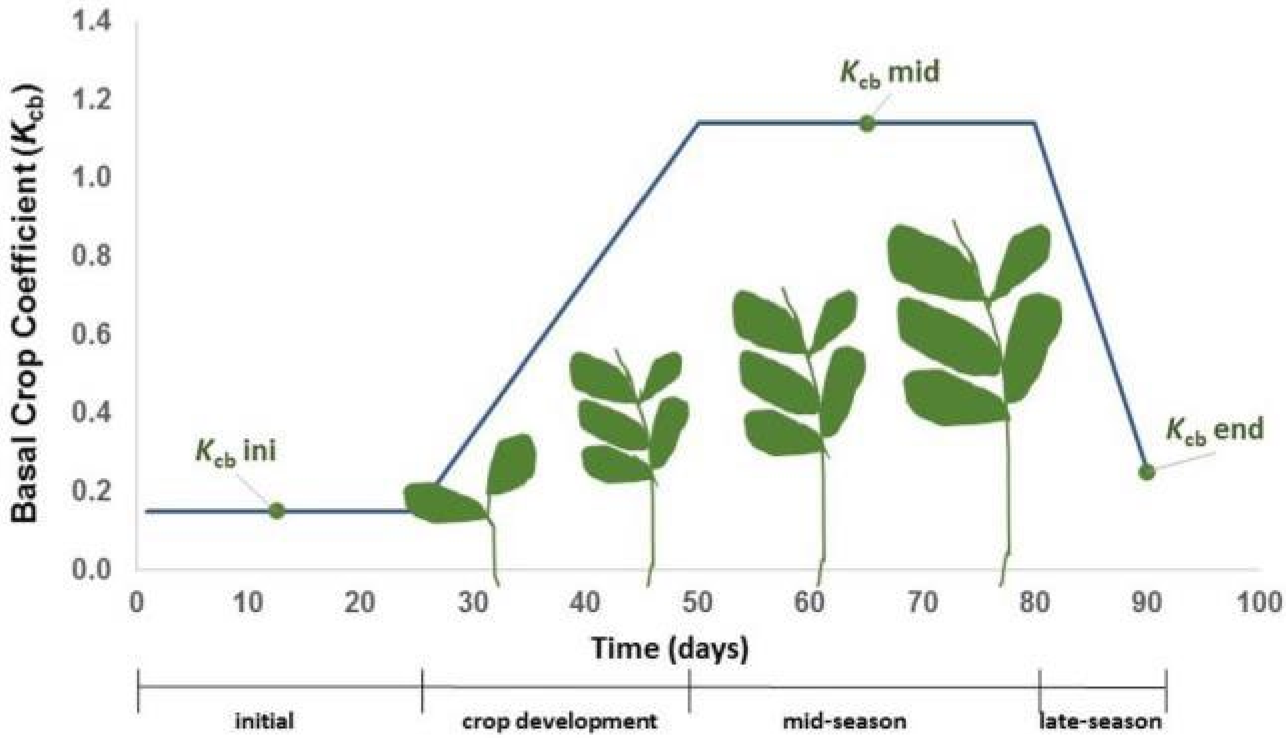
$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)}$$

Penman Monteith

Allen, R., Pereira, L. and Smith, M. (1998) *FAO Irrigation and drainage paper 56*. FAO - Food and Agriculture Organization of the United Nations.

Evapotranspiration – crop coefficient

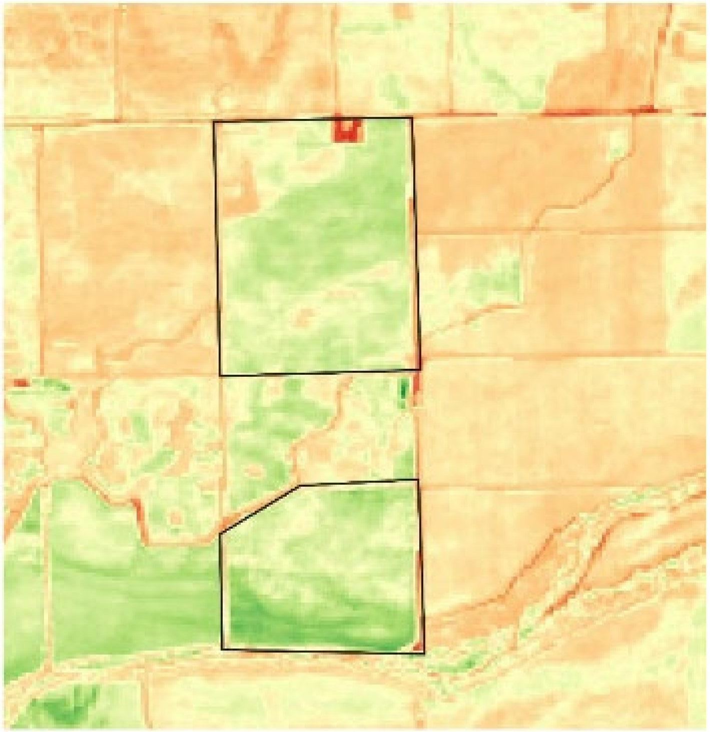
It considers the crop's **water requirements**, **growth stage**, and other factors that influence its water use.



Allen, R., Pereira, L. and Smith, M. (1998) *FAO Irrigation and drainage paper 56*. FAO - Food and Agriculture Organization of the United Nations.

Evapotranspiration

Using **Sentinel-2** images, and the Simple Algorithm for Evapotranspiration Retrievement (**SAFER**) model to estimate daily and seasonal actual evapotranspiration in vineyard.

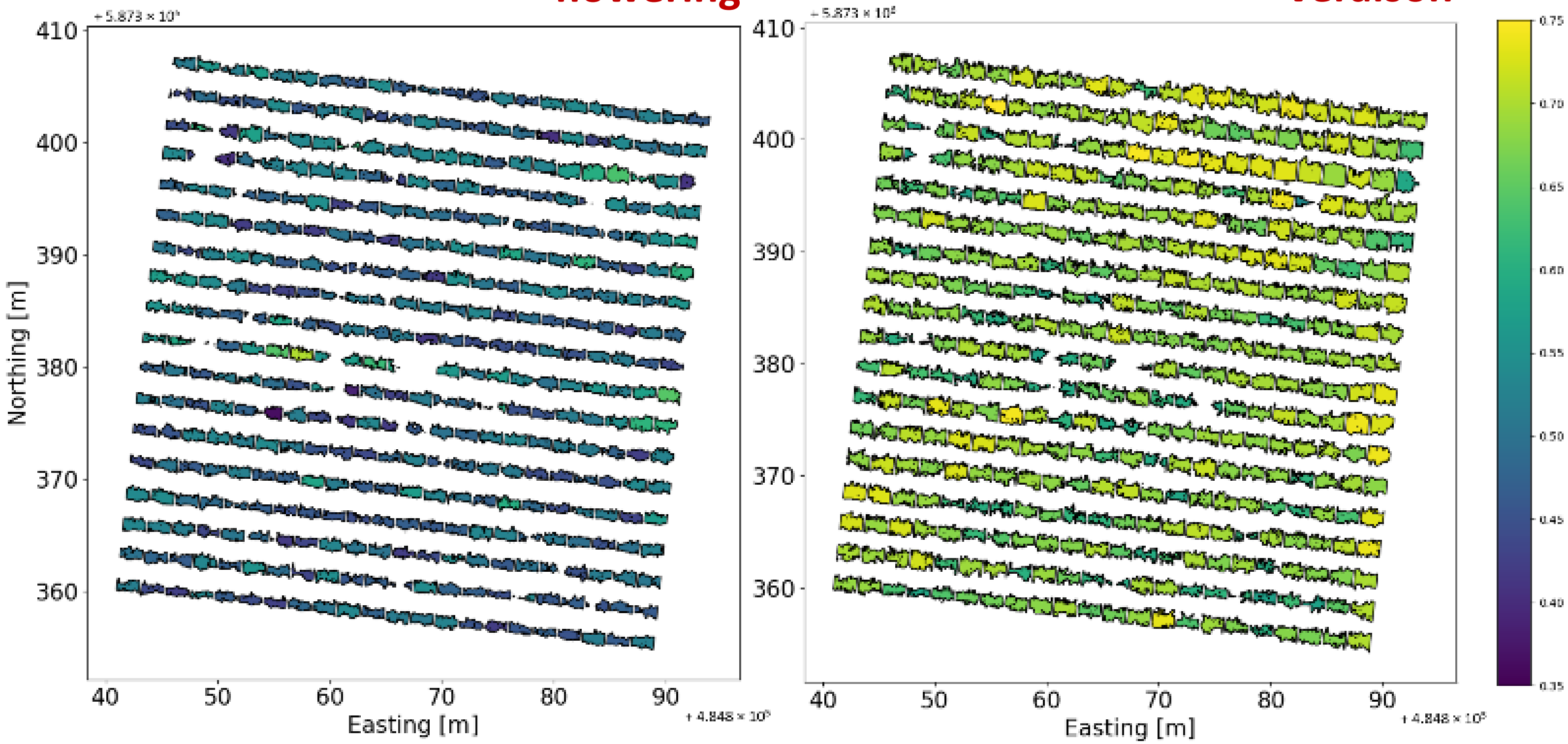


Safre, A.L.S., Nassar, A., Torres-Rua, A., Aboutalebi, M., Saad, J.C.C., Manzione, R.L., de Castro Teixeira, A.H., Prueger, J.H., et al. (2022). *Irrigation Science* **40**(4): 635–654.

Evapotranspiration – crop coefficient

Estimation of kc at the single vine level to capture the spatial variability of water requirements.

flowering **veraison**

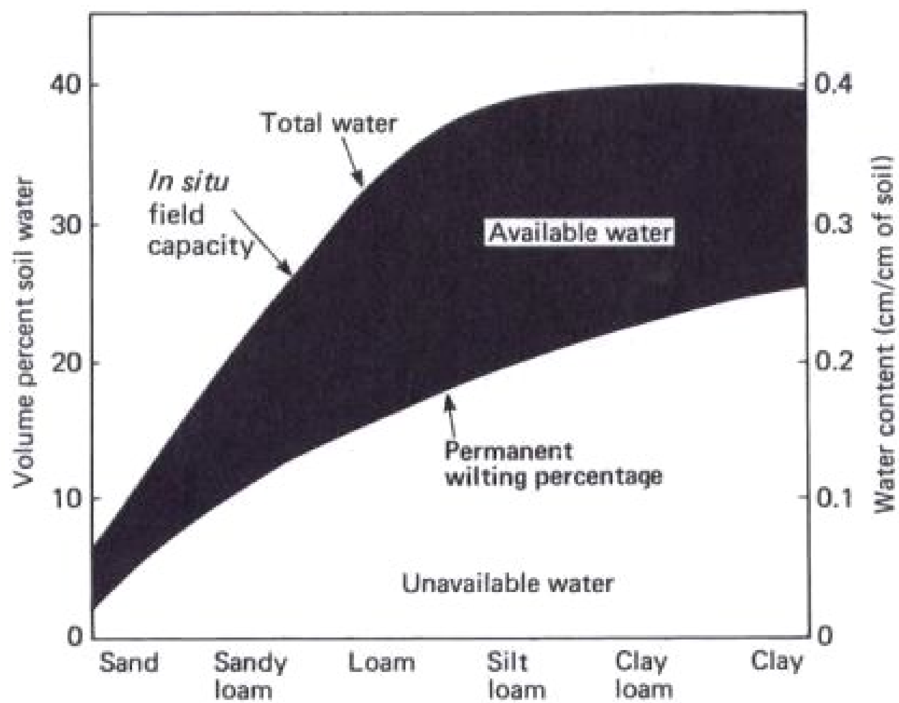


Gautam, D., Ostendorf, B. and Pagay, V. (2021). *Remote Sensing* **13**(13):2639.

Available water content

different **texture** = different available water content

texture	water content	
	range	average
Sandy soils	33-42	36
Sand-silty soils	62-83	67
Loam	83-125	104
Silty soils	125-192	158
Clay-Silty soils	146-208	175
Claily soils	133-208	167



Criddle et al. 1956. Methods for Evaluating Irrigation Systems. Agricultural Handbook No. 82. Soil Conservation Service, US Department of Agriculture, Washington, DC, p. 24.

We want irrigation but also a bit stress

We need to introduce the concept of **water potential**

<u>the tension of the water inside the plant</u>

Created by

- Transpiration of the water at leaf level
- Soil water potential

We measure with the **Scholander chamber**

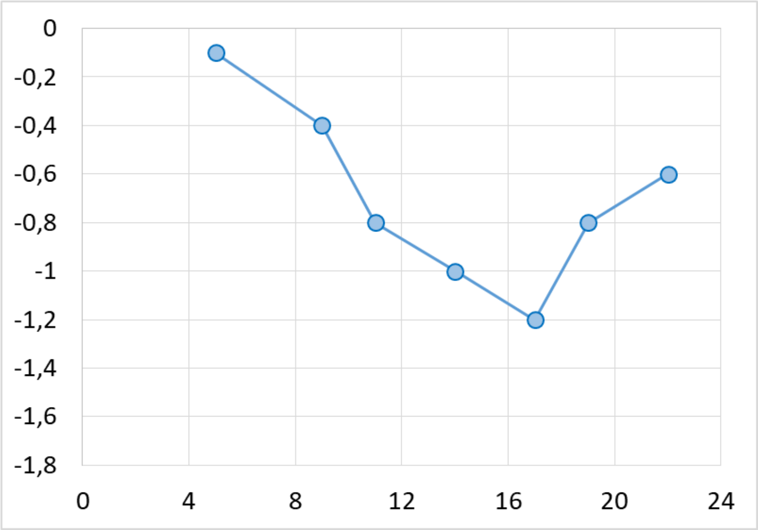
Leaf water potential

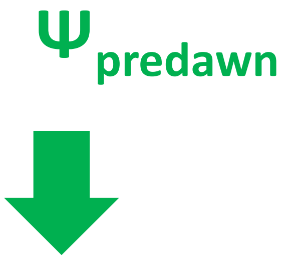
plant **transpiration** is mainly affected by the **vapor pressure deficit** (VPD) between the mesophyll and the atmosphere;

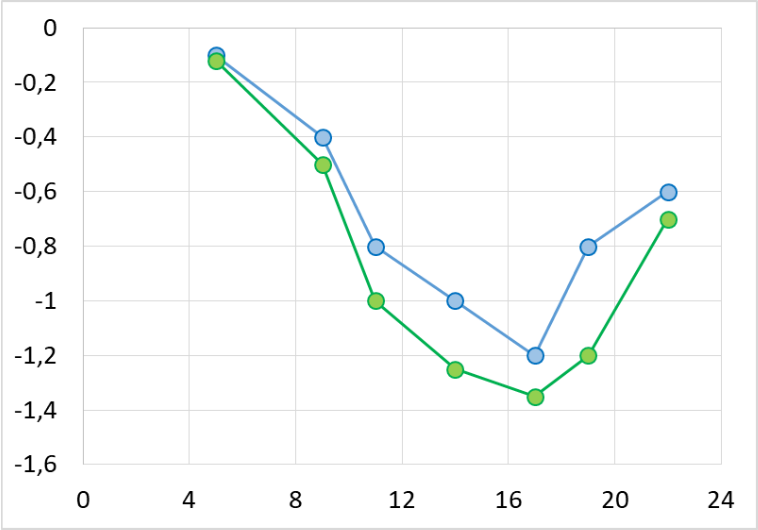
VPD **increase** with **air temperature** and **decrease** with increasing **air humidity**

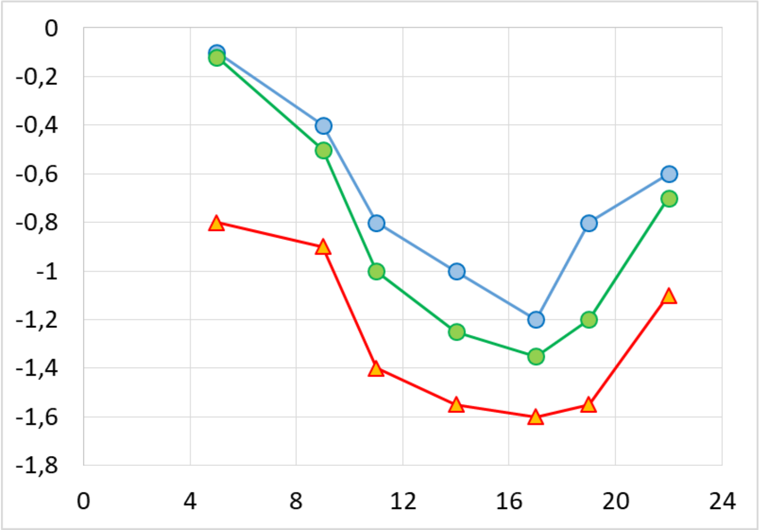
Low soil moisture increase the tension

Leaf water potential

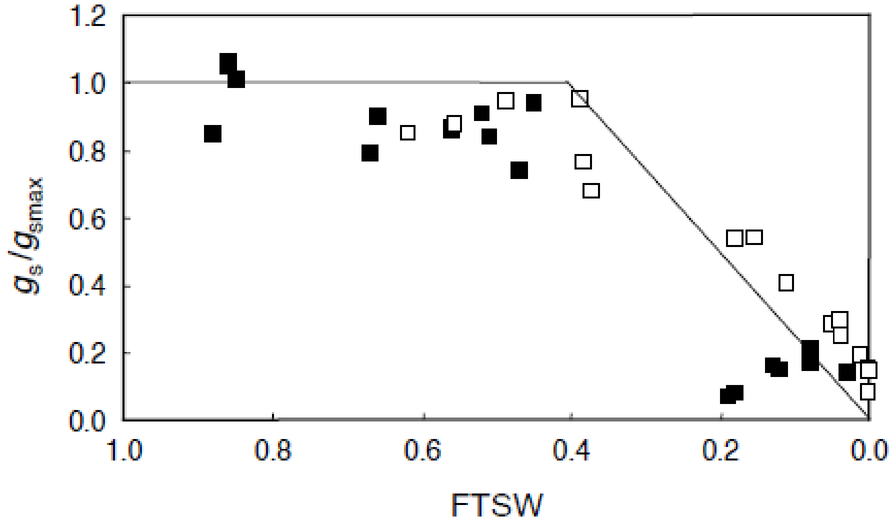


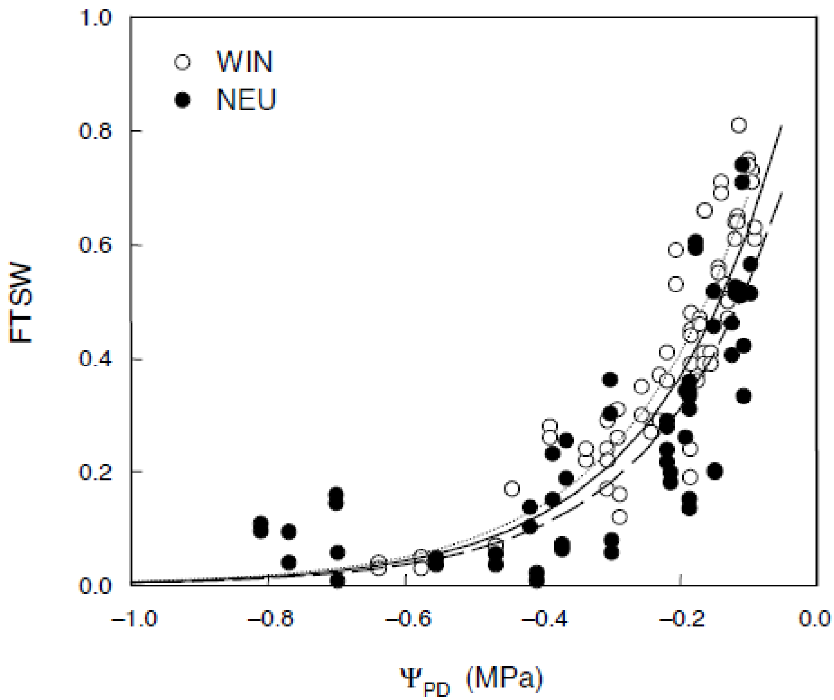






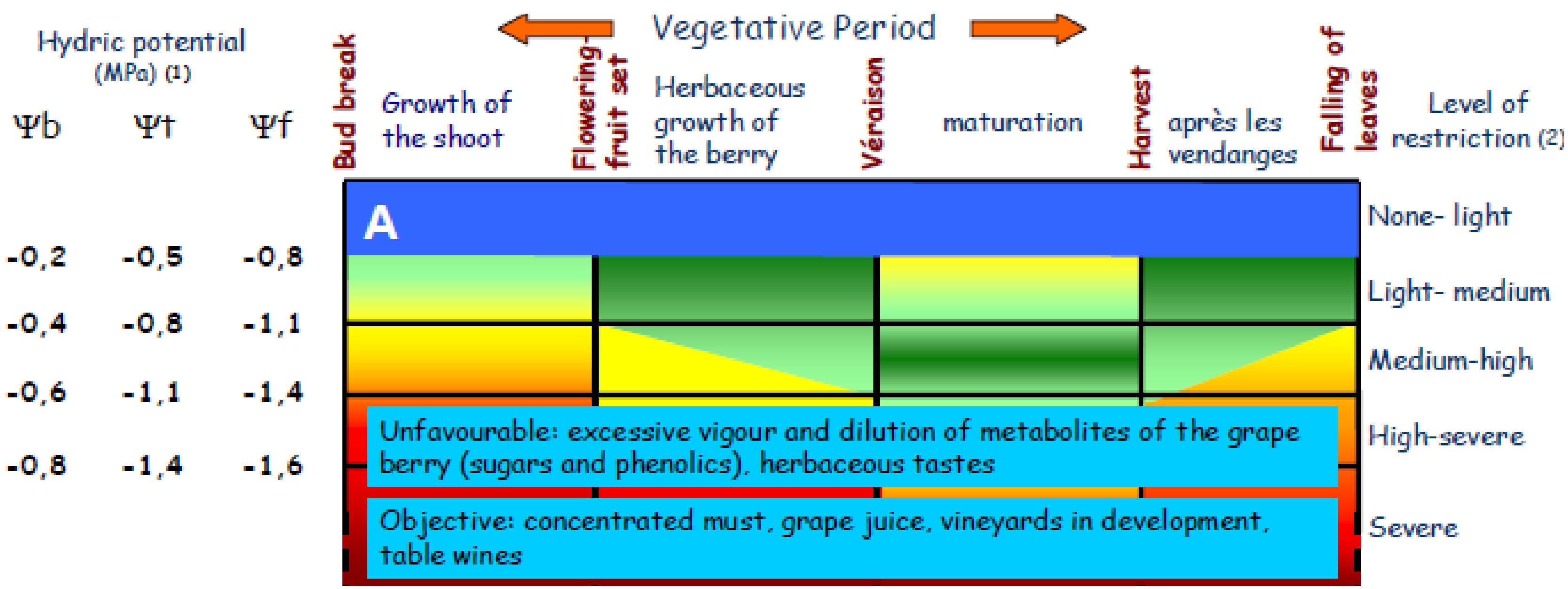
We want irrigation but also a bit stress



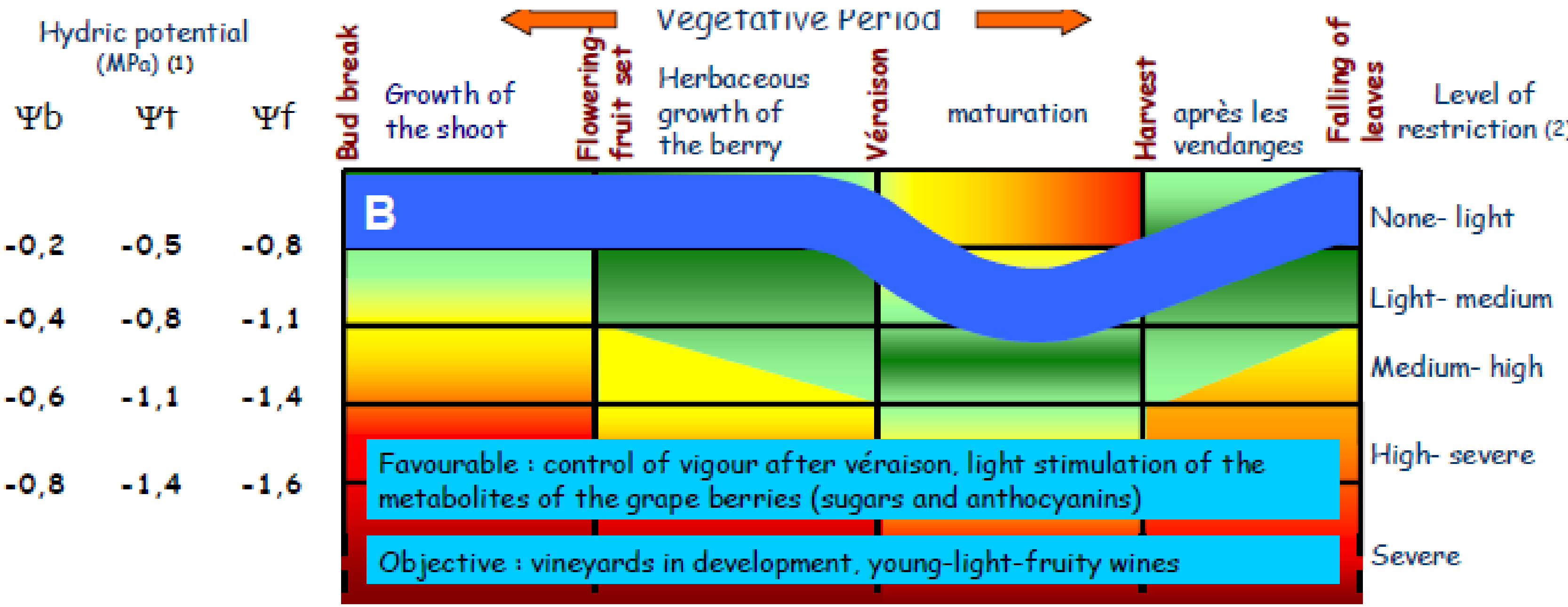


Lebon E., Dumas V., Pieri P., Schultz H.R. (2003). *Functional Plant Biology* **30**:699-710

Deficit irrigation based on Ψ_{PD}

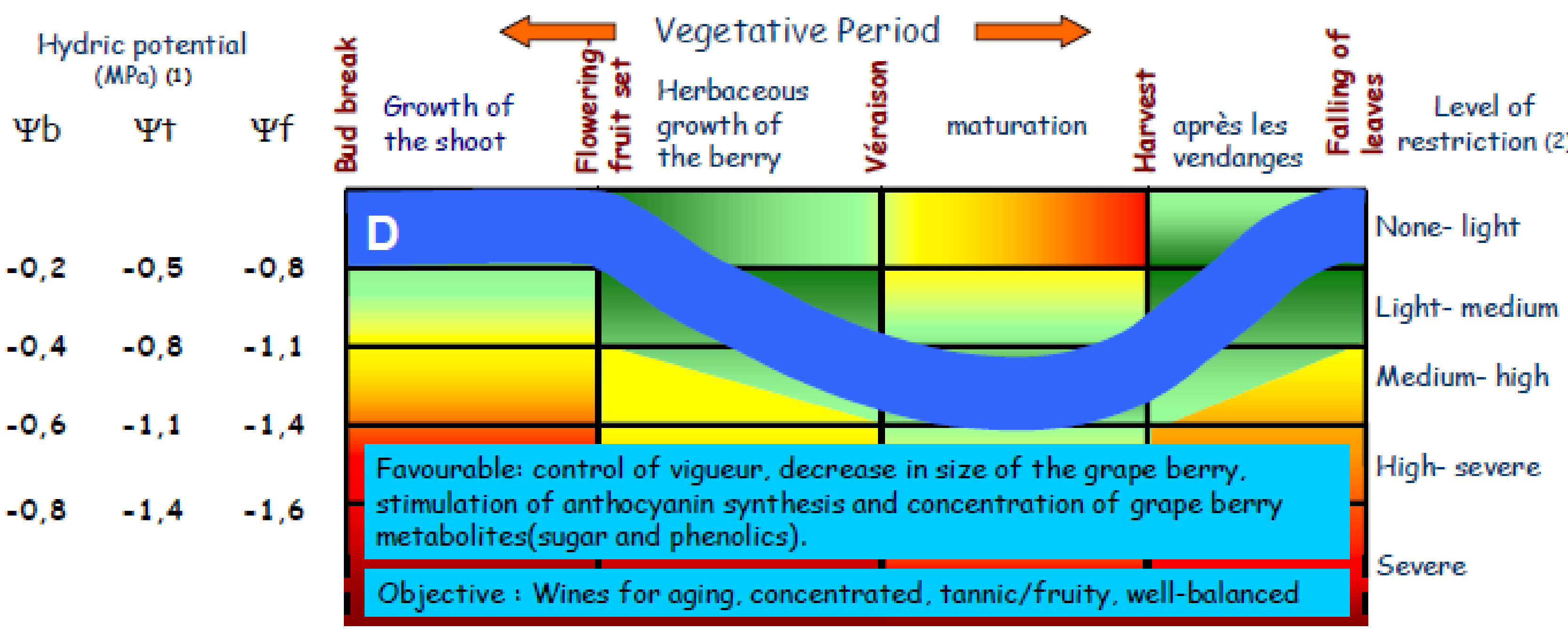


Deficit irrigation based on Ψ_{PD}



Ojeda 2008. Qualitative precision irrigation in the vineyard. *Infowine* **5**

Deficit irrigation based on Ψ_{PD}



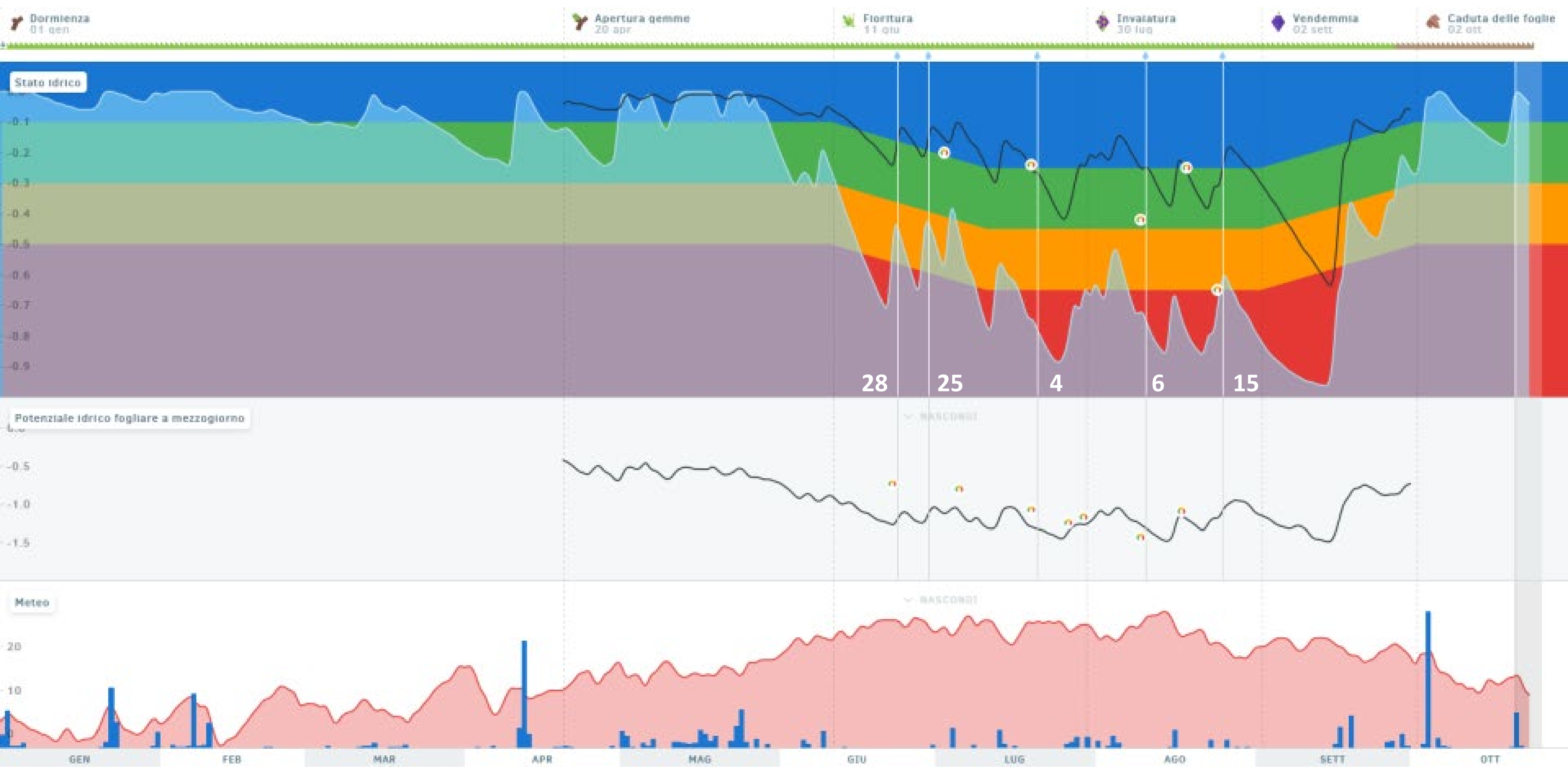
Ojeda 2008. Qualitative precision irrigation in the vineyard. *Infowine*

Deficit irrigation – VINTEL®

Pinot grigio Udine 2021 – Well Watered – **115 mm**

Deficit irrigation – VINTEL®

Pinot grigio Udine 2021 – Moderate deficit – **77 mm**



Deficit irrigation – VINTEL®

Pinot grigio Udine 2021 – Severe deficit – **68 mm**

Deficit irrigation – VINTEL®

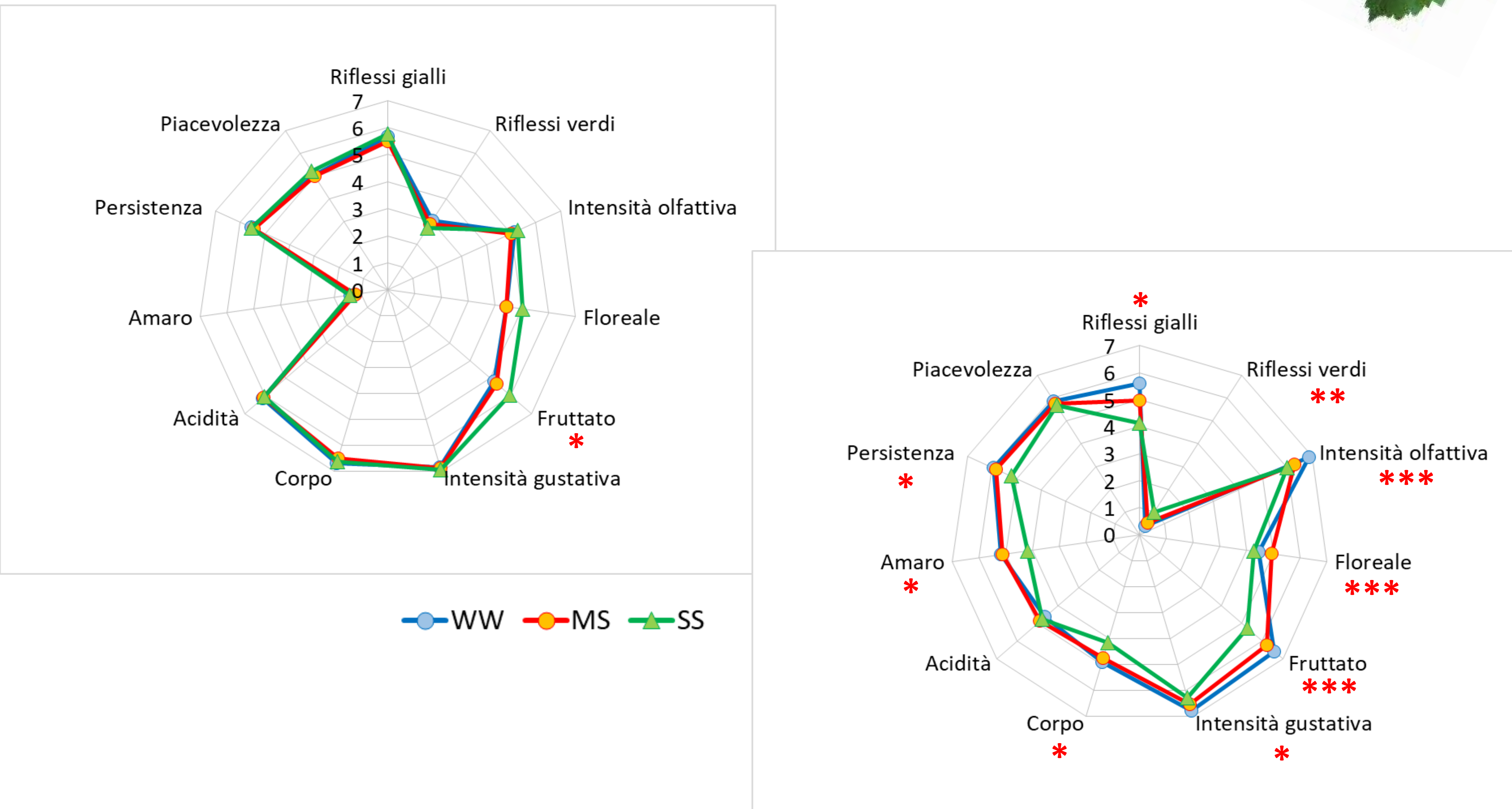
Deficit irrigation – VINTEL®

Deficit irrigation – VINTEL®

year	treatment	cluster number	yield (kg/vine)	cluster weight (g)
2021	well-watered	27,8	3,15	116
	moderate deficit	26,9	**2,76**	**102**
	severe deficit	28,0	**2,89**	**104**
2022	well-watered	23,8	3,98	171
	moderate deficit	23,0	**3,48**	**153**
	severe deficit	**19,9**	**3,11**	**156**

Deficit irrigation – VINTEL®

Deficit irrigation – VINTEL®



How much water for a young vineyard ?

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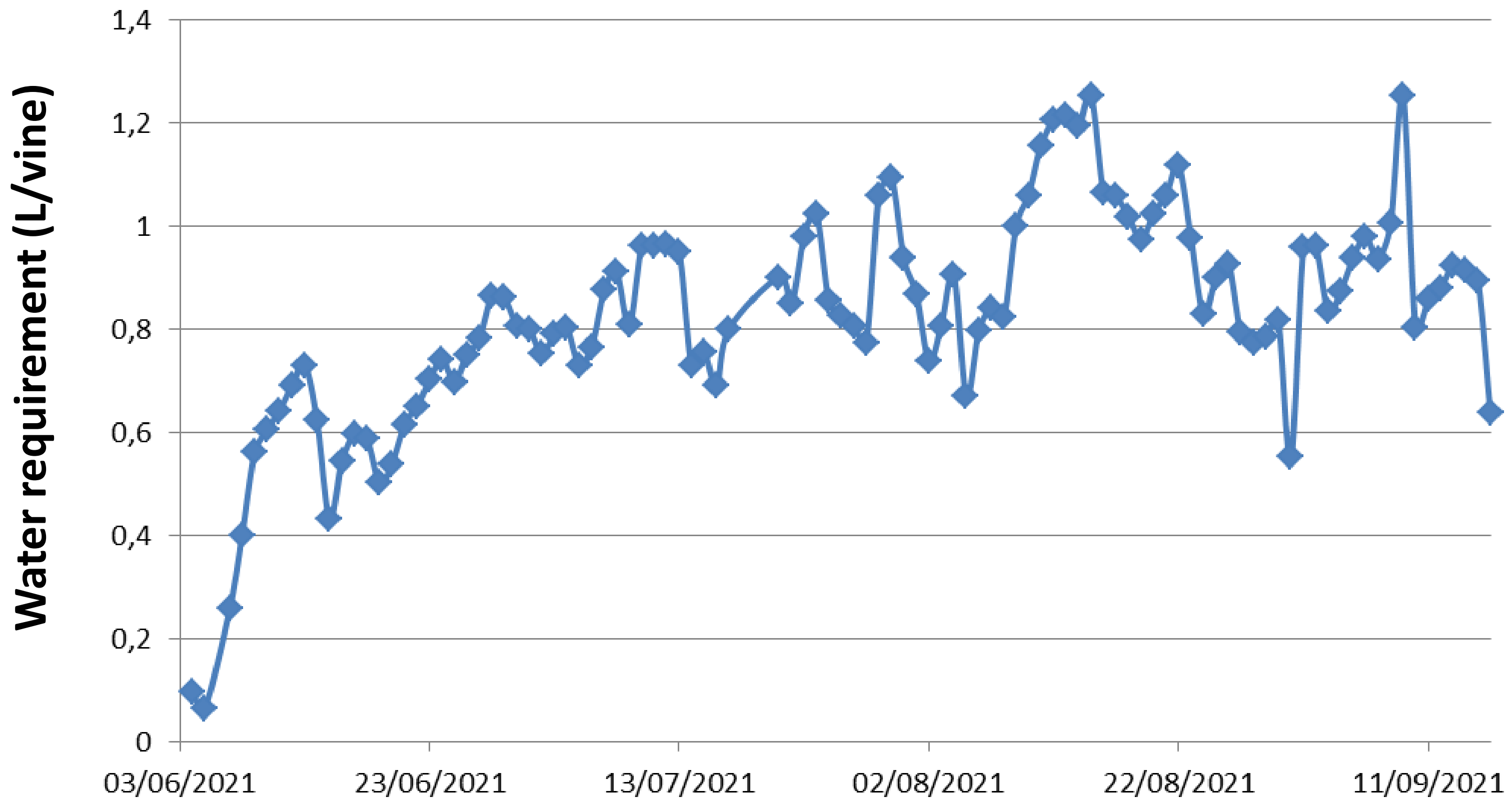
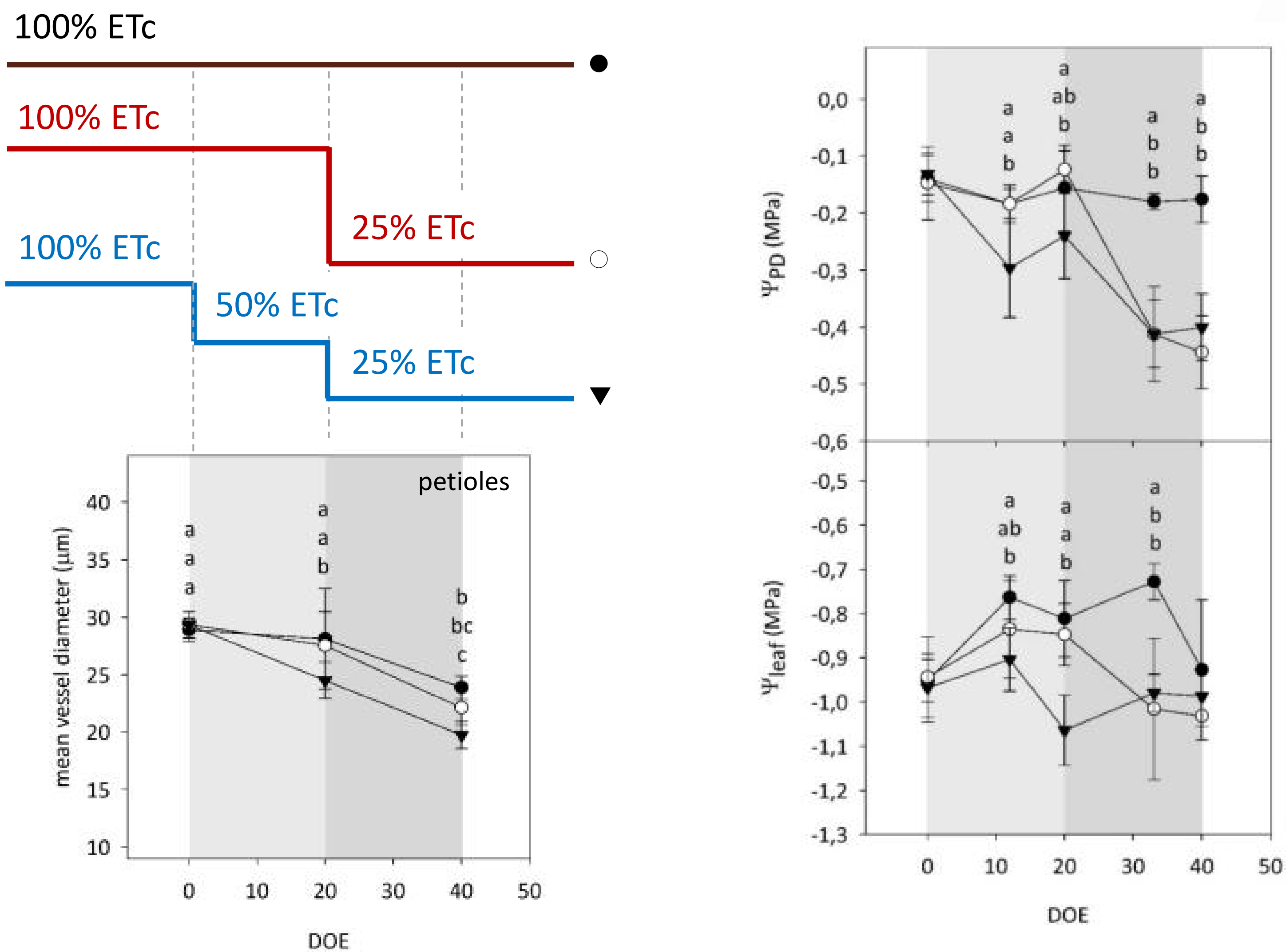


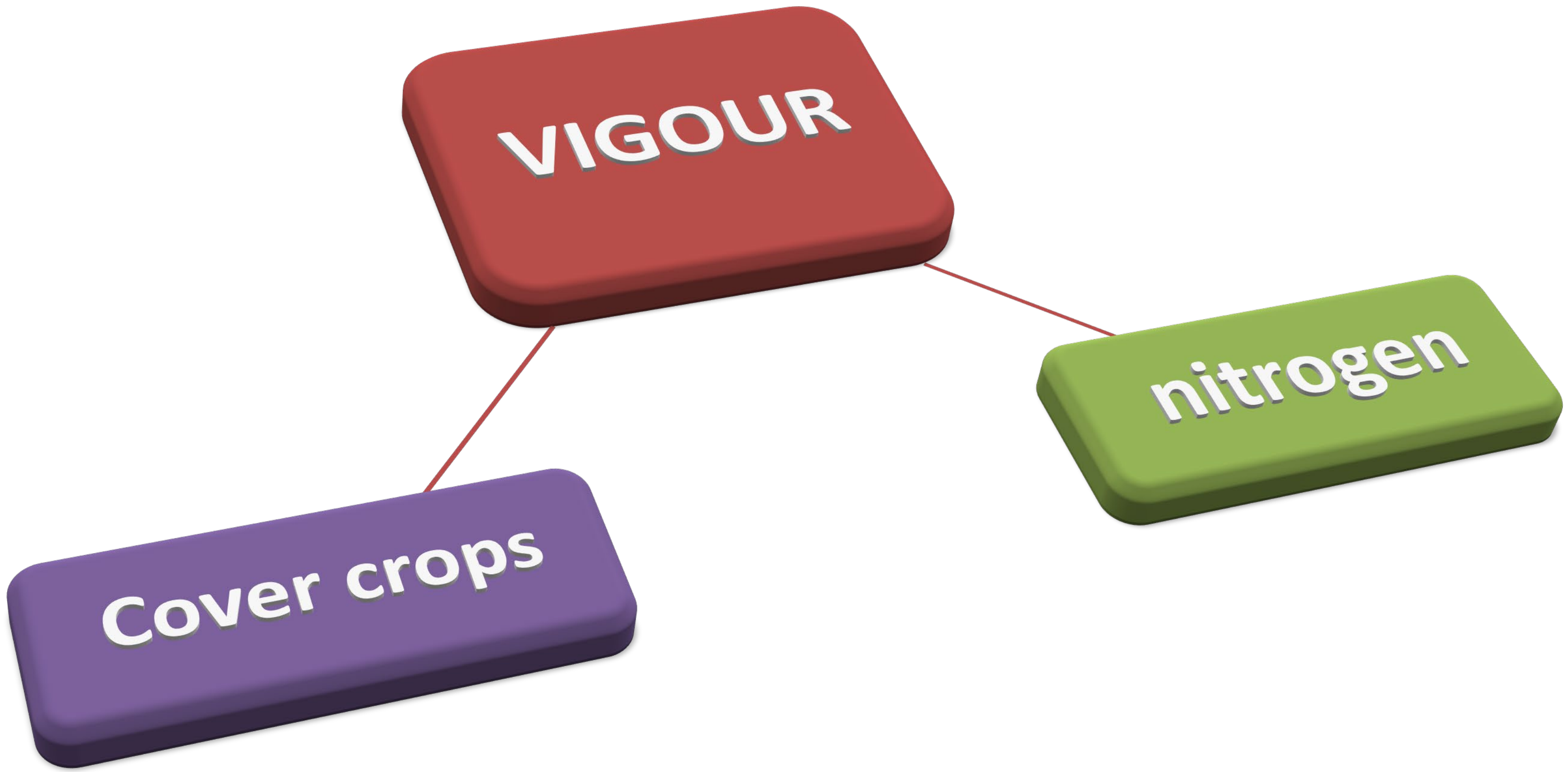
Why so much water ??? **Root depht** and **adaptative mechanisms**

How to increase resilience



Braidotti R. (2022). PhD thesis, University of Udine

Can we reduce the vigour & increase resilience ?



Soil management with Cover crops

- conservation of **fertility**
- maintenance of grapevines on **canopy-crop equilibrium** - modulate the vigour
- improve **organic matter**, increase **porosity** and also the **available water content** in the soil
- improve **soil softness** and reduce **compactness**

Soil management with Cover crops

Grape vegetative parameters recorded in 2013 and 2014 in the two treatments and clones in comparison. NDVI was measured on 6 September 2013 and 16 August 2014, while pruning was weighted on 13 January 2014 and 18 March 2015

Factor		NDVI	Pruning weight ($kg \cdot vine^{-1}$)
Year (Y)	2013	0.703 ± 0.008	0.478 ± 0.047
	2014	0.635 ± 0.009	0.299 ± 0.054
		***	**
Treatment (T)	Tillage (TT)	0.689 ± 0.014	0.469 ± 0.060
	Mowing (MT)	0.650 ± 0.013	0.308 ± 0.044
		***	**
Clone (C)	R3	0.665 ± 0.016	0.316 ± 0.045
	297	0.673 ± 0.015	0.460 ± 0.067
		ns	*
Interactions	Y × T	ns	ns
	Y × C	ns	ns
	T × C	ns	ns

Bigot G., Mosetti D., Cargnus E., Freccero A., Kiaeian Moosavi F., Lujan C., Stecchina M., Tacoli F., Zandigiacomo P., **Sivilotti P.** and Pavan F. (2021). *Vitis Journal of Grapevine Research* **61**:53–62.

Soil management with Cover crops

Factor		Number of larval nests of *Lobesia botrana* / 50 bunches		Percentage of berries infected by		
		Second generation	Third generation	Downy mildew	Grey mould	Sour rots
Year (Y)	2013	48.5 ± 3.08	143.3 ± 22.5	0.24 ± 0.09	14.3 ± 5.6	3.1 ± 0.8
	2014	5.25 ± 0.90	61.50 ± 8.08	0.59 ± 0.25	57.8 ± 13.0	69.5 ± 18.9
		***	**	ns	***	***
Treatment (T)	Tillage (TT)	27.25 ± 8.73	113.6 ± 22.9	0.57 ± 0.26	53.0 ± 14.9	42.2 ± 20.3
	Mowing (MT)	26.50 ± 8.23	91.1 ± 22.1	0.26 ± 0.07	19.1 ± 5.5	30.5 ± 15.8
		ns	ns	ns	**	*
Clone (C)	R3	24.13 ± 7.25	113.6 ± 22.9	0.49 ± 0.25	23.1 ± 9.9	12.4 ± 3.7
	297	29.63 ± 9.44	91.1 ± 22.1	0.33 ± 0.12	49.0 ± 13.8	60.2 ± 22.3
		ns	ns	ns	*	***
Interactions (Sign. F)	Y × T	ns	ns	ns	*	ns
	Y × C	*	ns	ns	ns	***
	T × C	ns	ns	ns	ns	ns

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Soil management with Cover crops

Factor		Number of bunches/vine	Average bunch weight (g)	Yield ($kg \cdot vine^{-1}$)	Average berry weight (g)
Year (Y)	2013	22.4 ± 1.0	82.4 ± 9.2	1.9 ± 0.3	1.334 ± 0.033
	2014	15.7 ± 81.7	72.6 ± 3.9	1.2 ± 0.2	1.725 ± 0.030
		***	*	***	***
Treatment (T)	Tillage (TT)	19.4 ± 1.7	83.3 ± 6.0	1.7 ± 0.3	1.588 ± 0.069
	Mowing (MT)	18.7 ± 2.0	71.6 ± 7.8	1.4 ± 0.3	1.471 ± 0.086
		ns	*	*	**
Clone (C)	R3	16.2 ± 1.9	62.3 ± 4.3	1.0 ± 0.1	1.526 ± 0.088
	297	21.9 ± 1.1	92.7 ± 4.7	2.1 ± 0.2	1.533 ± 0.073
		***	***	***	ns
Interactions	Y × T	*	ns	ns	ns
	Y × C	*	*	ns	ns
	T × C	ns	ns	ns	ns

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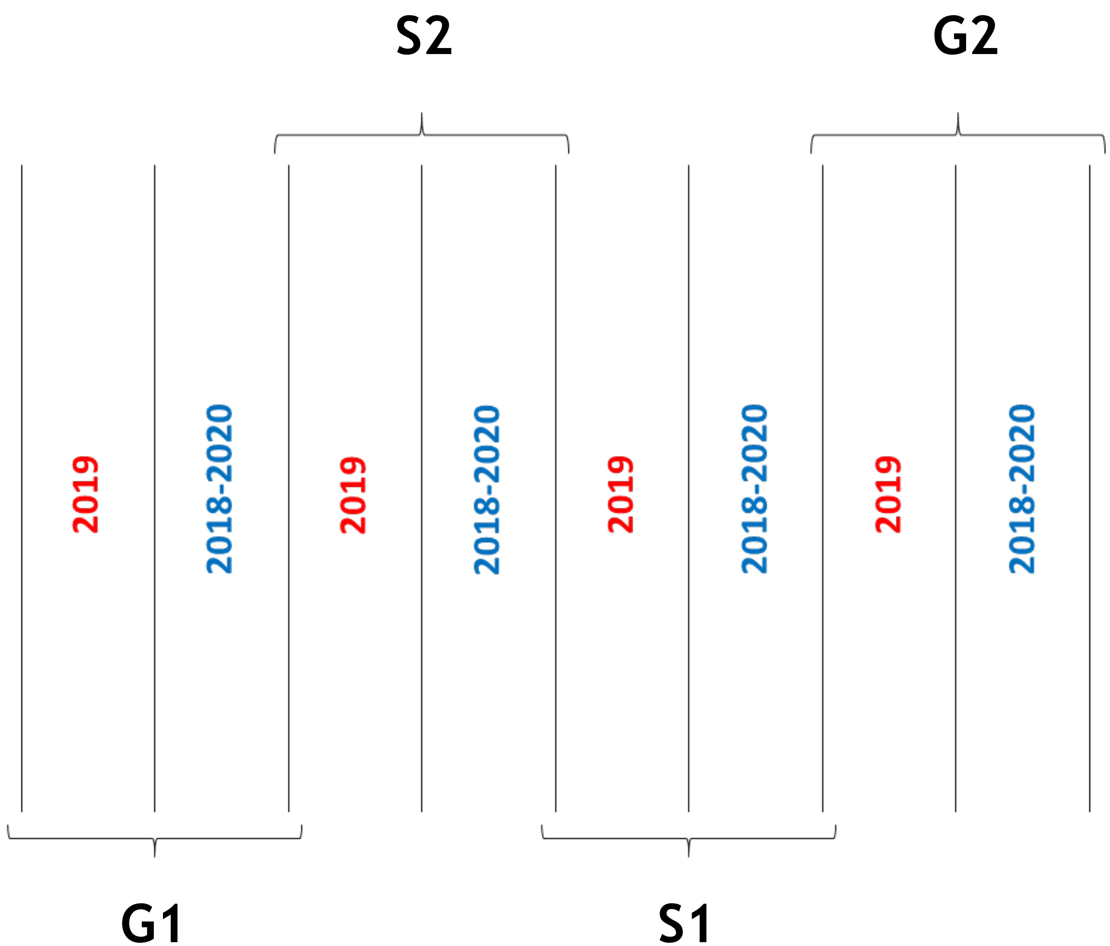
Cover crops: shredding *vs* green manuring

Experimental design



S1 e S2 = shreded CC
(early or late)

G1 e G2 = green manuring
(early or late)

Experimental design

18/10/2018
17/05/2019
31/10/2019
20/05/2020
23/10/2020
03/06/2021

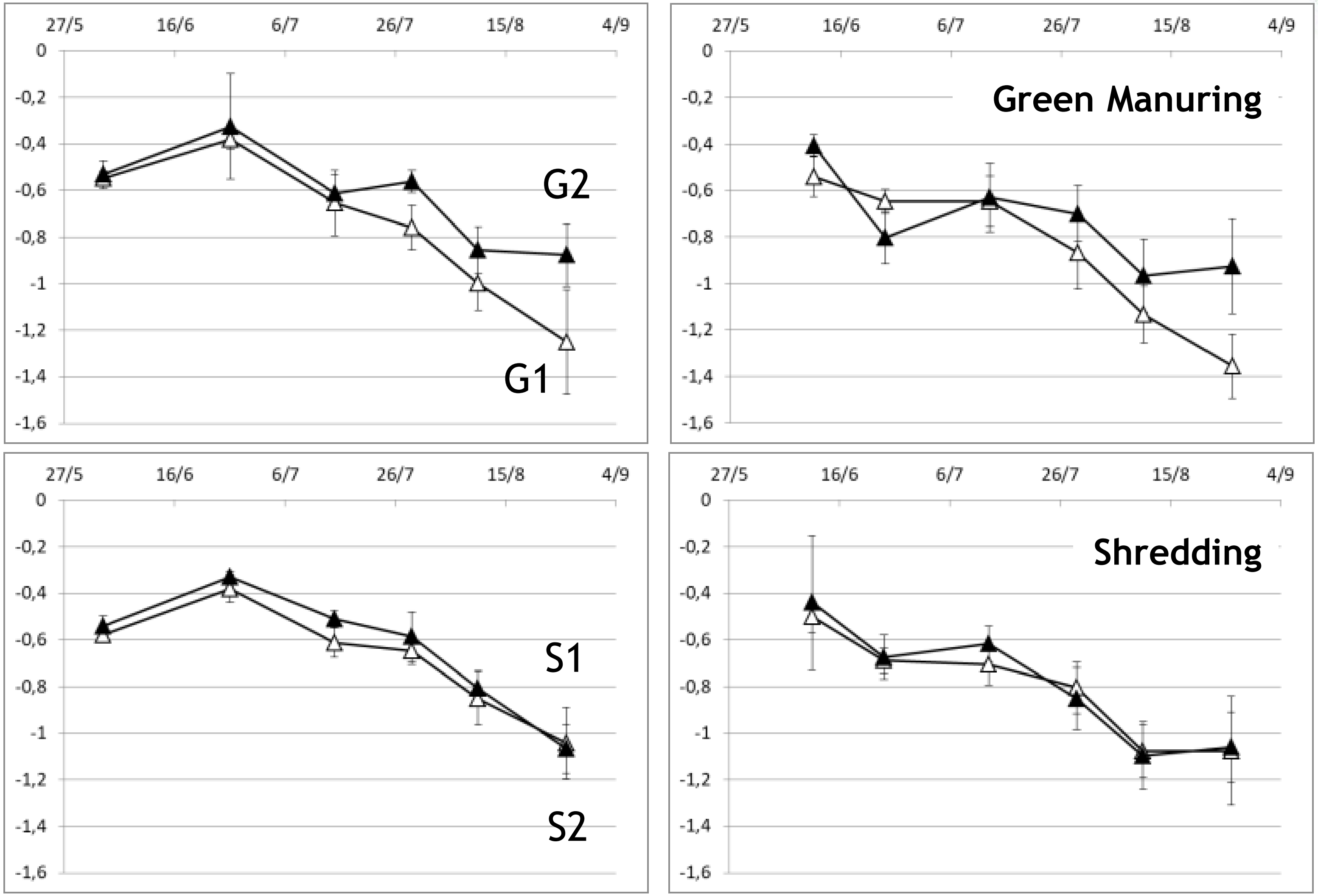
Early
Shredding – Green manuring

18/10/2018
16/06/2019
31/10/2019
19/06/2020
23/10/2020
24/06/2021

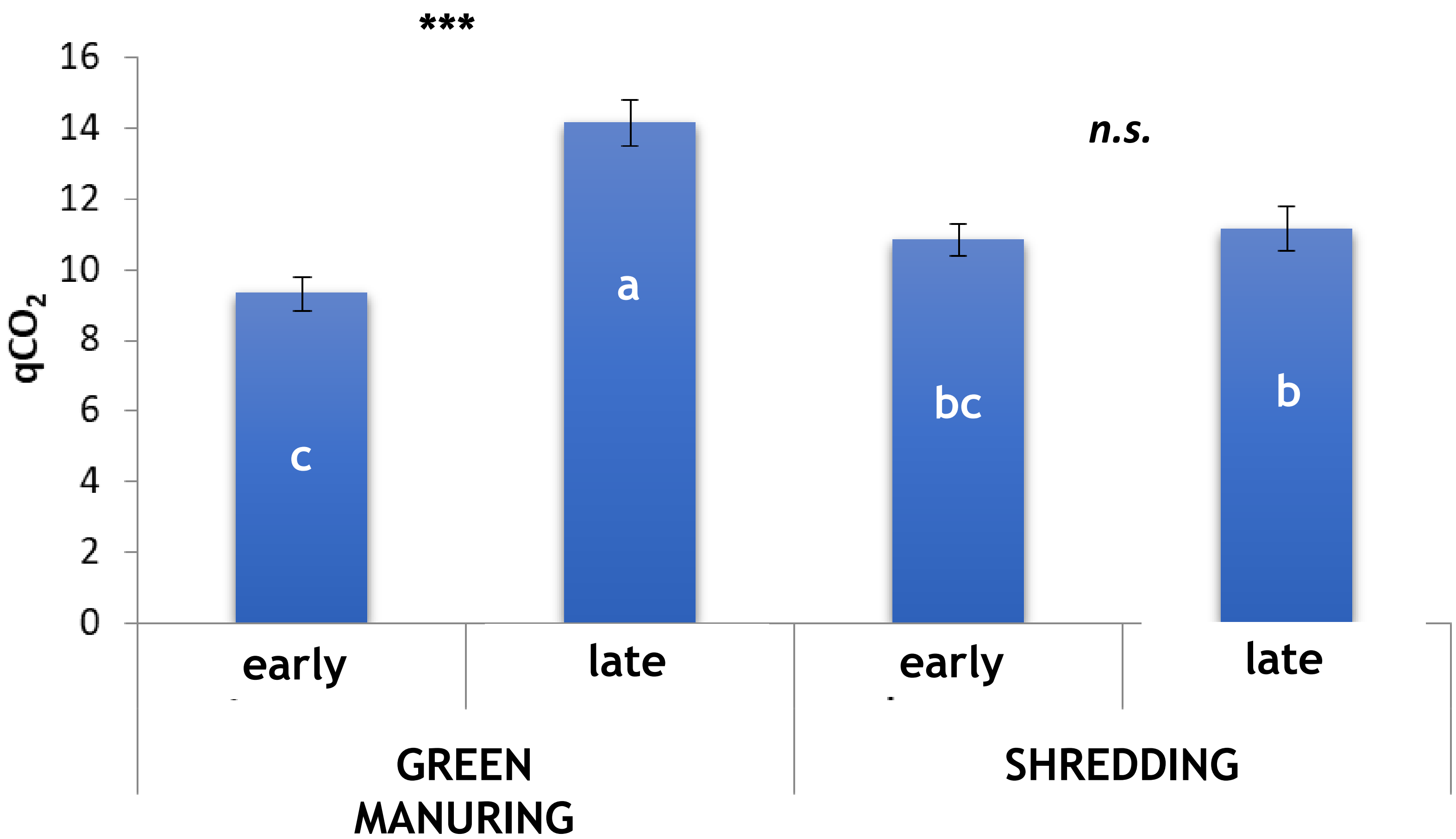
Late
Shredding – Green manuring

First timing of cover crop termination

Plant water status



Microbial metabolic quotient



Nitrogen management

VITICOLTURA

● PROVE DI NUTRIZIONE DELLA VITE NELLA ZONA DOC FRIULI ISONZO

Fertirrigazione del Pinot grigio: più qualità e più guadagno

Dal confronto tra concimazione tradizionale e fertirrigazione della vite emerge che quest'ultima consente di ottenere un miglioramento degli standard quali-quantitativi delle uve e, quindi, anche un aumento di margini economici per l'azienda vitivinicola

di **G. Bigot, L. Bigot, A. Freccero, M. Stecchina, D. Mosetti, C. Lujan, P. Sivilotti**

La gestione della corretta nutrizione minerale, in special modo quella azoto-potassica, si può considerare una delle sfide future per la migliore gestione fisionutrizionale dei vigneti

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Nitrogen management

3 fertilization treatments:

treatments	N	P_2O_5	K_2O	CaO	MgO
granular fertilizer	72	30	43	0	5
fertigation 1	53	44	60	19	9
fertigation 2	69	43	39	9	22

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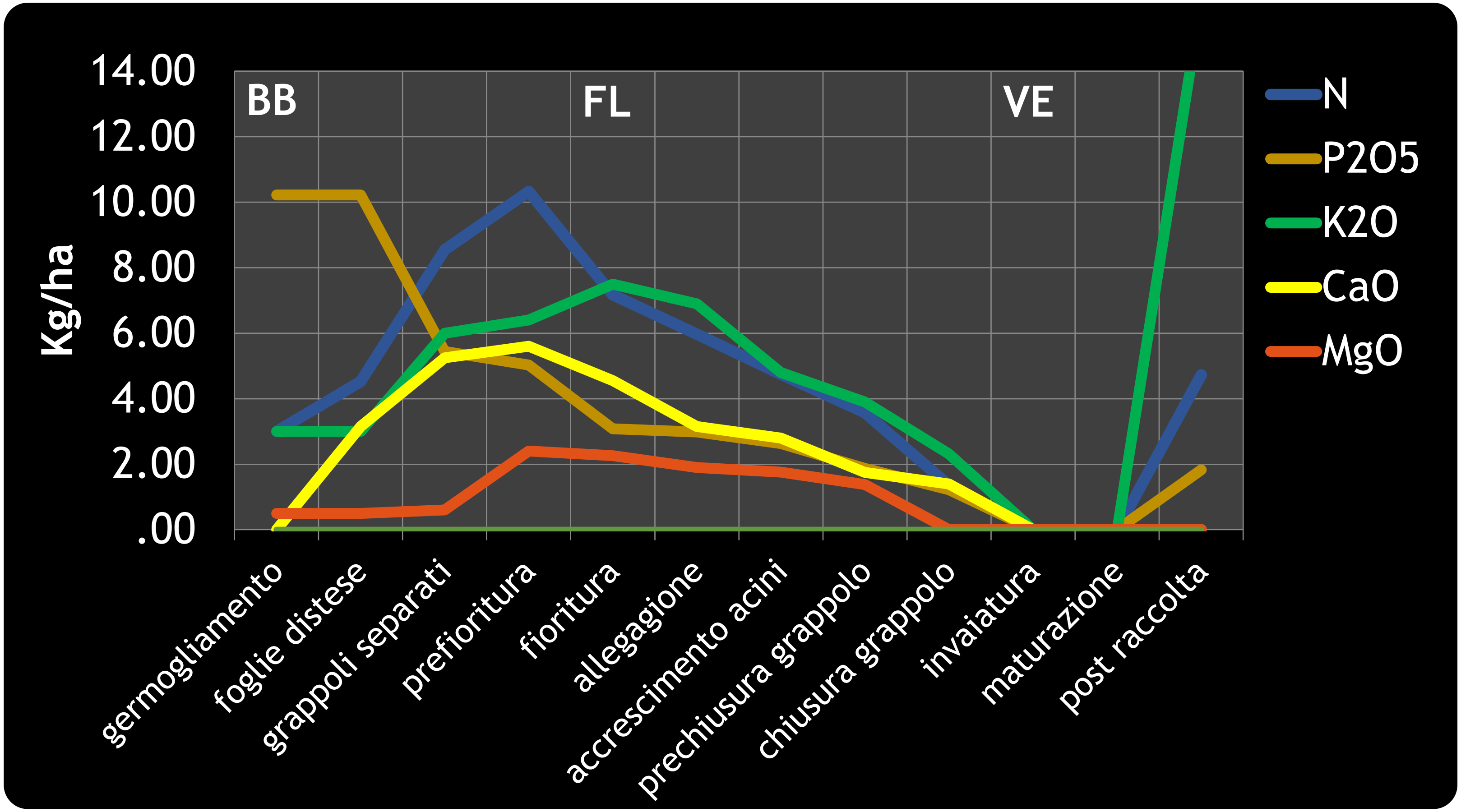
Nitrogen management

Fertigation 1



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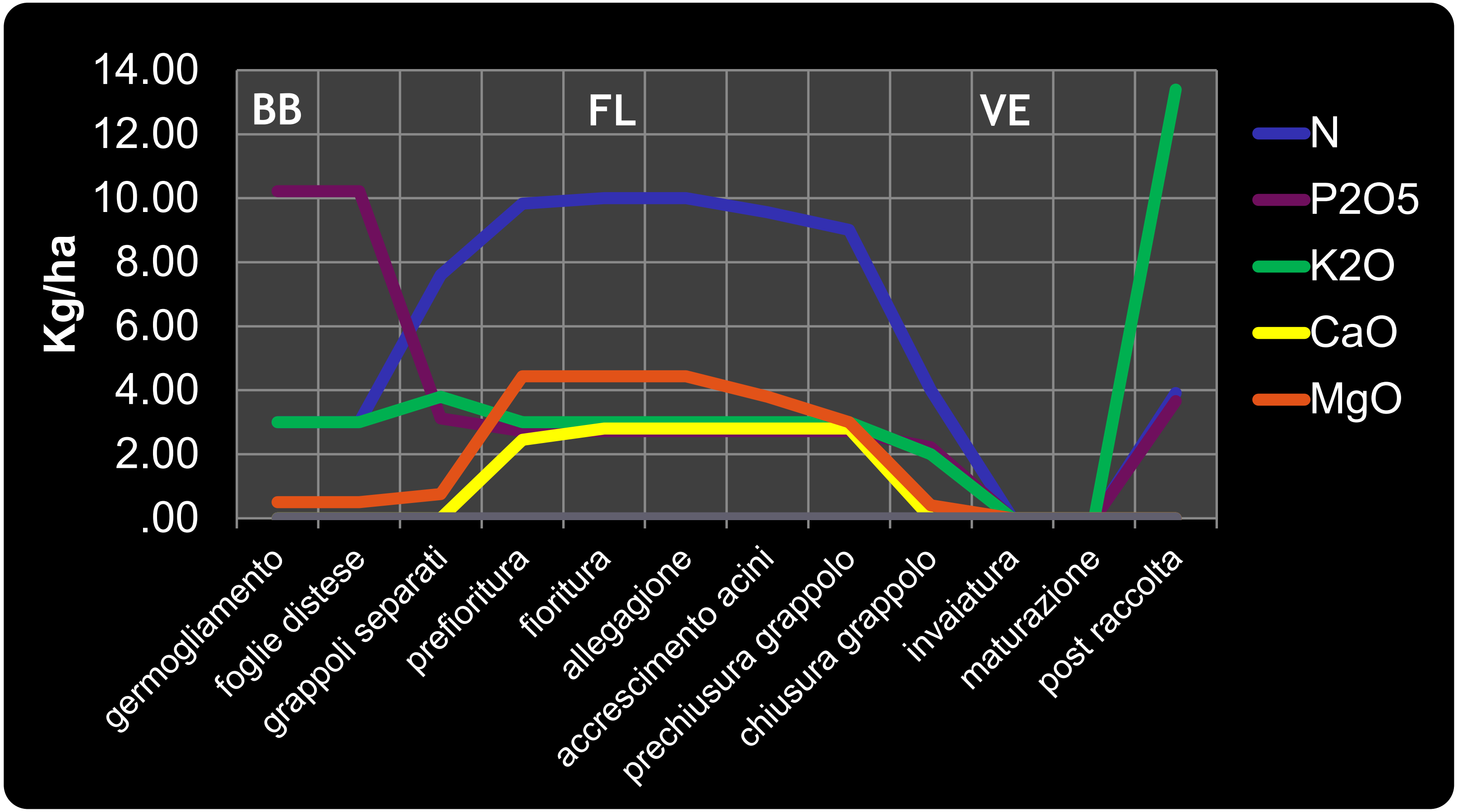
Nitrogen management

Fertigation 2



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Nitrogen management

	cluster weigth (g)	cluster number	yield (kg/vine)
granular fertilizer	133 a	16,0 b	9,91 b
fertigation 1	123 b	18,5 a	10,8 a
fertigation 2	121 b	18,4 a	10,5 ab
sign. F	*0,000 ****	*0,000 ****	*0,033 **

	TSS (Brix)	titratable acidity (g/L)	pH	Nitrogen recovery (%)
granular fertilizer	21,5	6,39 b	3,24 b	15,9 c
fertigation 1	21,4	6,52 a	3,28 a	28,9 a
fertigation 2	21,5	6,53 ab	3,28 a	24,1 b
sign. F	*0,751 n.s.*	*0,039 **	*0,000 ****	*0,000 ****

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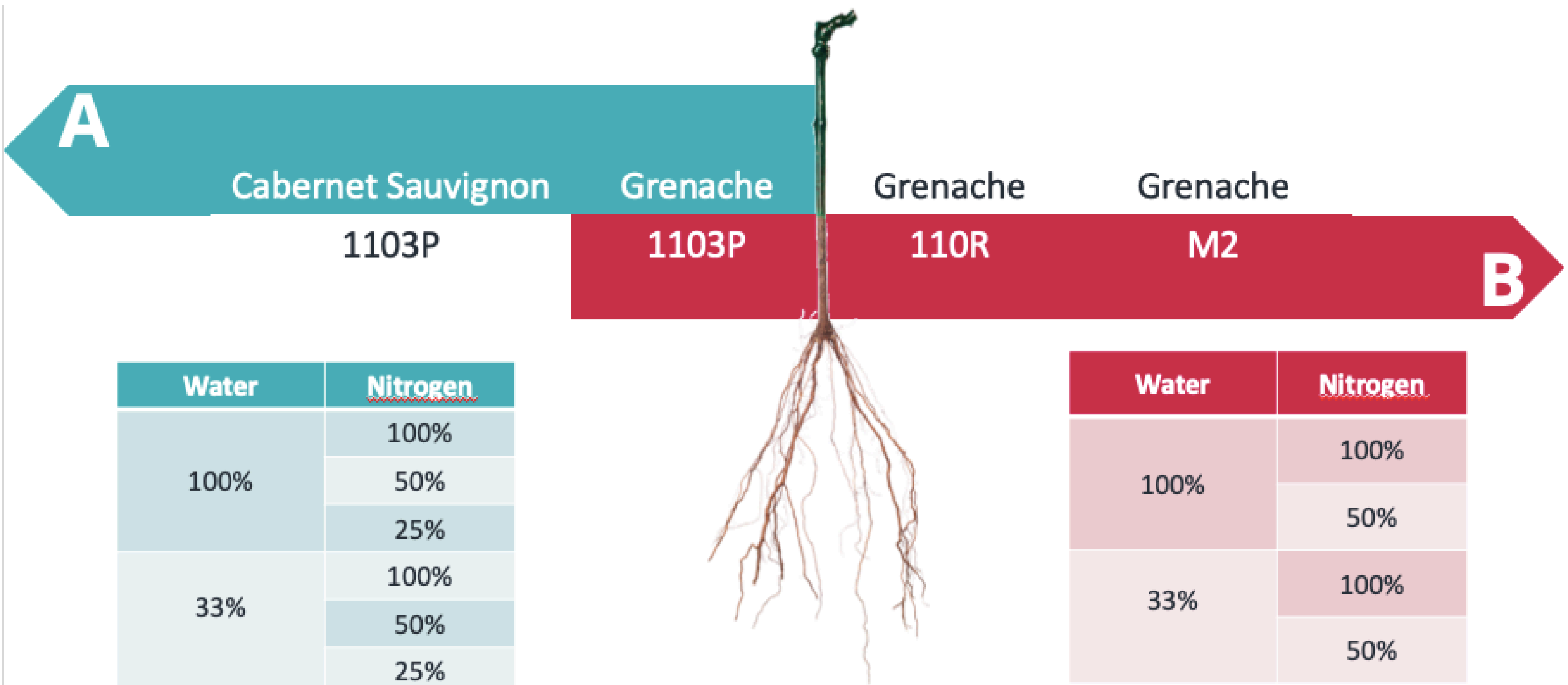
Is nitrogen fertilisation excessive ?



Water	Nitrogen
100%	100%
	50%
	25%
33%	100%
	50%
	25%

Water	Nitrogen
100%	100%
	50%
33%	100%
	50%

Pichierri A. PhD thesis… Work in progress

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Thanks for your attention