fondazione banfi

SANGUIS JOVIS

ALTA SCUOLA DEL SANGIOVESE

Il dilemma climatico in vigna: adattarsi o innovarsi?

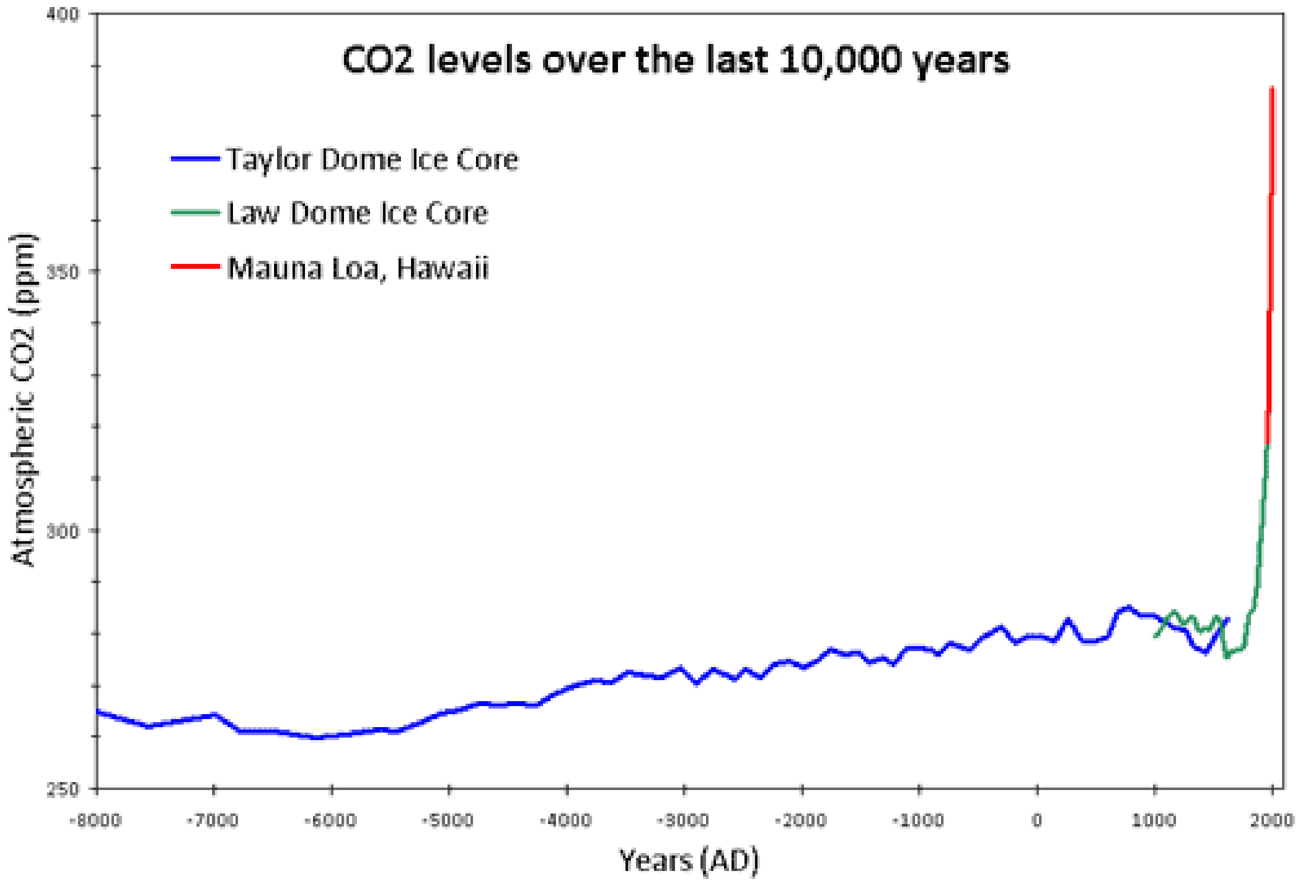
Enrico Peterlunger

Dipartimento di scienze agroalimentari, ambientali e animali

Università di Udine

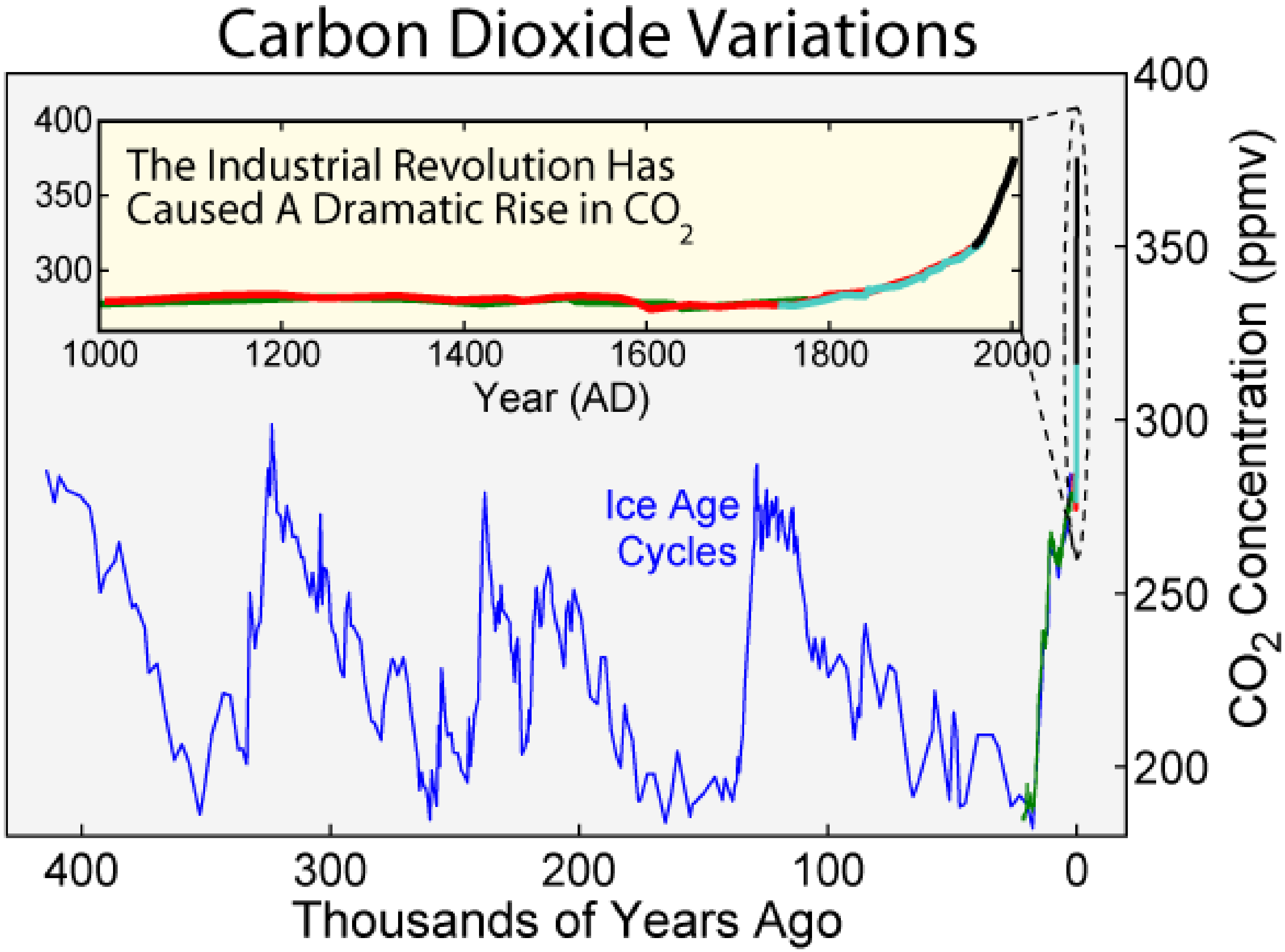
UNIVERSITÀ DEGLI STUDI DI UDINE

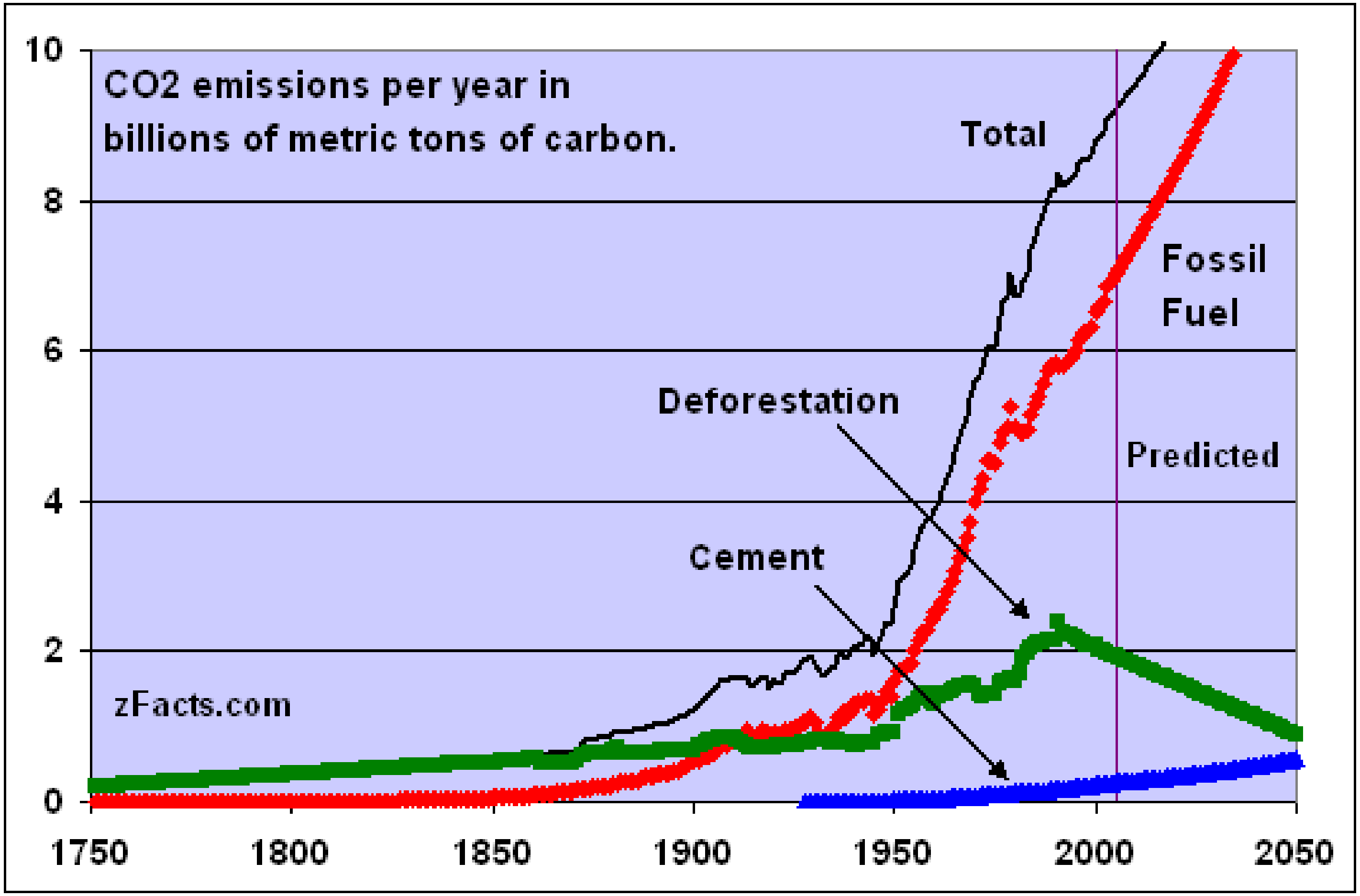
hic sunt futura



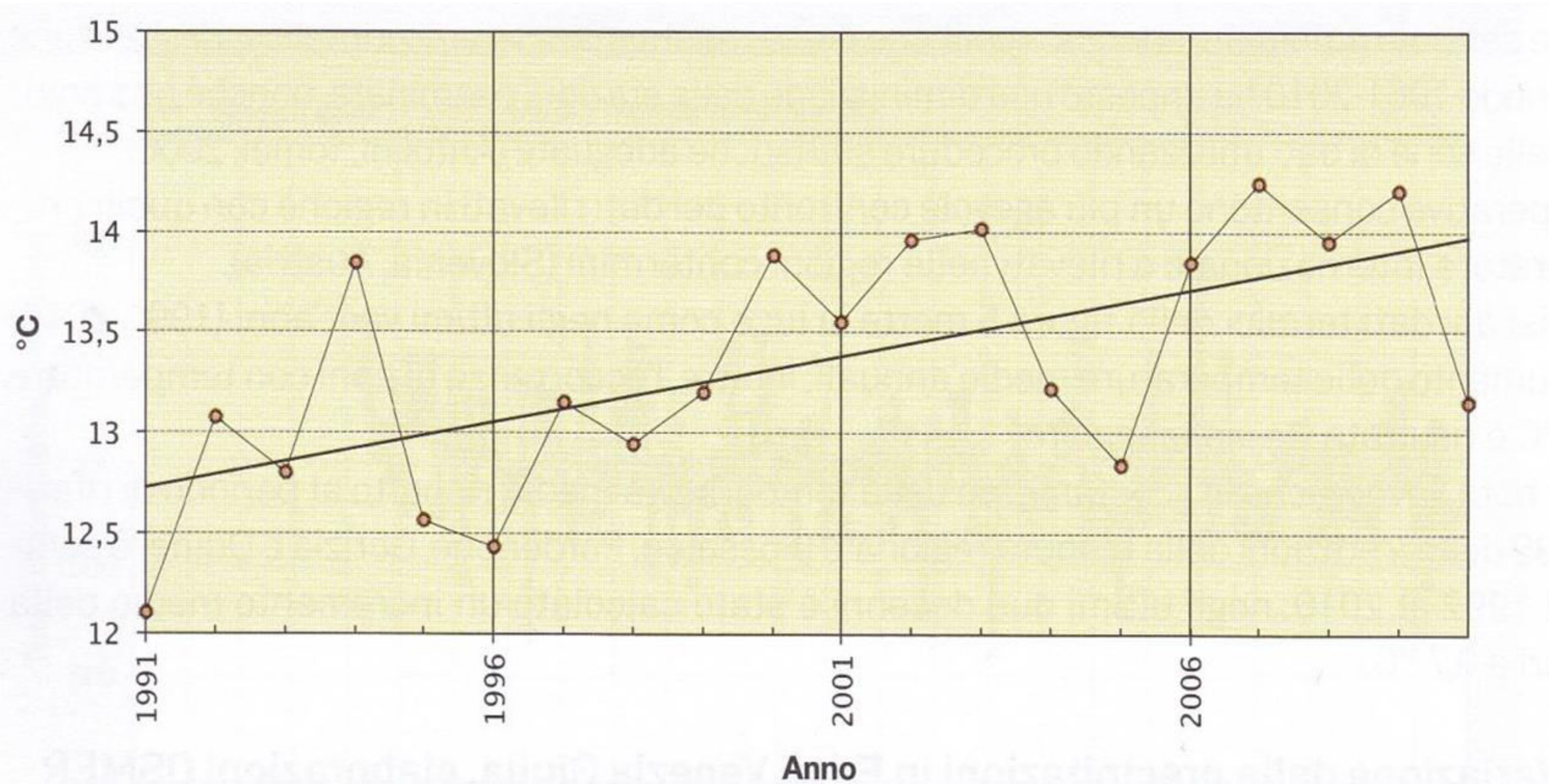
[CO2] 1980 ➔ 330 ppm

2018 ➔ 400 ppm


Carbon Dioxide Variations
The Industrial Revolution Has
Caused A Dramatic Rise in CO2
400
350
300
1000
1200
1400
1600
1800
2000
Year (AD)
Ice Age
Cycles
400
350
300
250
200
CO2 Concentration (ppmv)
400
300
200
100
0
Thousands of Years Ago

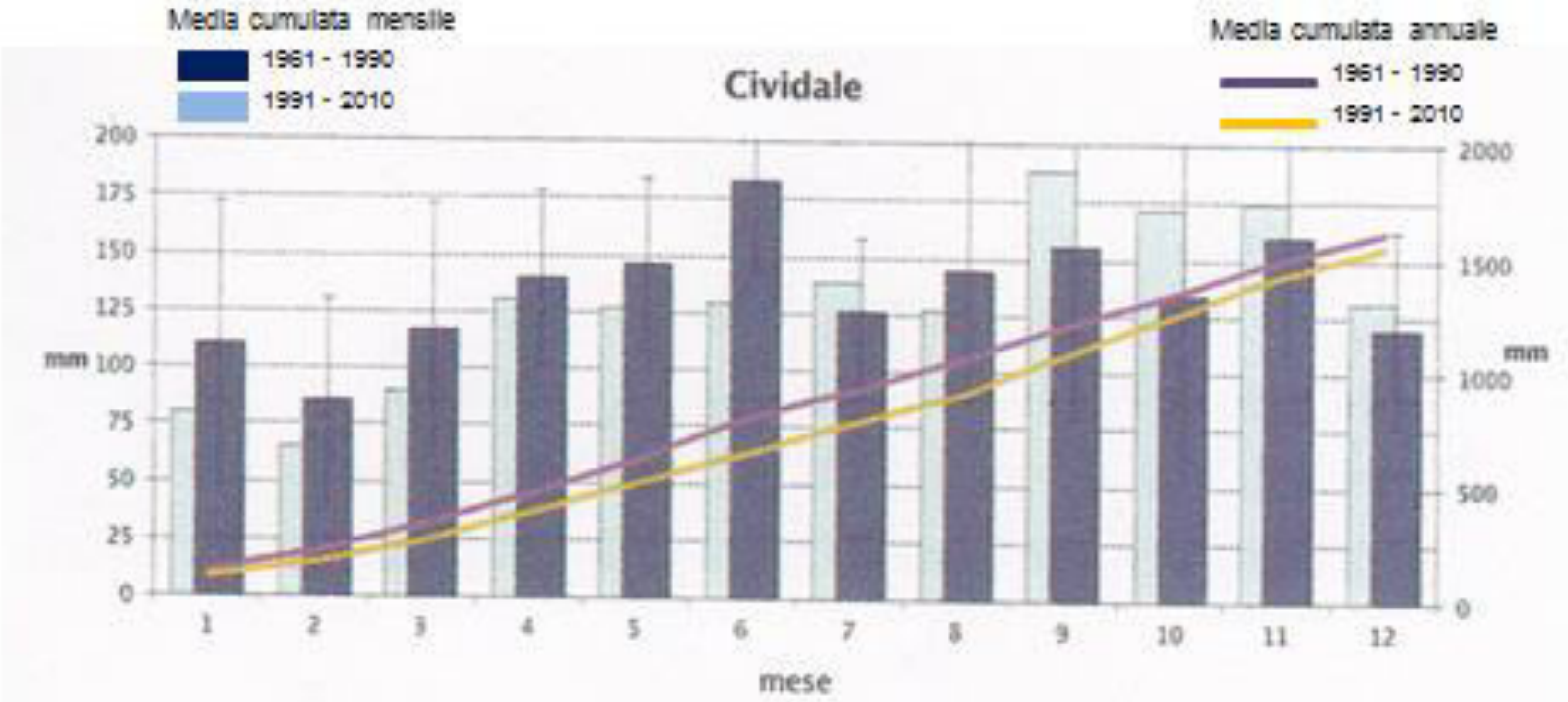


CO2 emissions per year in
billions of metric tons of carbon.
Total
Fossil
Fuel
Deforestation
Predicted
Cement
zFacts.com
10
8
6
4
2
0
1750
1800
1850
1900
1950
2000
2050



Aumento temperature regione FVG (fonte OSMER 2012)

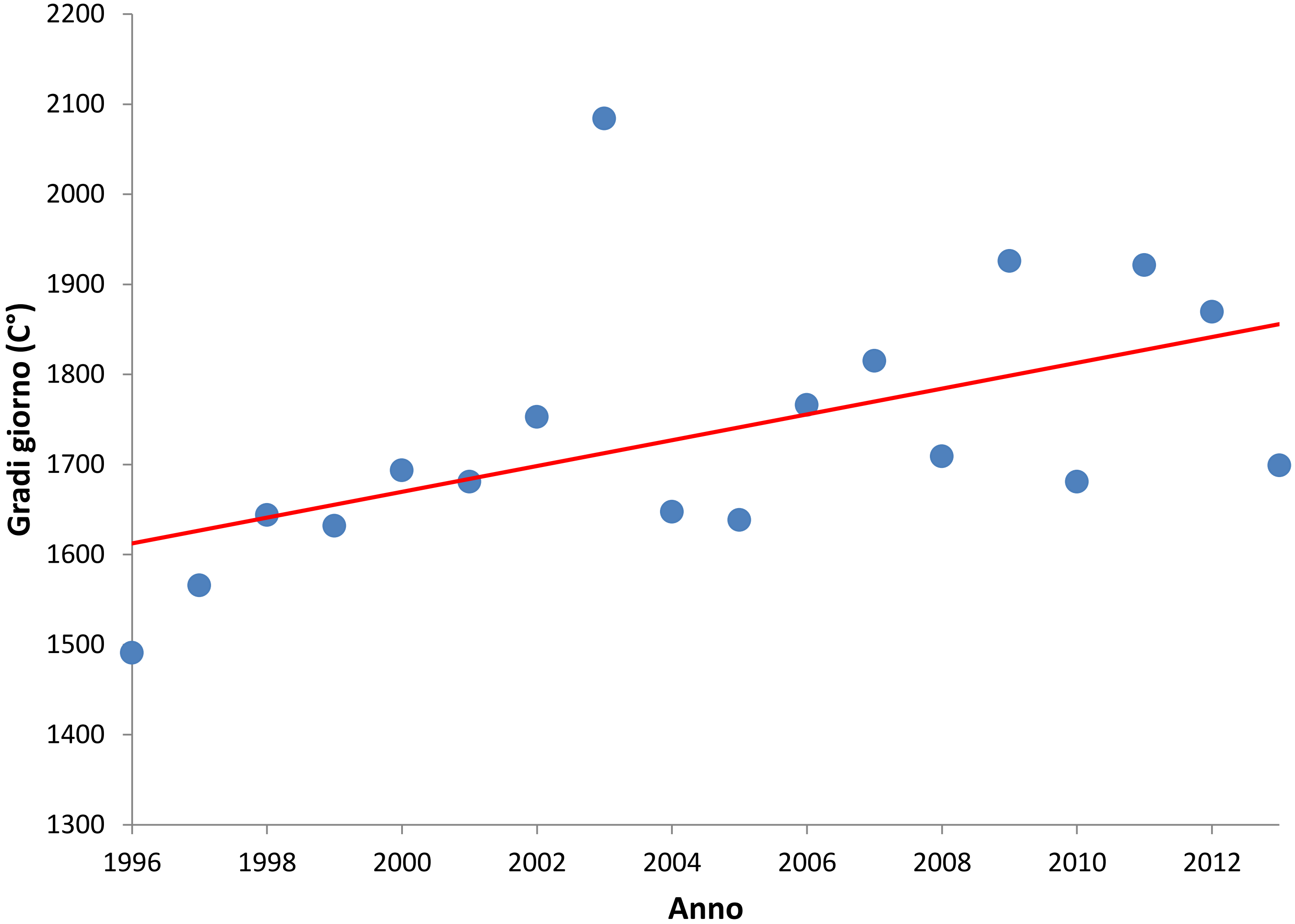
Modificazione nell'andamento delle precipitazioni cumulate mensili e annuali negli ultimi vent'anni in Friuli Venezia Giulia



Agenzia Regionale per la Protezione dell'Ambiente FVG – Osmer
Rapporto sullo stato dell'ambiente 2012

Cambiamento climatico in FVG: Gradi-giorno

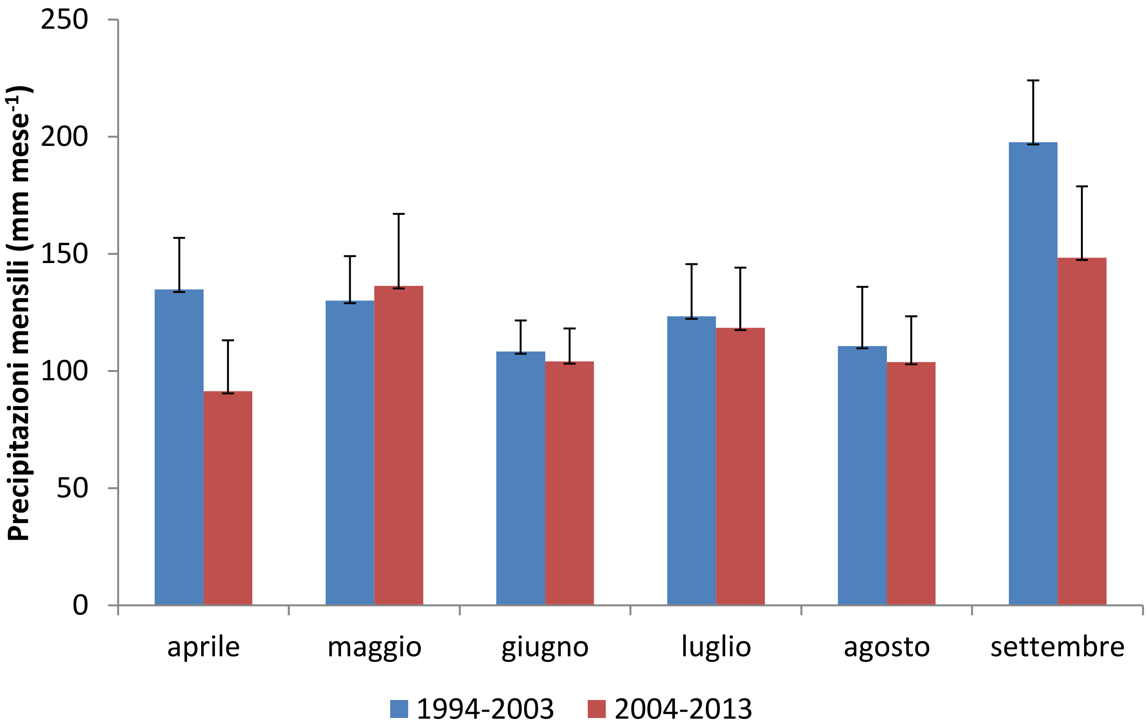
RISULTATI

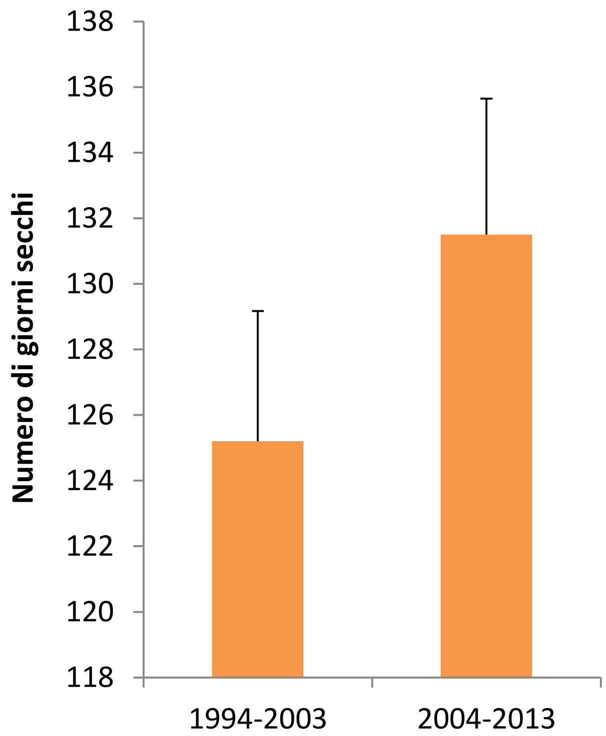


Gradi-giorno cumulati dal 1996 al 2013: da una media di 1600 a circa 1800-1900 GD

Cambiamento climatico in FVG: precipitazioni

RISULTATI





Precipitazioni mensili e numero di giorni secchi: confronto 1994-2003 Vs 2004-2013;

Differenze non significative statisticamente

Plant, Cell and Environment (2007) 30, 1381–1399 doi: 10.1111/j.1365-3040.2007.01716.x

Transcriptional regulation of anthocyanin biosynthesis in ripening fruits of grapevine under seasonal water deficit

SIMONE D. CASTELLARIN[1,2], ANTONELLA PFEIFFER[1], PAOLO SIVILOTTI[1], MIRKO DEGAN[1], ENRICO PETERLUNGER[1] & GABRIELE DI GASPERO[1,2]

[1]*Dipartimento di Scienze Agrarie e Ambientali, University of Udine, via delle Scienze 208 and* [2]*Istituto di Genomica Applicata, Parco Scientifico e Tecnologico Luigi Danieli, via Jacopo Linussio 51, 33100 Udine, Italy*

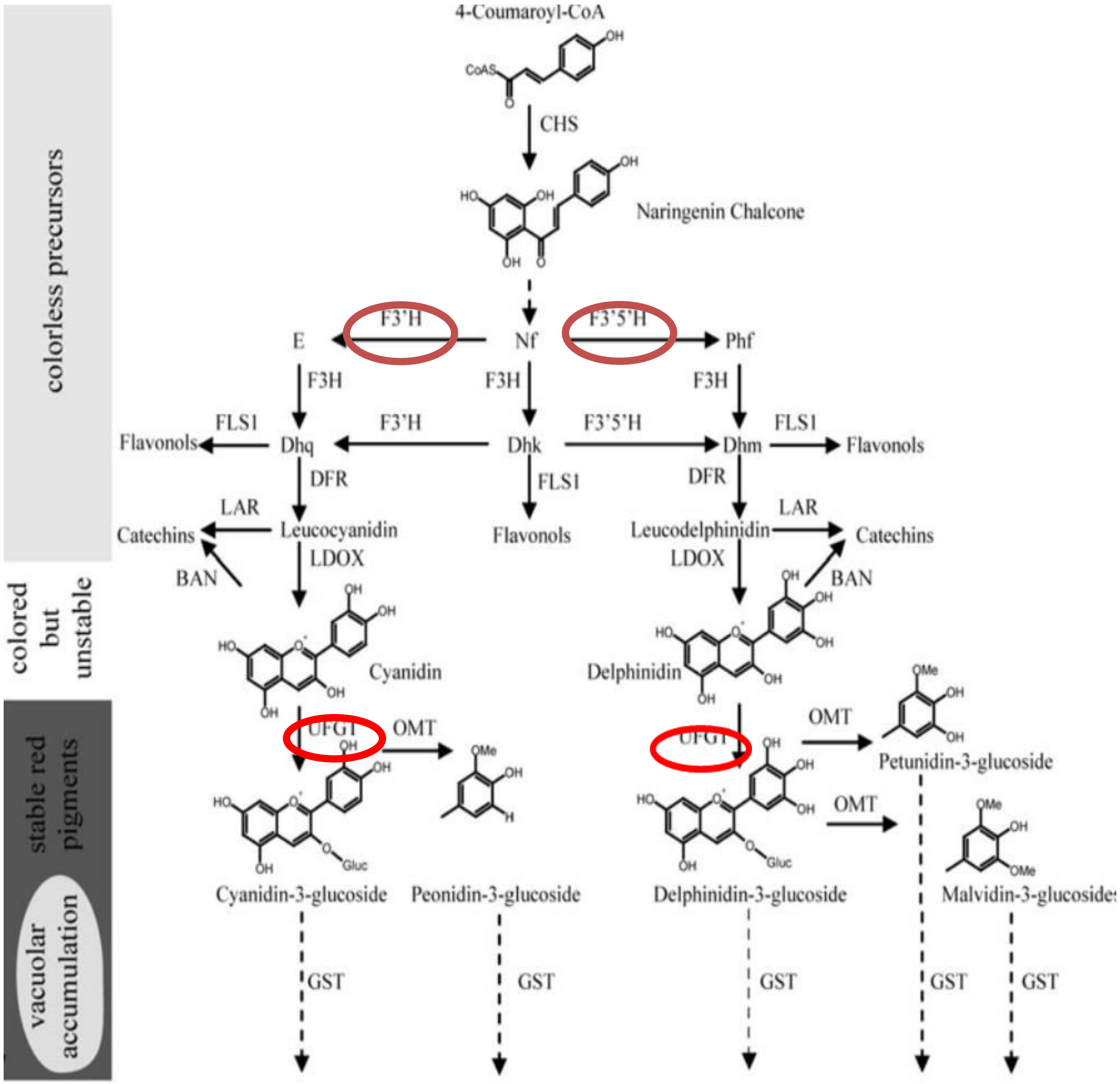
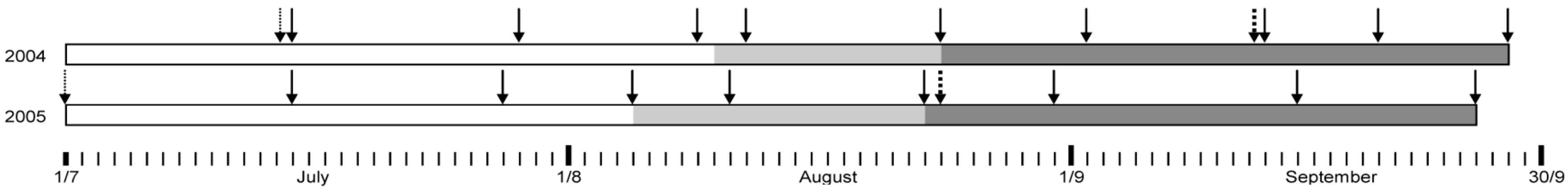


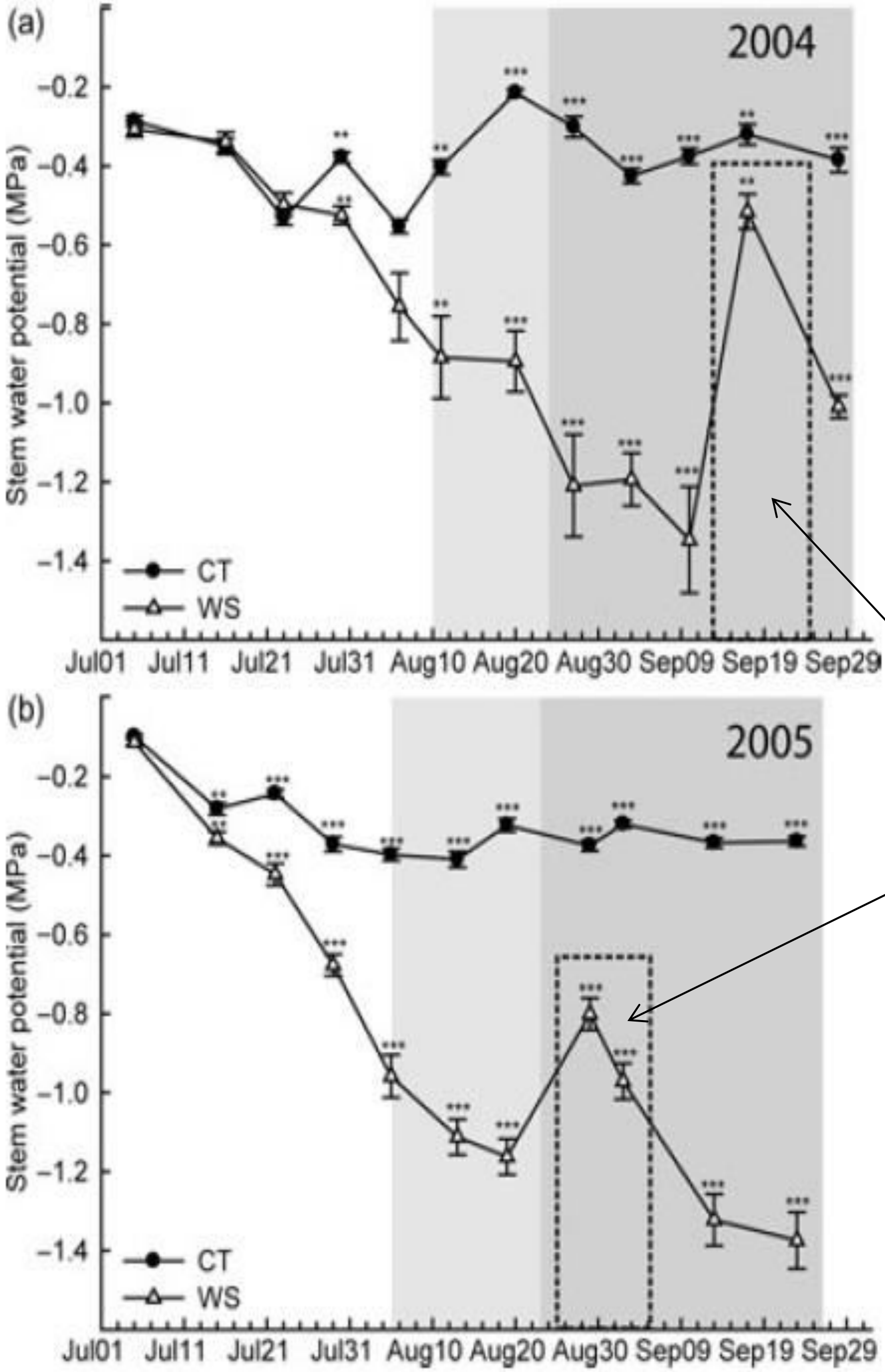
Figure 1. Key steps of the flavonoid pathway leading to anthocyanin biosynthesis. Transcripts of genes coding for all enzymes reported in this picture were analysed in this study. Dashed arrows indicate steps not considered in this study or steps for which the genetic control has not been elucidated in grape.Acronyms of the compounds reported in the picture stand for the following: E, eriodictyol; Nf,naringenin flavanone; Phf, pentahydroxyflavanone; Dhq, Dihydroquercetin; Dhk, dihydrokaempferol; Dhm,

dihydromyricetin.

Experimental design

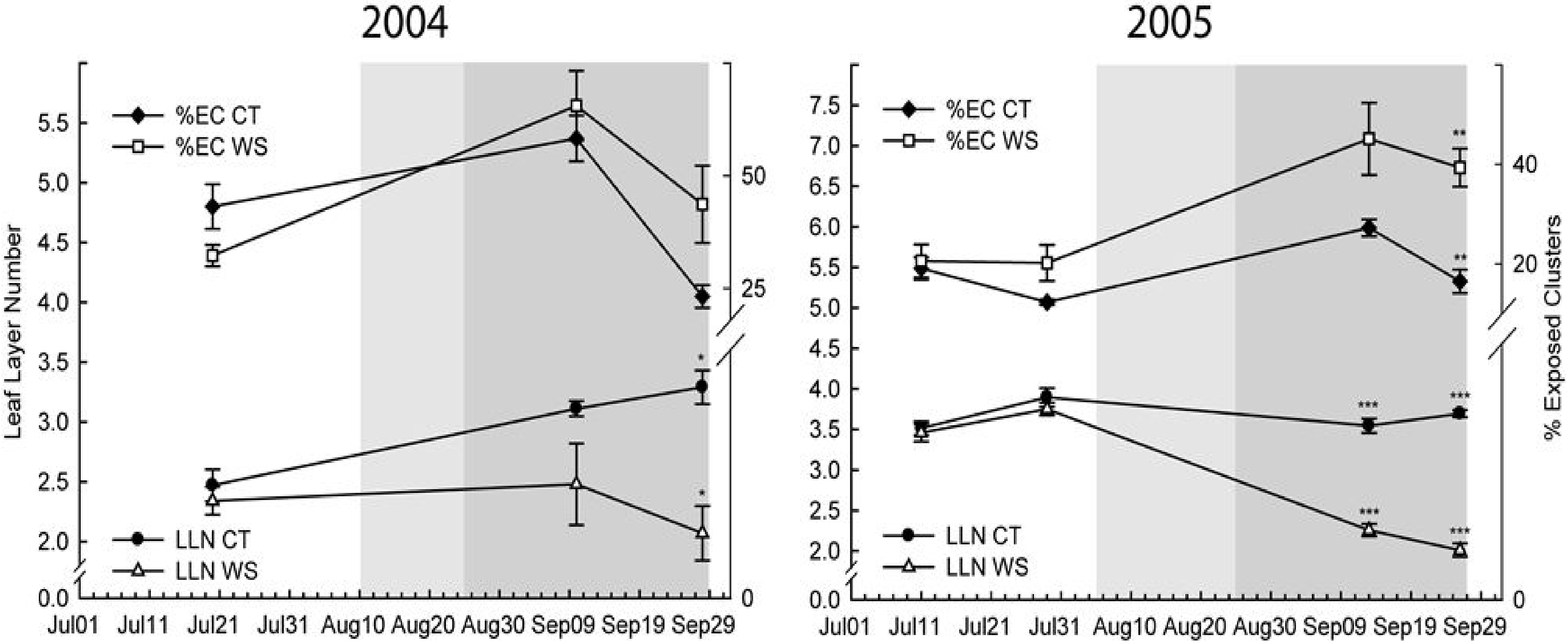
Experimental farm A. Servadei, University of Udine
cv MERLOT
Treatment: CT, WS
4 plots/treatment, 12 plants/plot





- Stem Water Potential Ψ_{stem}
- WS release with irrigation


WS
CT



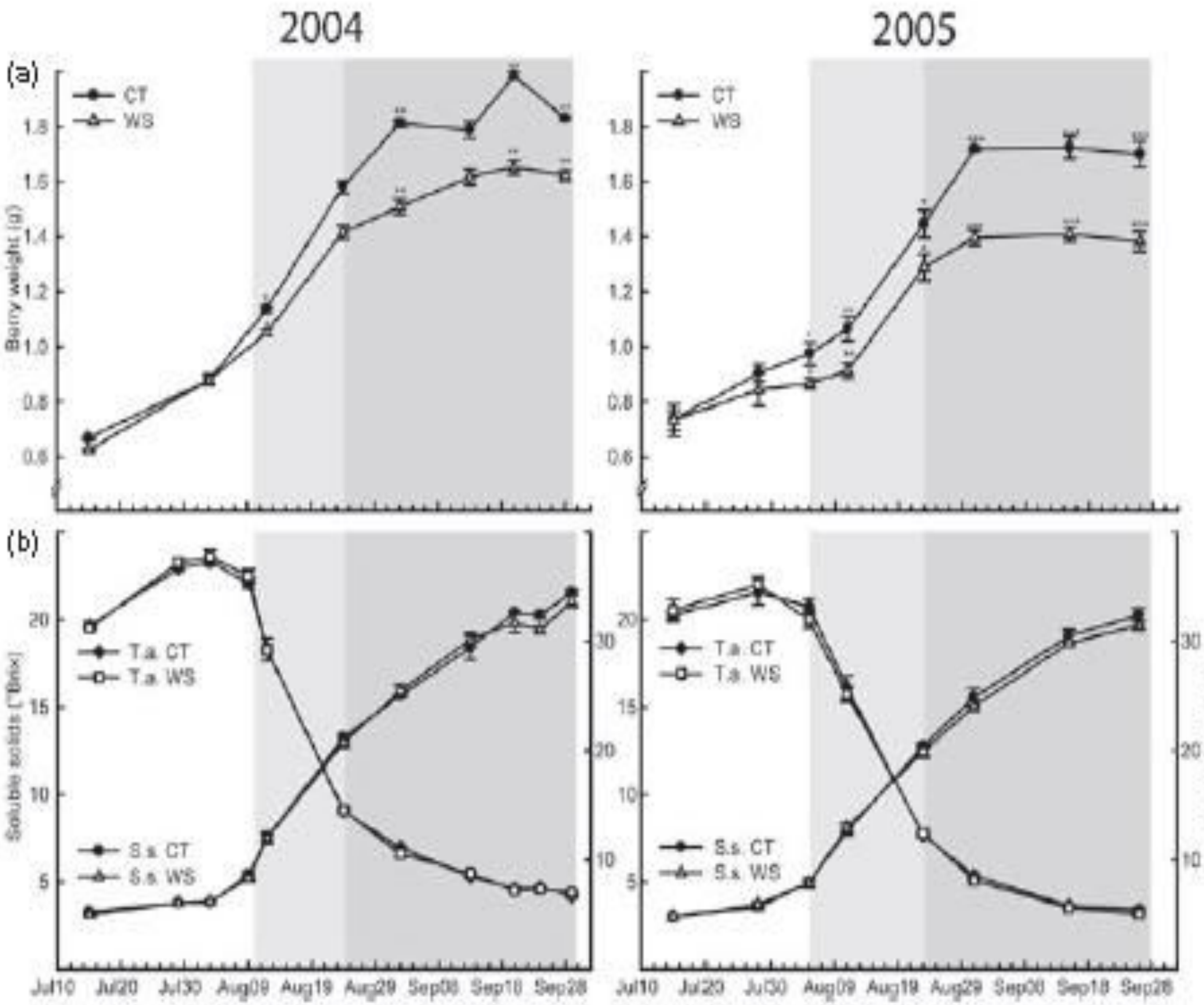
- % Exposed clusters

- Leaf Layer Number

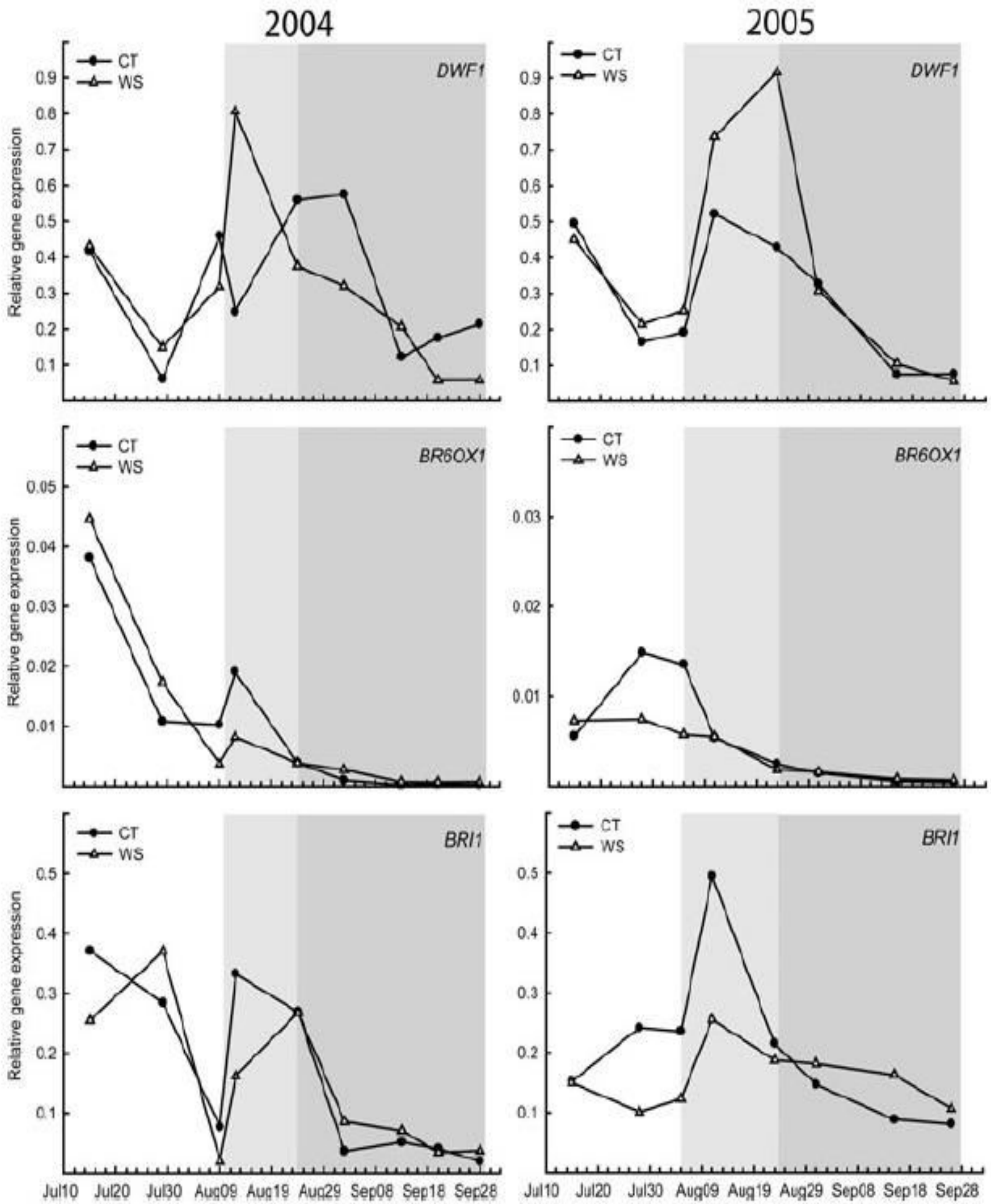
	Yield		Soluble solids	Titratable acidity	
	(kg vine^{-1})	(kg m^{-2})	(°Brix)	(g L^{-1})[a]	pH
CT 2004	4.59	1.83	21.5	6.7	3.35
WS 2004	3.75	1.50	21.0	7.1	3.20
	*	*	n.s.	n.s.	**
CT 2005	4.10	1.64	20.2	5.5	3.30
WS 2005	3.22	1.29	19.6	5.1	3.21
	*	*	n.s.	n.s.	***

Asterisks indicate significant differences between the treatments using the Student–Newman–Keuls test (*$P \leq 0.05$, **$P \leq 0.01$, ***$P \leq 0.001$).

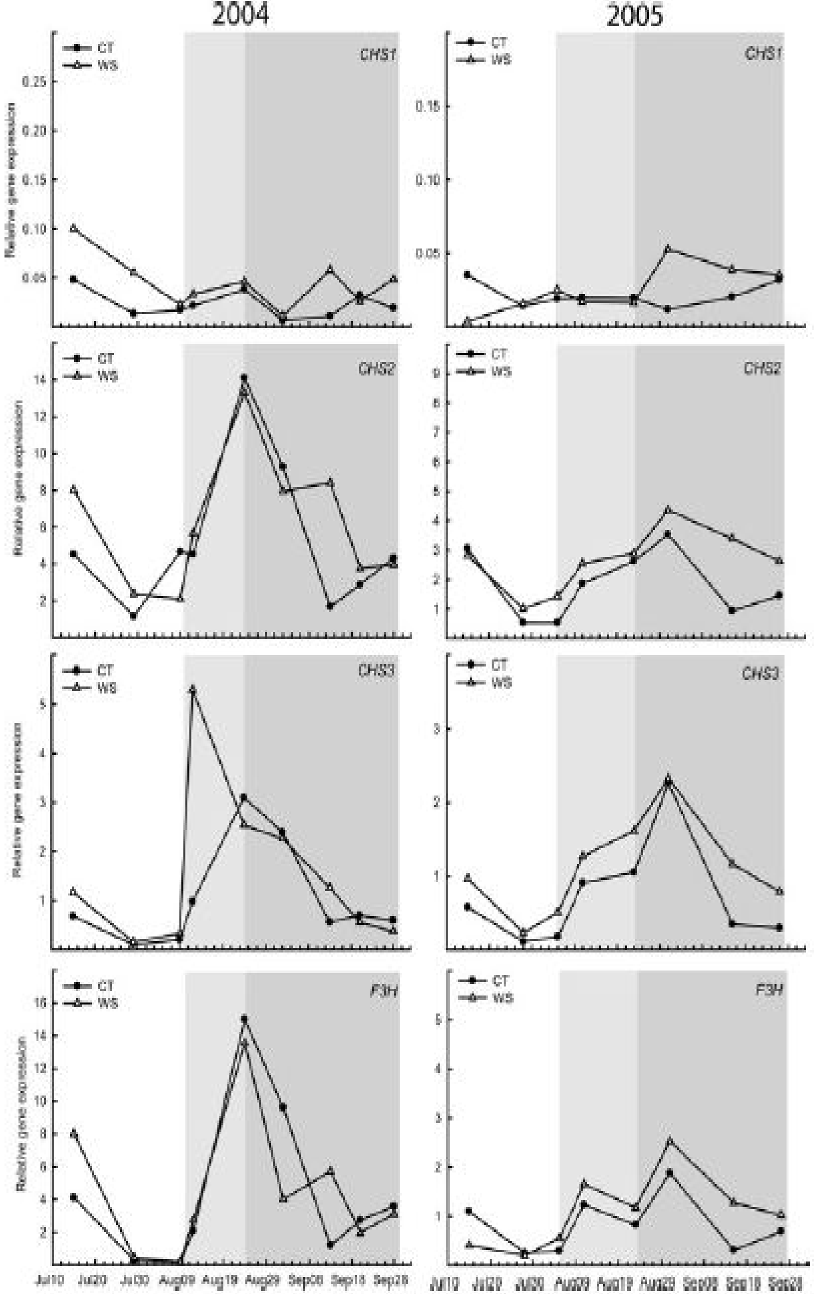
[a]Expressed as tartaric acid equivalents.

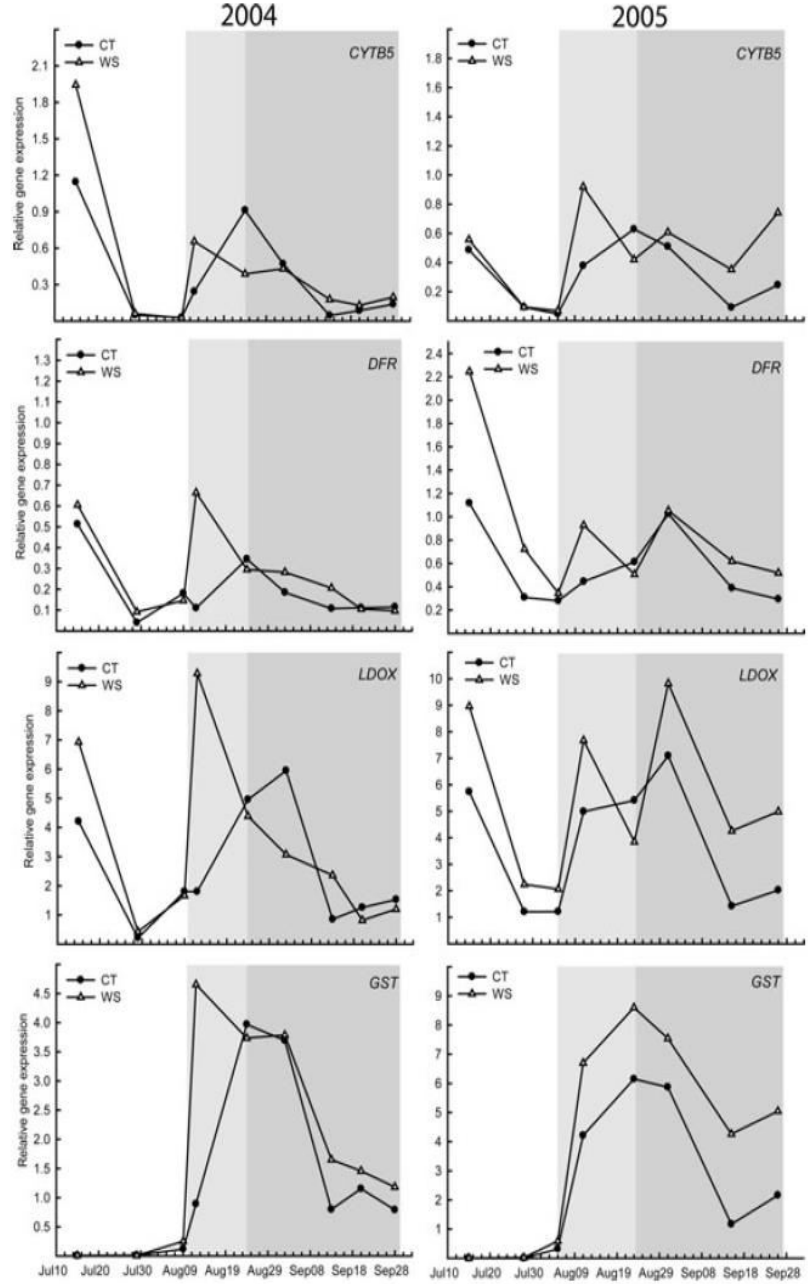


- Berry weight
- Soluble solids



- Brassinosteroid pathway related genes DWF1, BR6OX1, BRI1
- Markers of ripening advancement
- Earlier induction of ripening in WS

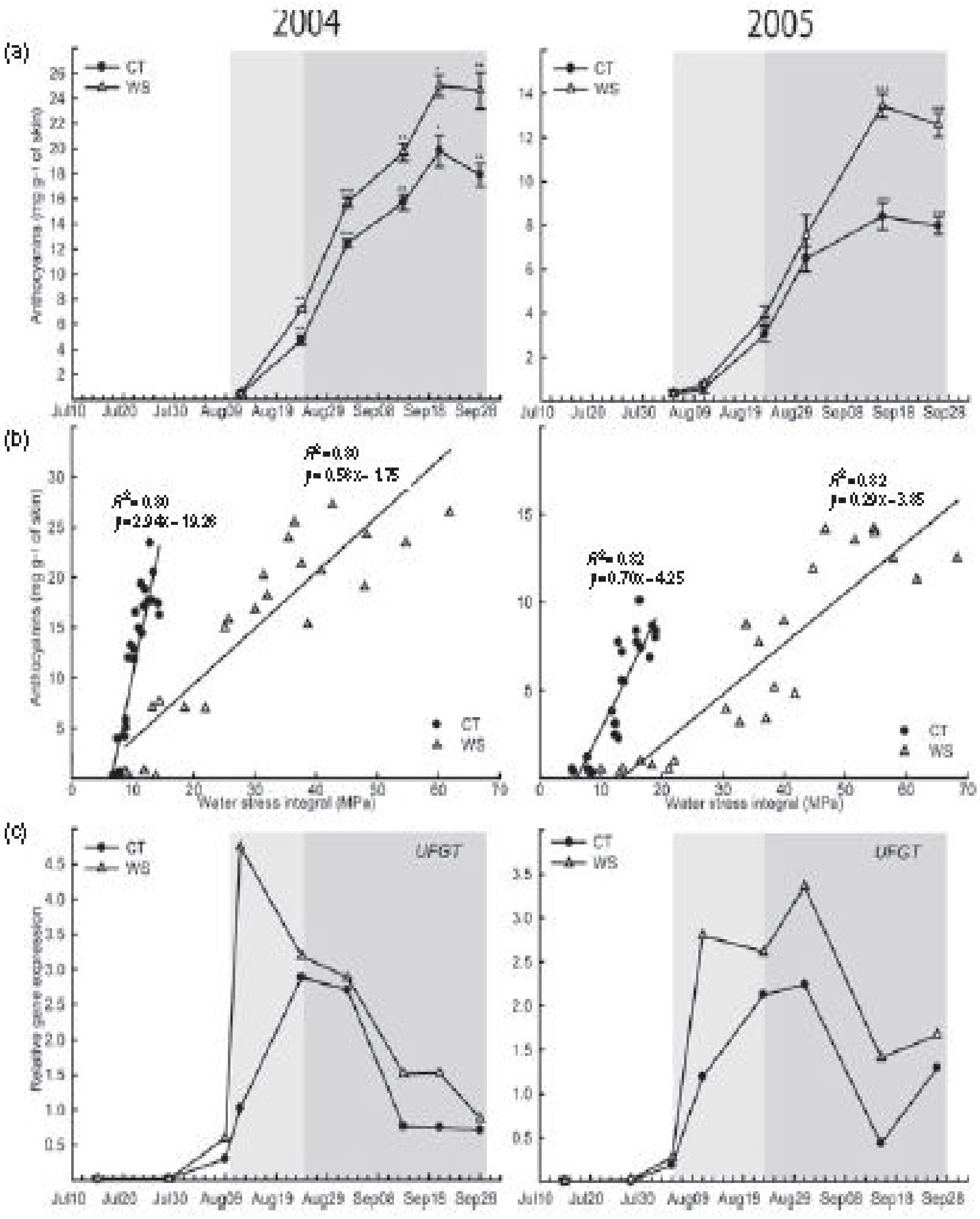




- Anthocyanin synthesis genes - ↑ in WS

Gene	Ratio of gene expression in red to green berries	Linear regression (R^2)		
		Total anthocyanins	Radiation	Day–night temperature fluctuation
CHS1	5.7	0.66	0.96	0.97
CHS2	14.2	0.95	0.40	0.39
CHS3	39.9	0.94	0.78	0.76
F3H	28.8	0.82	0.27	0.27
F3'H	11.1	0.43	0.69	0.68
F3'5'H	74.1	0.74	0.93	0.89
CYTB5	51.6	0.50	0.92	0.51
DFR	7.3	0.09	0.32	0.31
LDOX	12.1	0.40	0.80	0.77
UFGT	46.6	0.84	0.91	0.88
GST	146.6	0.24	0.61	0.59
OMT	38.4	0.92	0.44	0.43
MybA	13.9	0.34	0.71	0.69
MybB	6.0	0.03	0.28	0.23
MybC	4.9	0.66	0.93	0.90
MybD	0.8	0.11	0.24	0.23
Myb5a	1.6	0.01	0.10	0.70

Table 2. Transcript abundance of anthocyanin genes in red and green berries collected on the same bunch at the beginning of cluster pigmentation, correlation between the integral of gene expression during time series throughout ripening (x) and total anthocyanin content (Y) as well as between climate parameters (x) and cumulative transcript level throughout the course of ripening (Y)



- Anthocyanin increase in WS

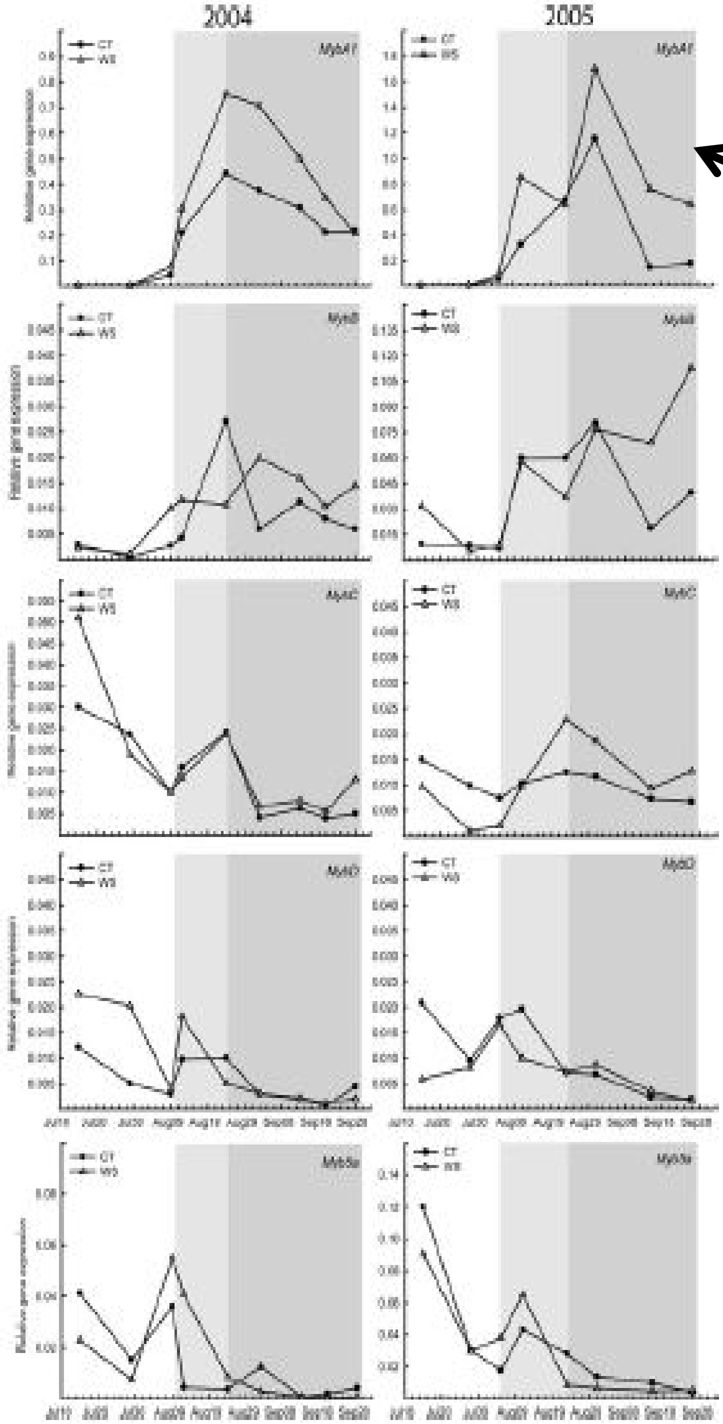
- Studied the linear relationship between

  integral of mRNA accumulation

  of specific genes (UFGT, CHS2, CHS3, F3H, GST)

and

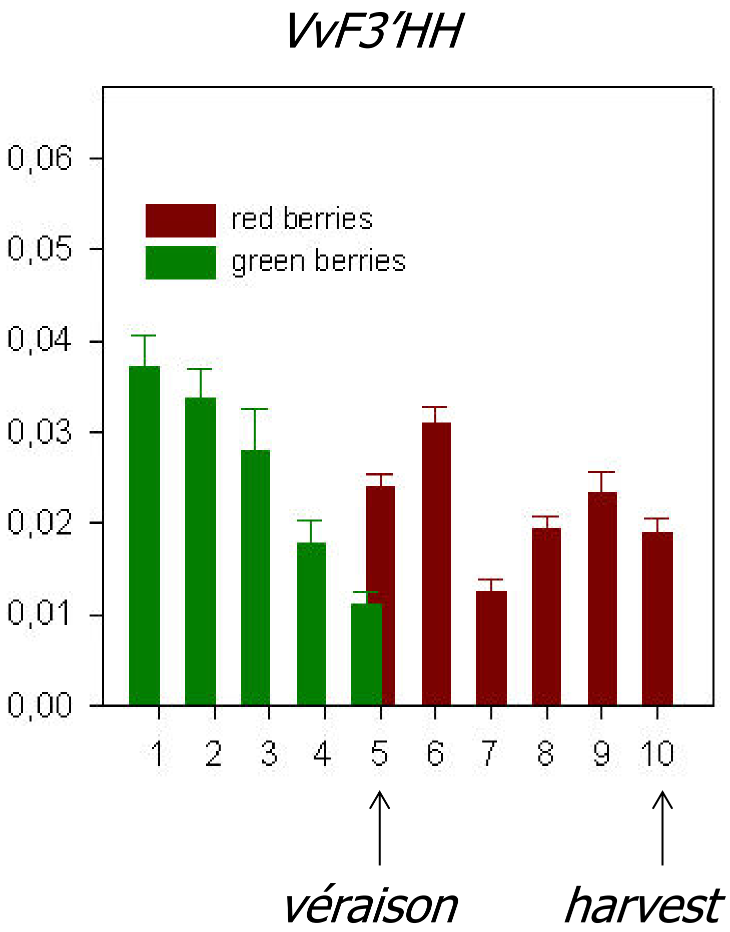
  metabolite content

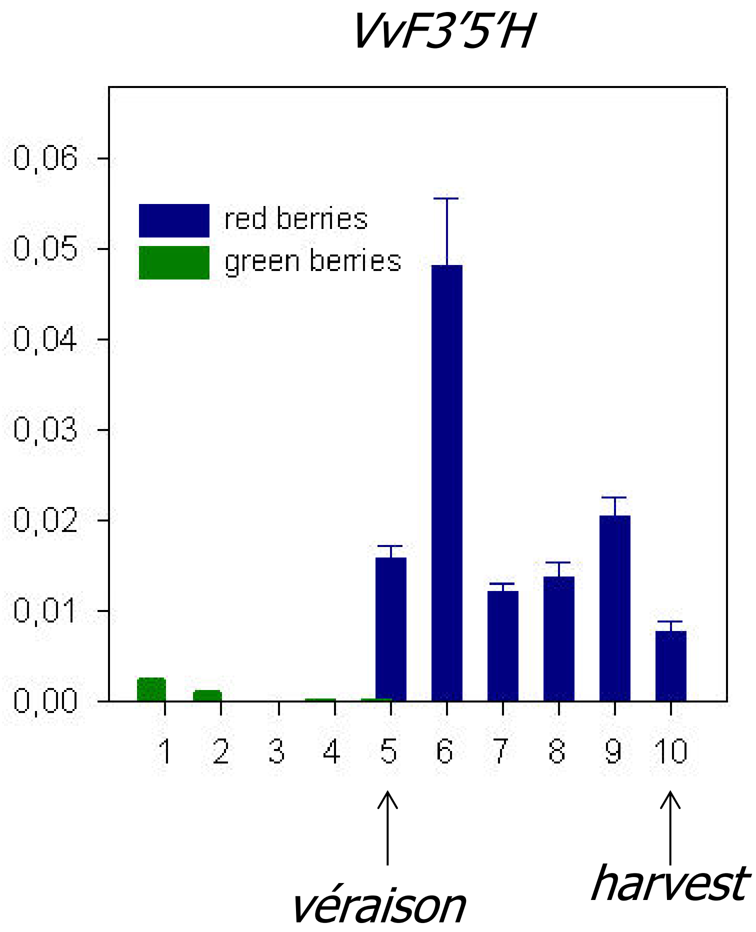


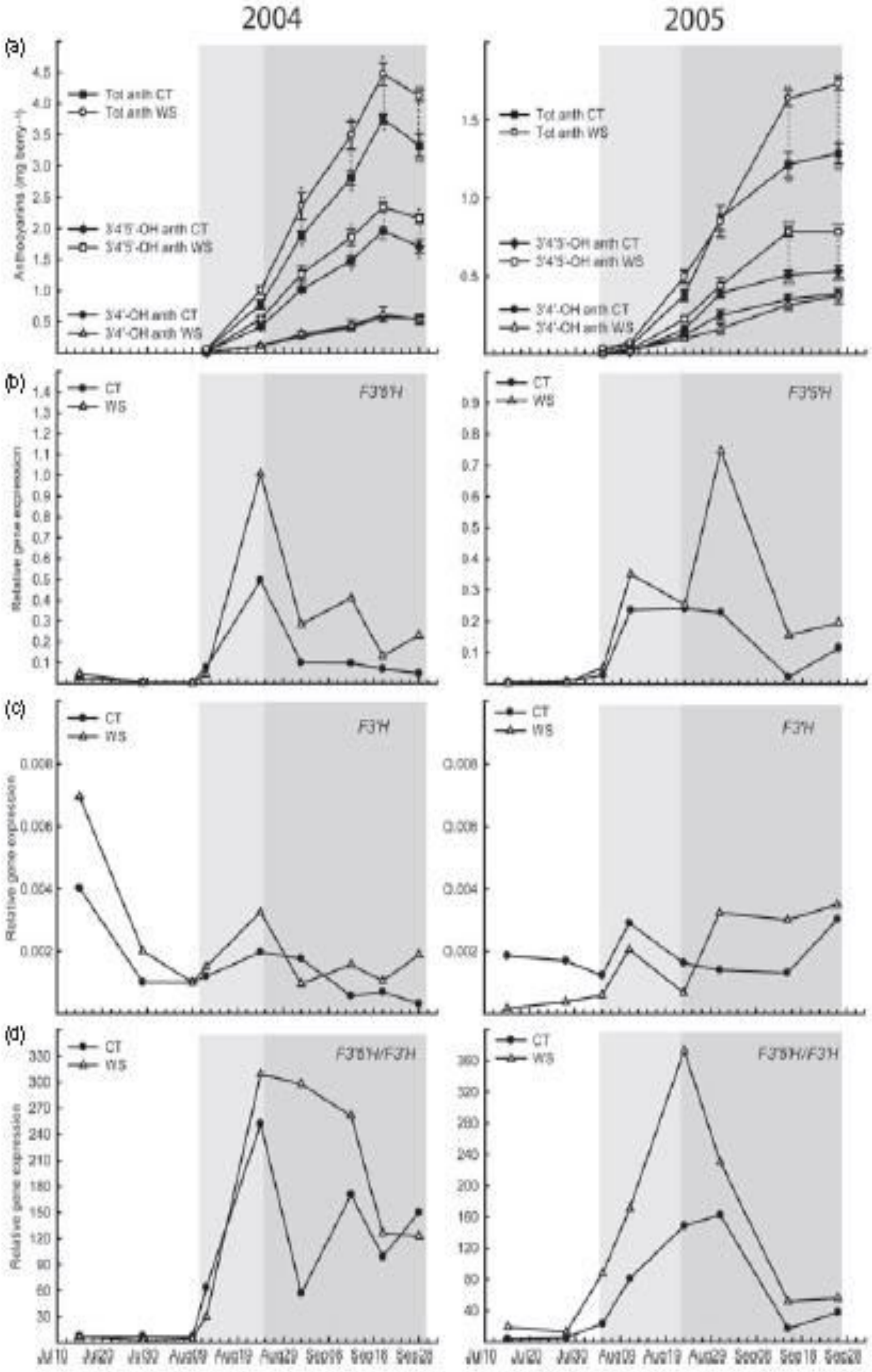
MybA1

- Transcription factors increase in WS

Expression of flavonoid hydroxylases in the skin of ripening berries







- Ratio between Tri-hydroxyl (Del,Pet,Mal) / Di-hydroxyl (Cyan,Peon) increased with WS

- WS 🡅 blue berries

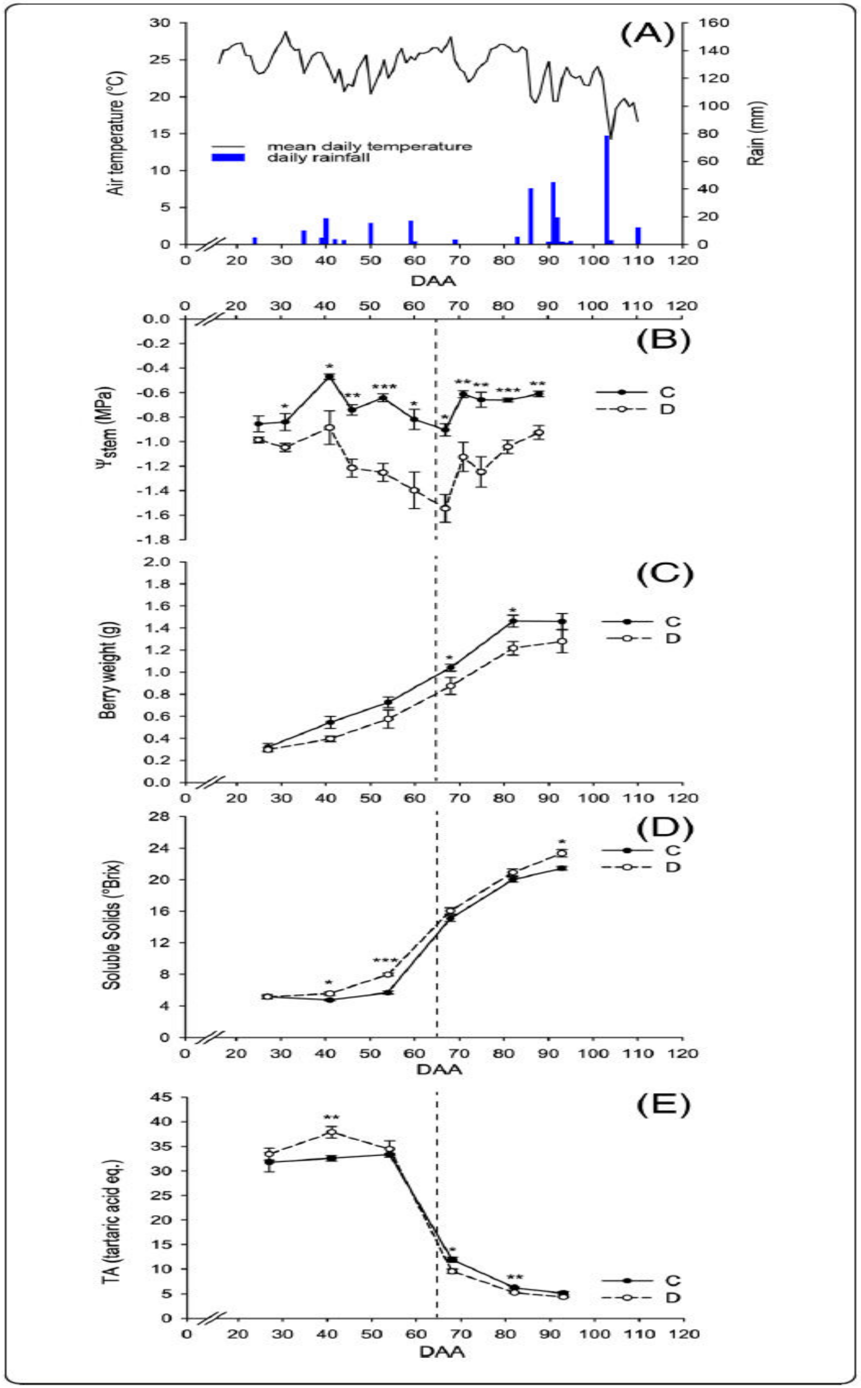
Savoi *et al. BMC Plant Biology* (2016) 16:67
DOI 10.1186/s12870-016-0760-1

BMC Plant Biology

RESEARCH ARTICLE Open Access

Transcriptome and metabolite profiling reveals that prolonged drought modulates the phenylpropanoid and terpenoid pathway in white grapes (*Vitis vinifera* L.)

Stefania Savoi[1,2], Darren C. J. Wong[3], Panagiotis Arapitsas[1], Mara Miculan[2,4], Barbara Bucchetti[2], Enrico Peterlunger[2], Aaron Fait[5], Fulvio Mattivi[1] and Simone D. Castellarin[2,3*]


(A)
Air temperature (°C)
Rain (mm)
mean daily temperature
daily rainfall
DAA
(B)
Ψstem (MPa)
C
D
(C)
Berry weight (g)
C
D
(D)
Soluble Solids (°Brix)
C
D
DAA
(E)
TA (tartaric acid eq.)
C
D
DAA

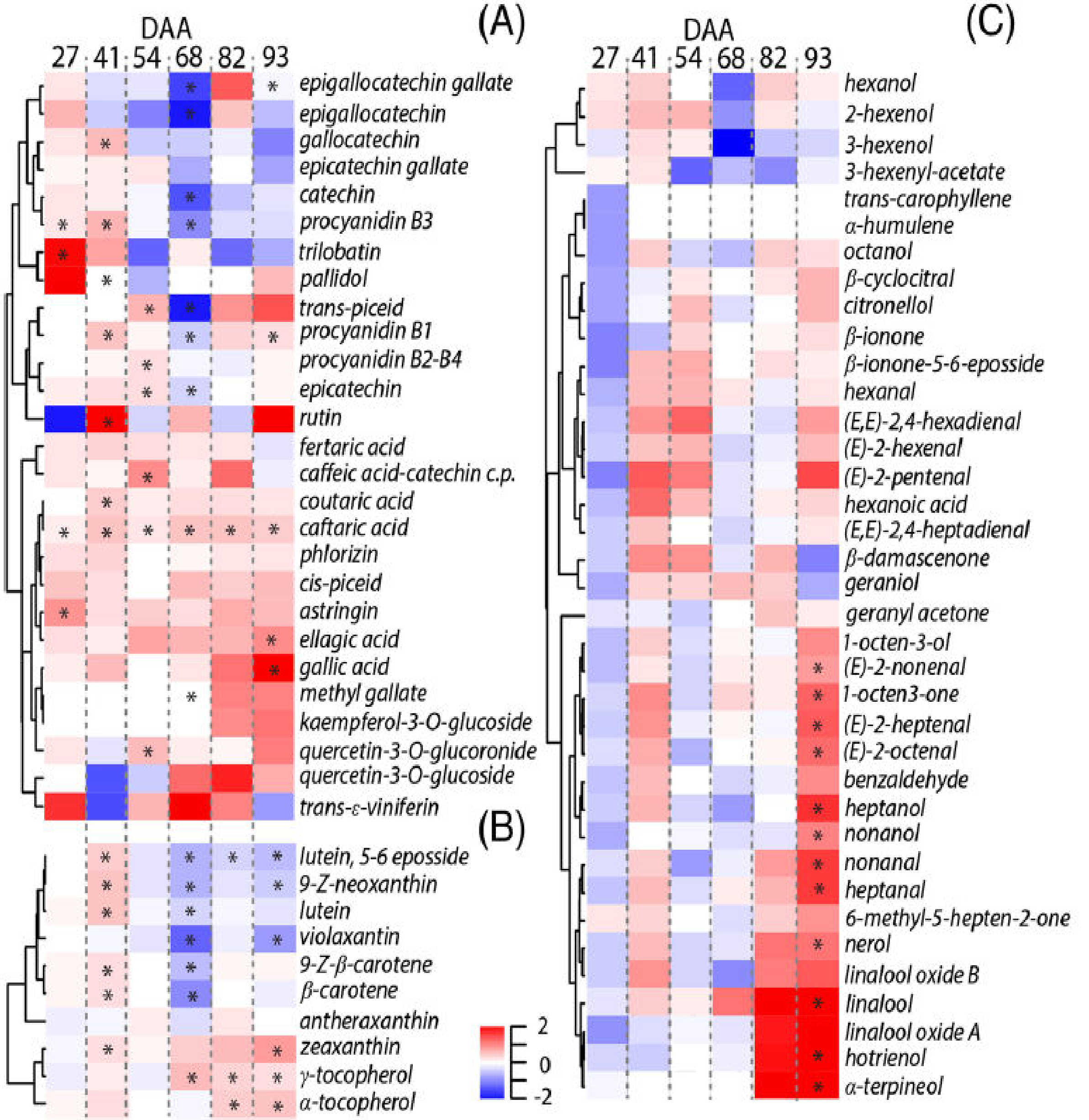


Fig. 2 Effect of water deficit on secondary metabolites during fruit development. Heatmaps represent $\log_2$FC(D/C) of the **a** phenolic, **b** carotenoid and tocopherol, and **c** VOC concentration under water deficit conditions at 27, 41, 54, 68, 82, 93 DAA. *Blue* and *red boxes* indicate lower and higher concentration in D, respectively. *Asterisks* indicate significant differences ($P < 0.05$) between treatments. Metabolites were hierarchically clustered based on their response to water deficit

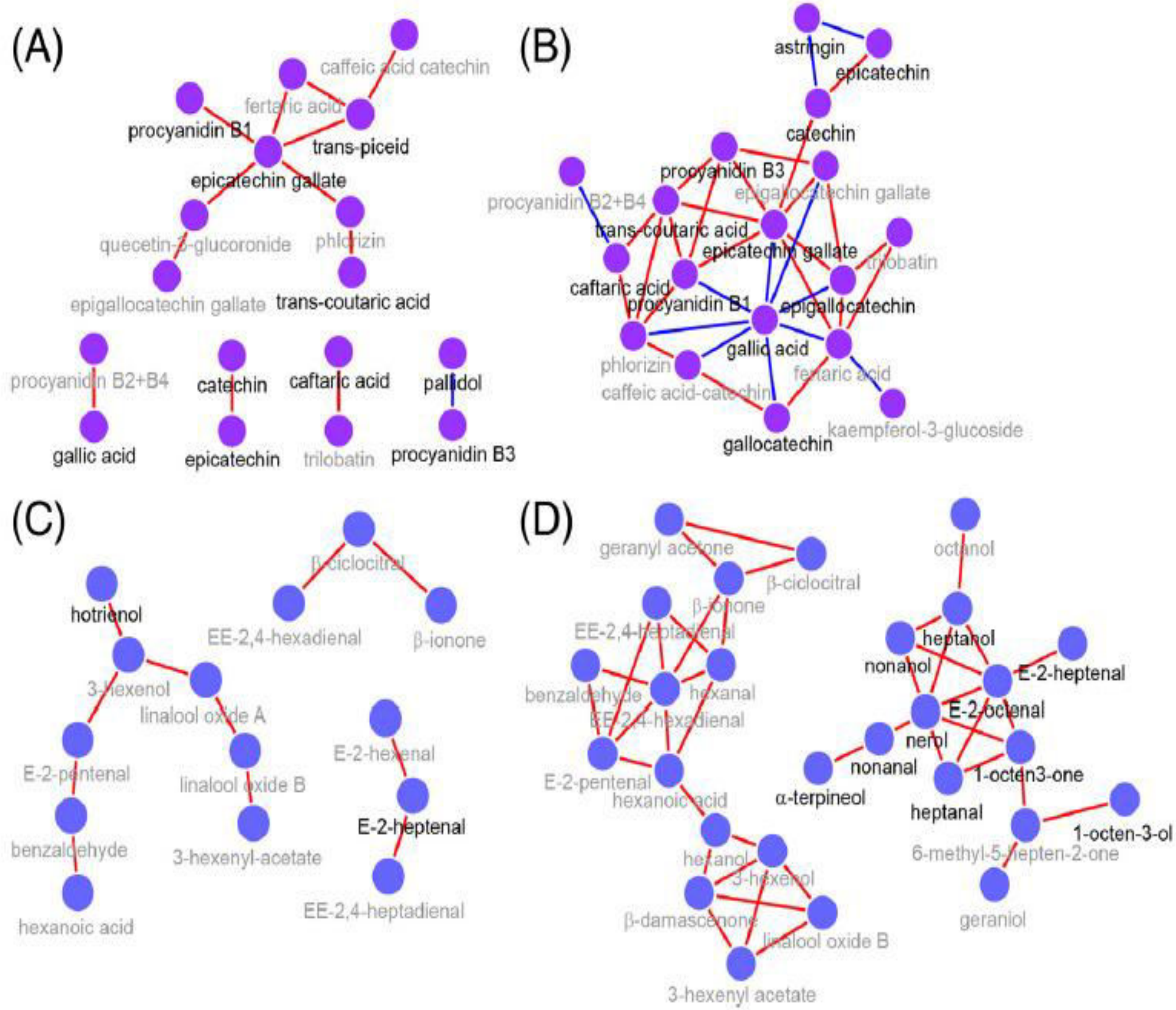


Fig. 3 Network representation of phenolics and VOCs in C (**a**, **c**) and D (**b**, **d**) berries during development. Nodes represent 'metabolites' and edges represent 'relationships' between any two metabolites. Edges colored in '*red*' and '*blue*' represent positive and negative correlations ($P < 0.001$), respectively. Metabolites in *bold* indicate a significant effect of water deficit on the concentration of that metabolite at one or more developmental stages. Number of correlating edges were 13, 35, 11, 42 in (**a**, **b**, **c**, and **d**), respectively. The average node neighborhood was 1.53, 3.89, 1.57, and 3.11 in (**a**, **b**, **c**, and **d**), respectively. The clustering coefficient was 0.08, 0.53, 0.00, and 0.49 in (**a**, **b**, **c**, and **d**), respectively

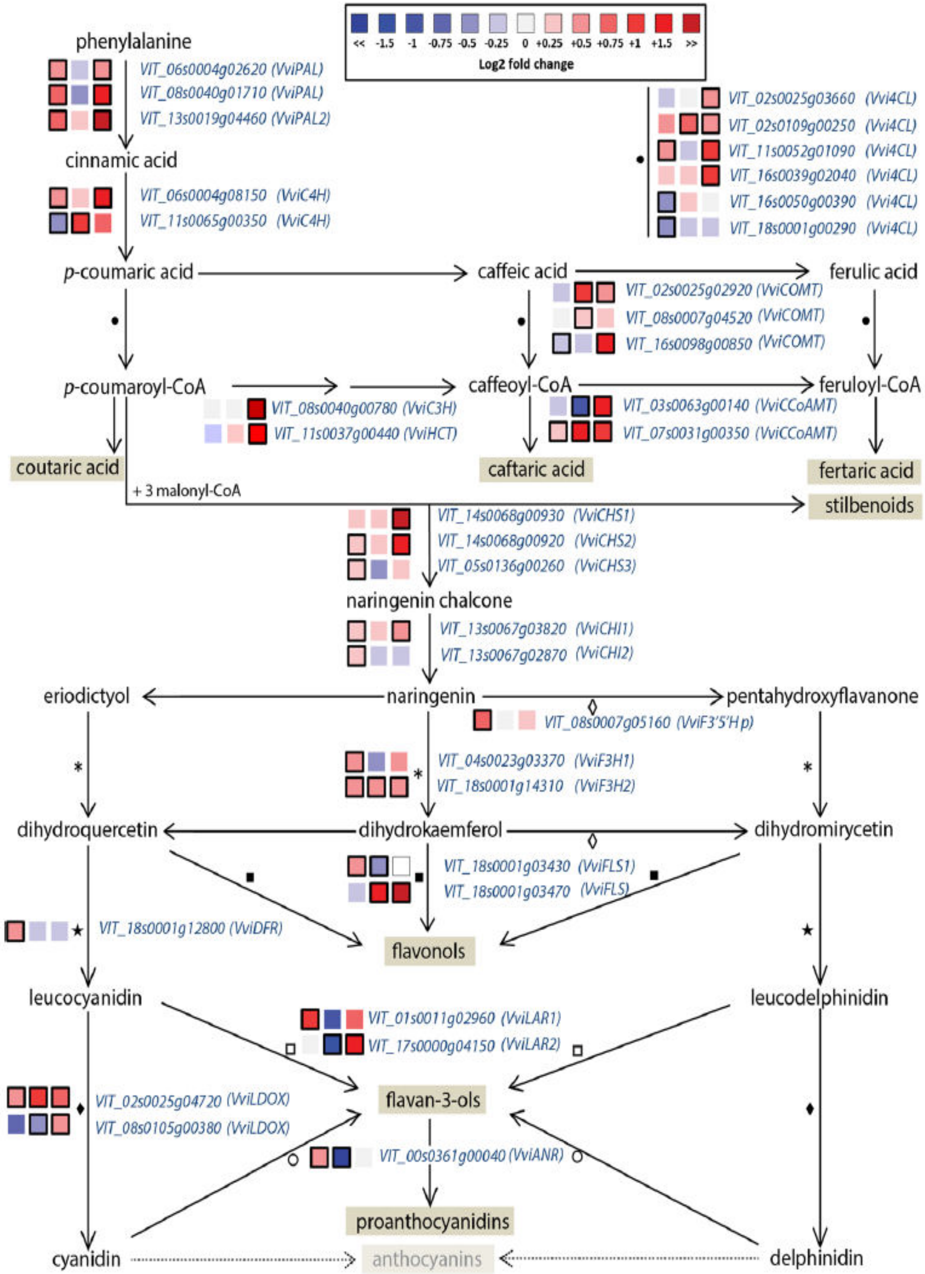


Fig. 5 Modulation of phenylpropanoid and flavonoid pathway under water deficit. Log_2FC (D/C) levels of differential gene expression are presented at 41 (left box), 68 (central box), and 93 (right box) DAA. *Blue* and *red boxes* indicate down or up regulation of the gene under water deficit, respectively. *Bold margins* identify significant differences ($P < 0.05$) between treatments. Symbols identify commonly regulated steps of the pathway. Transcript levels, expressed as normalized counts, in C and D berries at 41, 68, and 93 DAA, are reported in Additional file 13: Table S6 F

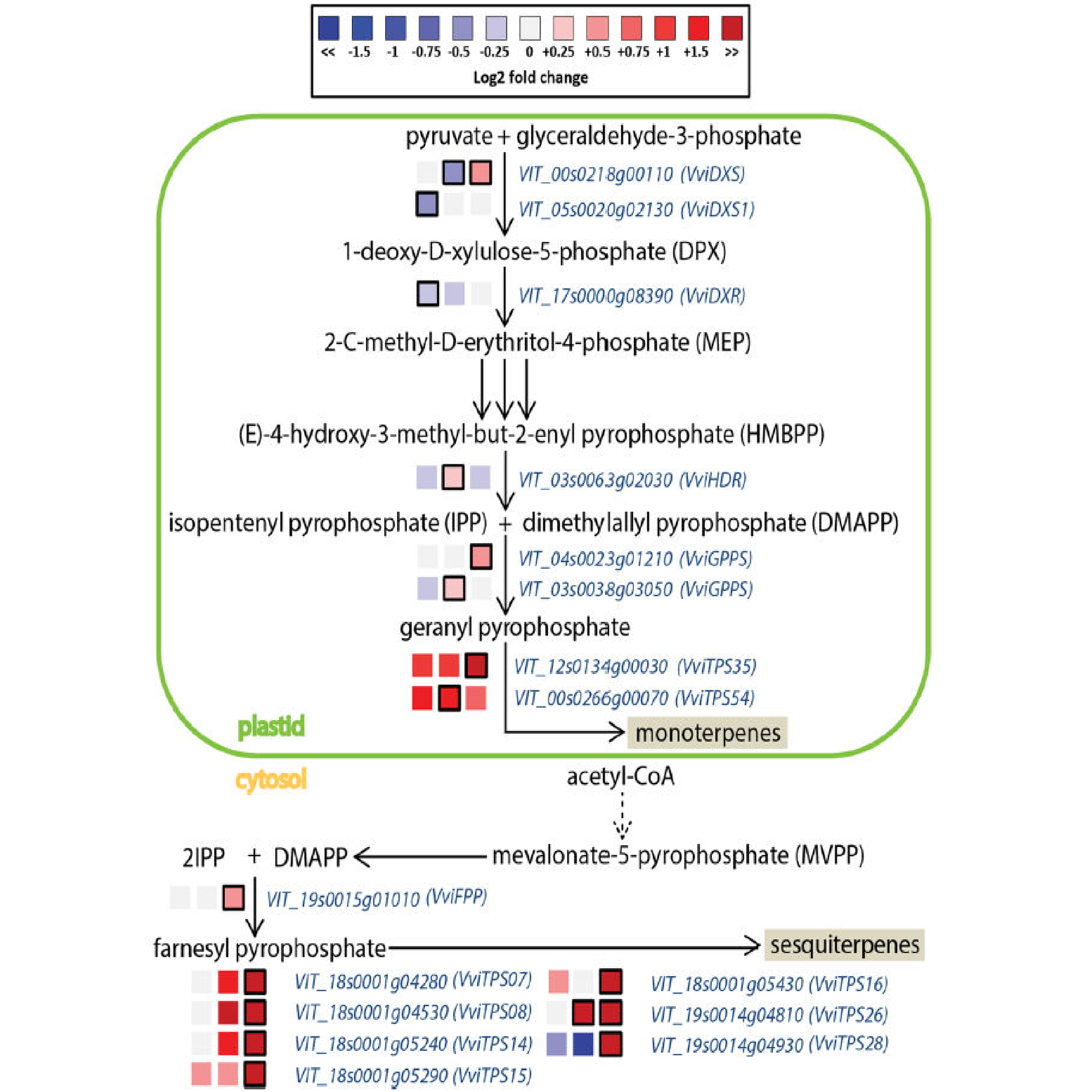


Fig. 7 Modulation of terpenoid pathway under water deficit. Log_2FC (D/C) levels of differential gene expression are presented at 41 (left box), 68 (central box), and 93 (right box) DAA. Blue and red boxes indicate down- or up-regulation of the gene under water deficit, respectively. Bold margins identify significant differences ($P < 0.05$) between treatments. Transcript levels, expressed as normalized counts, in C and D berries at 41, 68, and 93 DAA, are reported in Additional file 13: Table S6 H

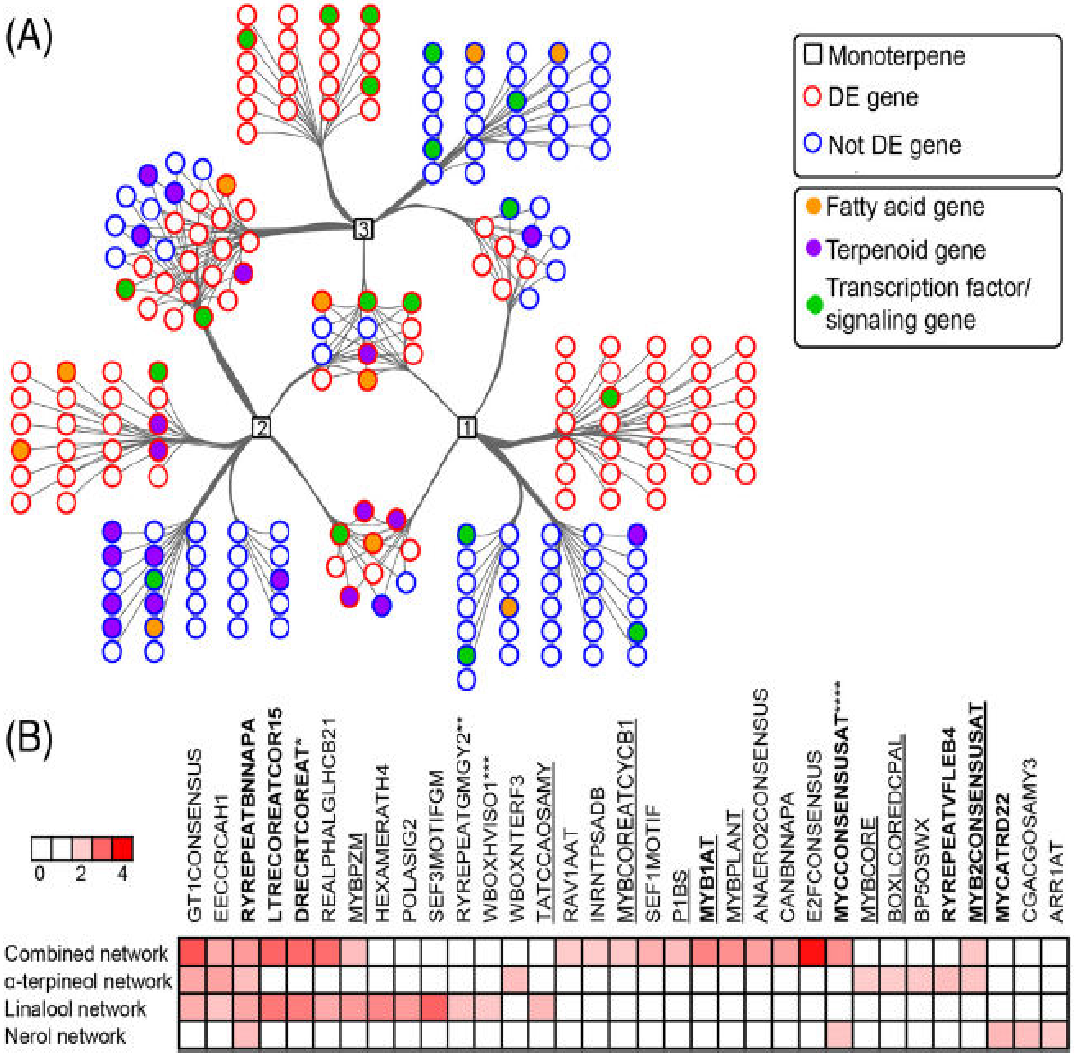


Fig. 8 Predicted gene-metabolite networks related to linalool (1), α-terpineol (2), and nerol (3) in grapevine berries during development. **a** Genes and metabolites are represented by circle and square nodes respectively. Edges represent associations ($P < 0.001$) between transcripts and metabolites. The top 100 correlators for each metabolite are shown. Node borders in red represent DE transcripts. Node colors indicate the pathway of the transcripts. **b** Heatmap of *cis*-regulatory elements enriched ($P < 0.01$) within the networks in **a**. *Cis*-regulatory elements in bold and underlined are associated with ABA/drought response and MYB binding, respectively. *Light* and *dark red color* denotes enrichment scores between 2 ($P < 0.01$) and 4 ($P < 0.0001$) respectively. White color represents no significant enrichment. *, **, ***, and **** denotes other PLACE *cis*-regulatory motifs sharing similar consensus sequence with the associated motif (Additional file 8: Table S7F)

WS may be useful also in white grapes improving aromatic quality

e.g. terpenes - linalol, terpineol, nerol

Data di vendemmia in Friuli

➔ anticipo

Negli ultimi 20 anni

➔ - 10 gg

Anticipo = 0,5 g / anno

Table 1 Budbreak, bloom, veraison, and harvest statistics for 18 *V. vinifera* cultivars, overall average and averages for early, middle, and late cultivars, 1964-2009, Conegliano, Italy.

	Budbreak					Bloom					Veraison					Harvest				
Cultivar[a]	**Mean**	**SD**	**Max**	**Min**	**Range**	**Mean**	**SD**	**Max**	**Min**	**Range**	**Mean**	**SD**	**Max**	**Min**	**Range**	**Mean**	**SD**	**Max**	**Min**	**Range**
Müller Thurgau (E)	14 Apr	6.2	27 Apr	1 Apr	26	5 Jun	7.7	19 Jun	13 May	37	30 Jul	7.6	16 Aug	12 Jul	35	6 Sep	10.0	29 Sep	23 Aug	37
Pinot Grigio (E)	16 Apr	6.5	30 Apr	2 Apr	28	5 Jun	8.0	23 Jun	14 May	40	4 Aug	8.5	23 Aug	16 Jul	38	8 Sep	12.2	17 Oct	18 Aug	60
Chardonnay (E)	13 Apr	7.3	27 Apr	28 Mar	30	3 Jun	8.7	21 Jun	13 May	39	5 Aug	9.2	23 Aug	14 Jul	40	8 Sep	10.1	29 Sep	16 Aug	43
Franconia (E)	12 Apr	7.3	30 Apr	27 Mar	34	6 Jun	8.8	23 Jun	15 May	39	7 Aug	10.5	1 Sep	17 Jul	46	12 Sep	13.7	10 Oct	17 Aug	54
Pinot noir (E)	15 Apr	5.9	28 Apr	1 Apr	27	6 Jun	9.1	27 Jun	16 May	42	8 Aug	9.7	31 Aug	15 Jul	47	17 Sep	13.9	3 Nov	25 Aug	70
Merlot (M)	18 Apr	7.1	4 May	1 Apr	33	8 Jun	8.1	25 Jun	17 May	39	12 Aug	9.2	31 Aug	22 Jul	40	18 Sep	13.2	24 Oct	22 Aug	63
Albana (M)	22 Apr	7.8	5 May	27 Mar	39	13 Jun	8.2	1 Jul	21 May	41	14 Aug	10.1	7 Sep	17 Jul	52	19 Sep	9.6	9 Oct	29 Aug	40
Tocai Friulano (M)	20 Apr	6.6	2 May	5 Apr	27	8 Jun	8.4	25 Jun	16 May	40	14 Aug	10.1	4 Sep	23 Jul	43	19 Sep	11.4	24 Oct	3 Sep	51
Cabernet franc (M)	17 Apr	6.6	28 Apr	1 Apr	27	7 Jun	8.9	25 Jun	15 May	41	14 Aug	9.0	7 Sep	25 Jul	44	24 Sep	9.5	12 Oct	31 Aug	42
Corvinone (M)	15 Apr	6.9	4 May	30 Mar	35	9 Jun	7.4	26 Jun	20 May	37	16 Aug	7.6	1 Sep	24 Jul	39	26 Sep	9.2	18 Oct	6 Sep	42
Prosecco (M)	11 Apr	6.2	24 Apr	28 Mar	27	6 Jun	8.1	22 Jun	14 May	39	16 Aug	9.8	7 Sep	27 Jul	42	27 Sep	12.0	19 Oct	30 Aug	50
Cabernet Sauvignon (L)	22 Apr	5.7	5 May	8 Apr	27	9 Jun	7.6	24 Jun	19 May	36	16 Aug	8.4	30 Aug	24 Jul	37	28 Sep	13.0	7 Nov	6 Sep	62
Garganega (L)	25 Apr	6.2	5 May	10 Apr	25	12 Jun	8.2	1 Jul	24 May	38	16 Aug	10.3	7 Sep	26 Jul	43	28 Sep	12.5	28 Oct	28 Aug	61
Marzemino (L)	13 Apr	7.7	30 Apr	28 Mar	33	8 Jun	7.7	25 Jun	21 May	35	16 Aug	8.5	7 Sep	2 Aug	36	28 Sep	13.1	1 Nov	26 Aug	66
Trebbiano di Soave (L)	20 Apr	6.8	5 May	6 Apr	29	9 Jun	7.7	25 Jun	20 May	36	18 Aug	10.5	7 Sep	24 Jul	45	28 Sep	12.8	24 Oct	29 Aug	56
Trebbiano Toscano (L)	25 Apr	7.0	8 May	9 Apr	29	12 Jun	7.5	1 Jul	21 May	41	20 Aug	8.8	7 Sep	26 Jul	43	30 Sep	11.4	24 Oct	7 Sep	46
Corvina (L)	16 Apr	6.7	28 Apr	1 Apr	27	8 Jun	8.0	25 Jun	17 May	39	21 Aug	10.8	17 Sep	2 Aug	46	2 Oct	11.8	25 Oct	8 Sep	47
Molinara (L)	18 Apr	6.5	2 May	1 Apr	31	9 Jun	7.8	24 Jun	21 May	34	24 Aug	10.8	17 Sep	20 Jul	59	3 Oct	9.8	25 Oct	15 Sep	40
Overall avg.	17 Apr	6.0	30 Apr	3 Apr	28	8 Jun	7.6	23 Jun	17 May	37	13 Aug	8.1	1 Sep	24 Jul	39	22 Sep	9.2	13 Oct	30 Aug	43
Early avg. (E)	14 Apr	6.4	28 Apr	1 Apr	27	5 Jun	8.2	20 Jun	14 May	37	5 Aug	7.9	19 Aug	14 Jul	35	10 Sep	10.1	7 Oct	20 Aug	49
Middle avg. (M)	17 Apr	6.2	1 May	2 Apr	29	9 Jun	7.8	25 Jun	17 May	39	14 Aug	8.4	4 Sep	25 Jul	41	22 Sep	8.4	10 Oct	3 Sep	37
Late avg. (L)	18 Apr	5.9	2 May	5 Apr	27	10 Jun	7.2	24 Jun	20 May	35	19 Aug	8.6	8 Sep	30 Jul	39	30 Sep	10.4	27 Oct	4 Sep	53

[a](E): early cultivars, (M): middle cultivars, (L): late cultivars.

(Tomasi *et al., 2011)*

Table 2 Linear trend characteristics (R^2, *p* value, slope or annual trend, and total trend over the 46 years) for each of the overall average phenological growth events and intervals between growth events (averaged over all 18 cultivars) for 1964–2009. Conegliano, Italy. (ns indicates that that trend for that variable is not significant.)

Variable	R^2	*p* value	Annual trend (days)	Total trend (days)
Budbreak	ns			
Bloom	0.36	≤0.001	-0.34	-16
Veraison	0.21	≤0.001	-0.29	-13
Harvest	0.37	≤0.001	-0.42	-19
Budbreak to bloom	0.30	≤0.001	-0.39	-18
Budbreak to veraison	0.22	≤0.001	-0.33	-15
Budbreak to harvest	0.14	≤0.001	-0.32	-15
Bloom to veraison	ns			
Bloom to harvest	ns			
Veraison to harvest	0.11	≤0.001	-0.14	-6

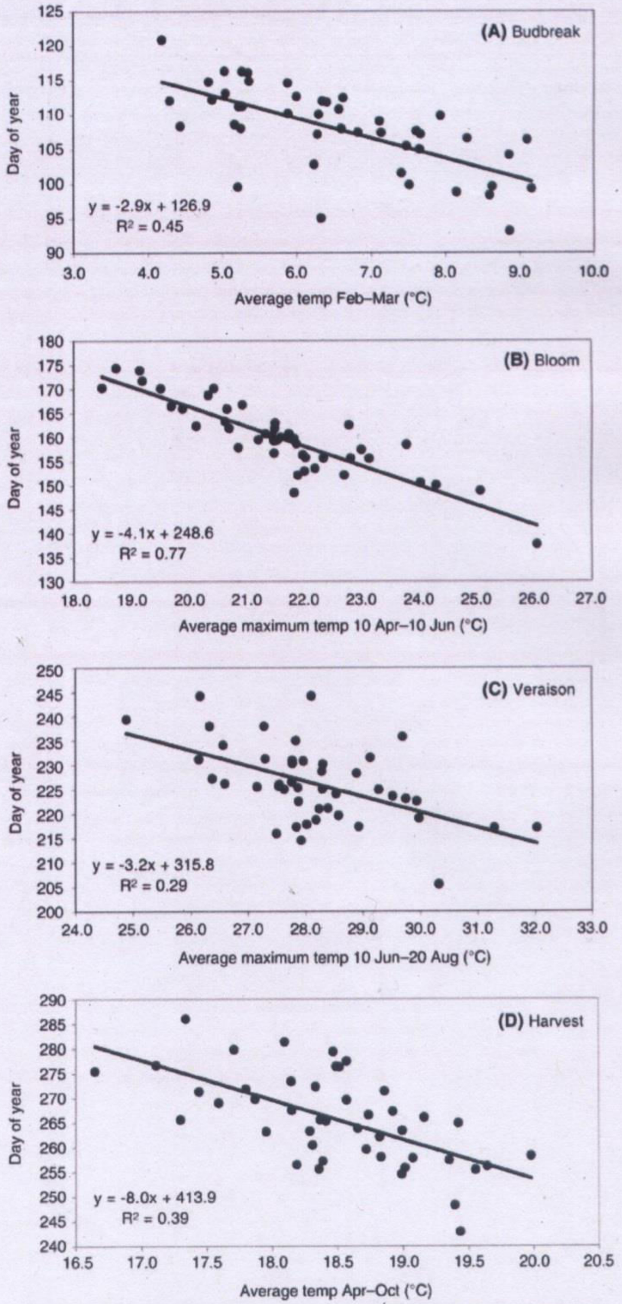


Figure 1 Relationships between the most significant climate parameter related to the average phenological dates of 18 *V. vinifera* cultivars for **(A)** budbreak, **(B)** bloom, **(C)** veraison, and **(D)** harvest, 1964–2009, Conegliano, Italy.

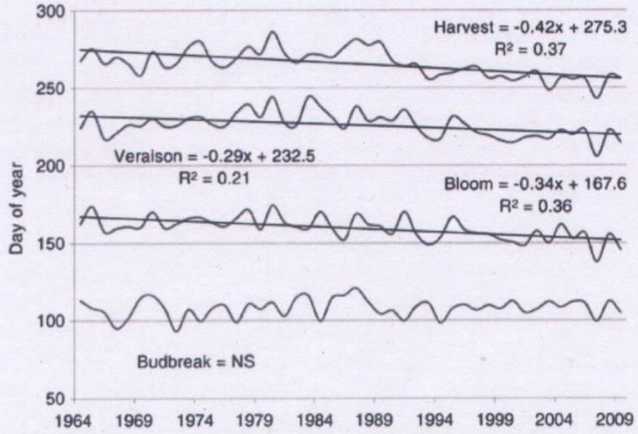


Figure 2 Time series and linear trends for the average phenological dates of 18 *V. vinifera* cultivars for budbreak, bloom, veraison, and harvest, 1964–2009, Conegliano, Italy.

Table 3 Linear trend characteristics (R^2, *p* value, slope or annual trend, and total trend over the 46 years) for annual (Jan to Dec) and growing season (Apr to Oct) climate parameters, 1964–2009, Conegliano, Italy. (ns indicates that that trend for that variable is not significant.)

Variable	R^2	*p* value	Annual trend	Total trend
Annual average temp	0.42	≤0.001	+0.034°C	+1.6°C
Annual max temp	0.51	≤0.001	+0.055°C	+2.5°C
Annual min temp	0.48	≤0.001	+0.044°C	+2.0°C
Annual precipitation	ns			
Growing season average temp	0.48	≤0.001	+0.051°C	+2.3°C
Growing season max temp	0.38	≤0.001	+0.052°C	+2.4°C
Growing season min temp	0.46	≤0.001	+0.051°C	+2.3°C
Growing season precipitation	ns			

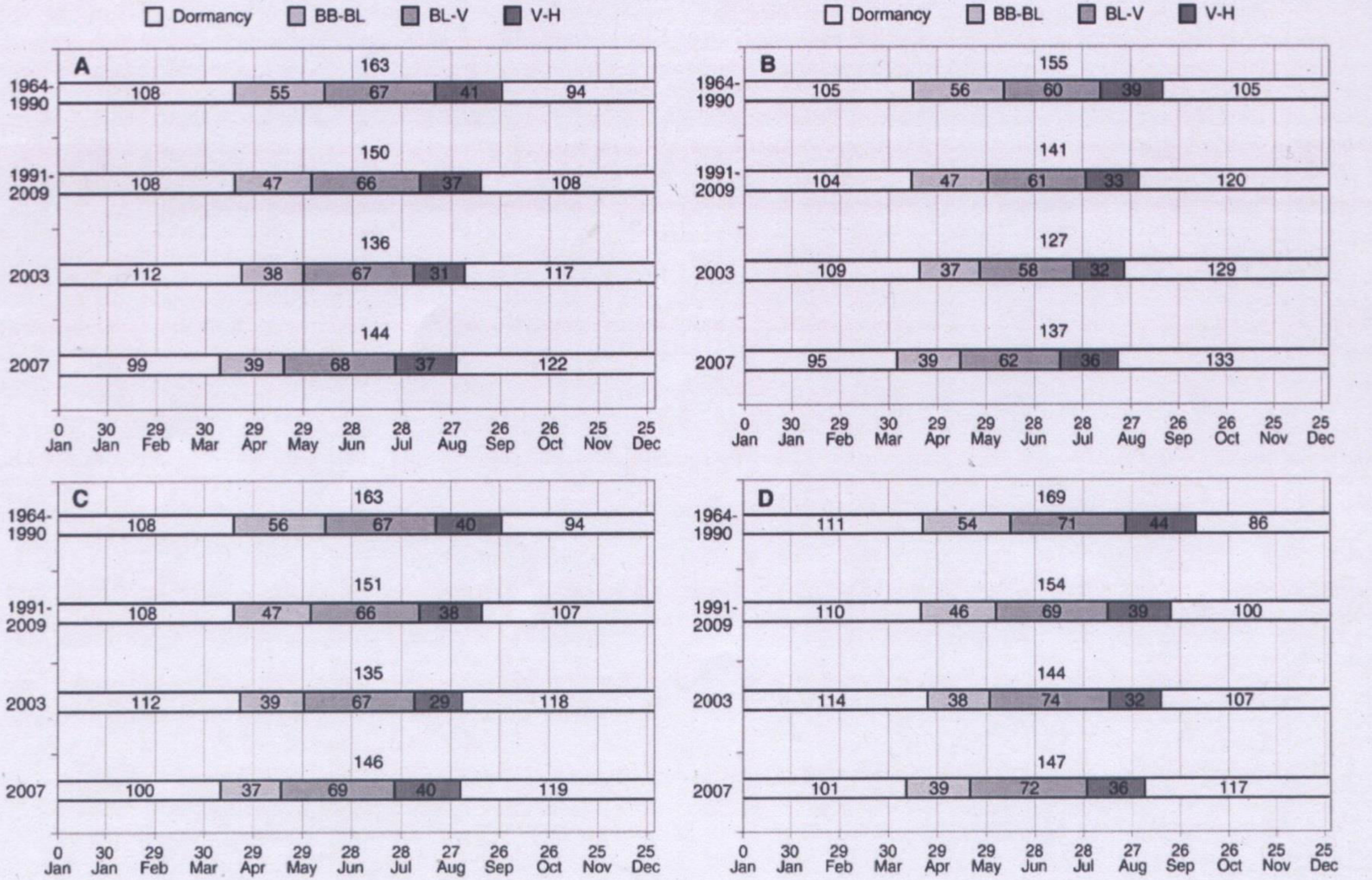


Figure 7 *Vitis vinifera* cultivar phenology before (1964–1990) and after (1991–2009) the average breakpoint and for the two extreme years 2003 and 2007, Conegliano, Italy, for (**A**) overall cultivar, (**B**) early cultivar, (**C**) middle cultivar, and (**D**) late cultivar (see Table 1 for cultivars in each category). The first segment of each bar is from the first of the year to the average budbreak (dormancy), the second segment is from budbreak to bloom (BB-BL), the third segment is from bloom to veraison (BL-V), the fourth segment is from veraison to harvest (V-H), and the last segment is from harvest to the end of the year (dormancy). The numbers above the middle bar segments are the total number of days from budbreak to harvest for each period or year.

Figure 1 (**A**) Mechanical prepruner at work in the spur-pruned cordon-trained Sangiovese vineyard, and (**B**) vines just after the prepruning treatment in winter.

Come adattare la tecnica colturale al cambio climatico?

Potatura in due tempi:

- **SHF**
- **LHF (BBCH 14)**
- **VLHF (BBCH 19)**

(Palliotti et al., 2017)

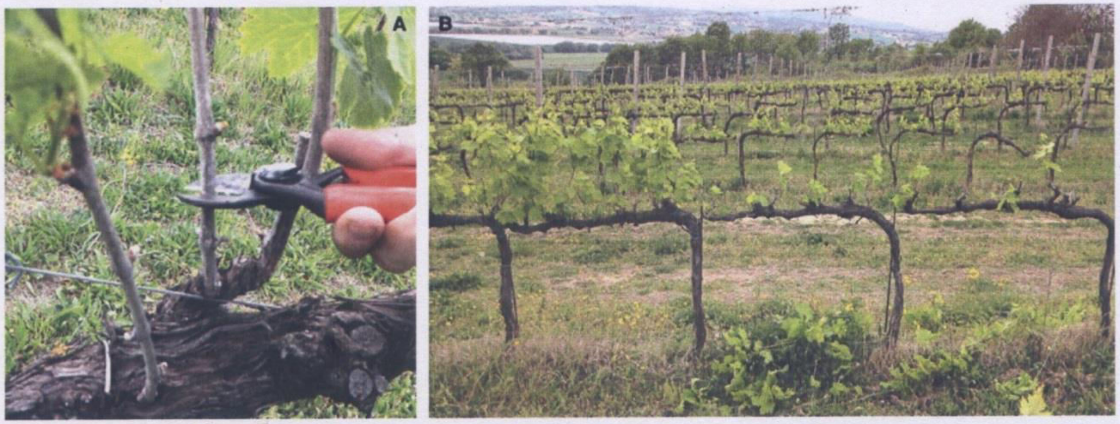


Figure 2 (**A**) Detail of hand-finishing (HF) performed on very late HF when the apical shoots growing on preshortened canes were at BBCH-19 (~20 cm long with eight to nine unfolded leaves), and (**B**) pre- and post-HF comparison.

Figure 3 Photos taken in 2015 on (**A**) 3 Aug during veraison, showing clusters on "regular" shoots; and (**B**) on 21 Aug during fruit ripening, showing clusters on "delayed" shoots.

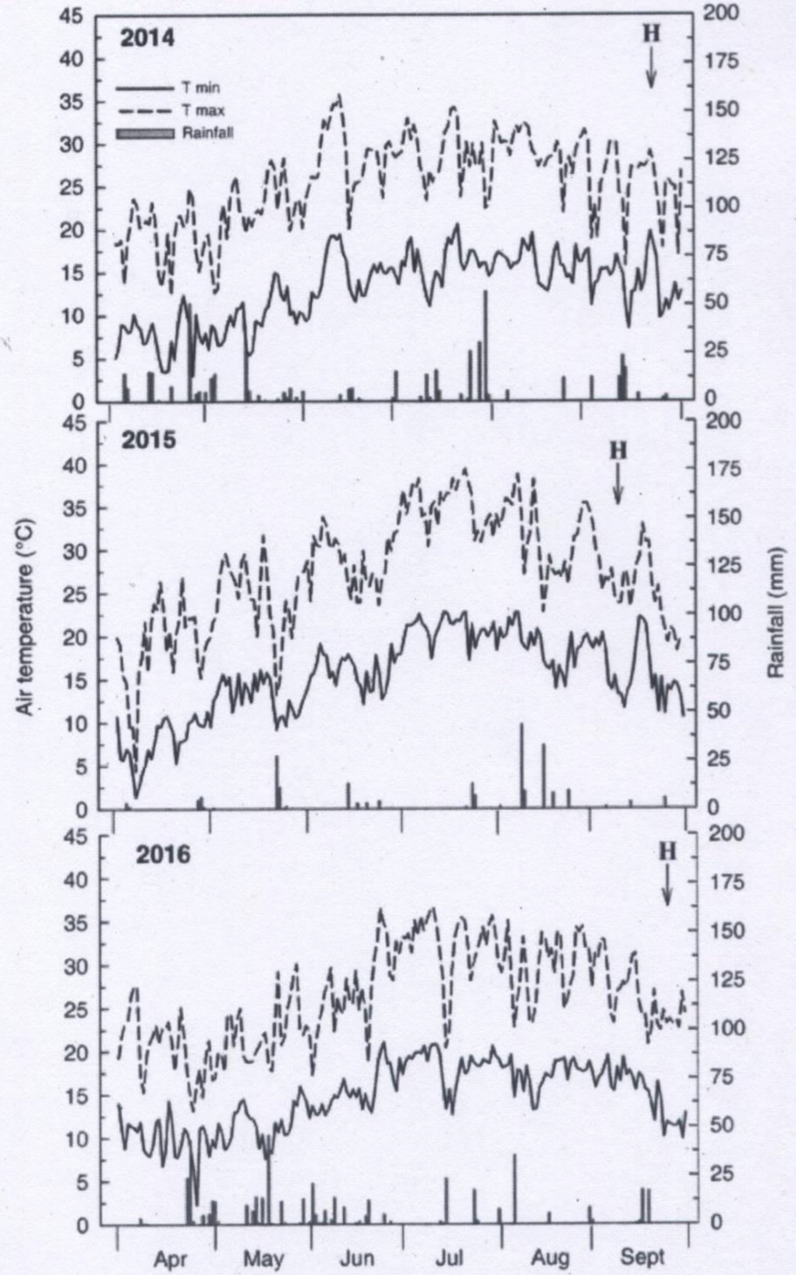


Figure 4 Seasonal trends of maximum and minimum air temperature (T) and rainfall in 2014, 2015, and 2016 seasons. H indicates harvest date.

Table 1 Phenological stage dates for spur-pruned Sangiovese vines mechanically prepruned in February and subjected to hand-finishing (HF) at different times: in February (SHF, standard HF) and after budburst, when apical shoots on canes retained during prepruning were ~10 cm long (LHF, late HF) or ~20 cm long (VLHF, very late HF). Italics indicate the dates of flowering and veraison on "delayed shoots."

Phenological stage	Treatment	Date 2014	Date 2015	Date 2016
Budburst (green shoot tips clearly visible = 50% of total buds)	SHF	20 March	18 March	23 March
	LHF	3 April (+14)	4 April (+17)	6 April (+14)
	VLHF	18 April (+29)	14 April (+27)	16 April (+24)
Flowering (50% of flowers open and caps fallen)	HF	30 May	20 May	24 May
	LHF	8 June (+9)	28 May (+8) *(12 June)*	1 June (+7) *(10 June)*
	VLHF	14 June (+15)	8 June (+19)	12 June (+19)
Veraison (50% of berries had changed color)	SHF	9 Aug	23 July	30 July
	LHF	13 Aug (+4)	27 July (+4) *(10 Aug)*	4 Aug (+5) *(8 Aug)*
	VLHF	16 Aug (+7)	31 July (+8)	9 Aug (+10)

Table 2 Crop weight and yield components at harvest in 2014, 2015, and 2016 on spur-pruned Sangiovese vines mechanically prepruned in February and subjected to hand-finishing (HF) at different times: February (SHF, standard HF) and after budburst, when apical shoots on canes retained with prepruning were ~10 cm long (LHF, late HF) or ~20 cm long (VLHF, very late HF).

	Nodes/vine pre HF (n)	Nodes/vine post HF (n)	Non sprouted nodes/vine (%)	Shoots/ vine (n)	Clusters/ shoot (n)	Yield/vine (kg)	Clusters/ vine (n)	Cluster wt (g)	Berry wt (g)	Berries/ cluster (n)
Treatment (T)										
SHF	102.8	12.1	5.3 b[a]	11.4 a	1.09 a	2.80 a	12.2 a	228 a	2.08	110 a
LHF	112.4	11.5	18.4 a	9.2 b	1.06 a	2.18 b	9.7 b	222 a	1.97	115 a
VLHF	110.0	11.8	22.1 a	9.4 b	0.79 b	1.60 c	7.5 c	197 b	2.09	93 b
Significance[b]	ns	ns	*	*	*	**	**	*	ns	*
Year (Y)										
2014	106.5	12.0	12.2	10.1	0.94	2.64 a	11.1 a	232 a	2.17 a	111
2015	107.4	11.7	16.7	9.8	0.88	1.80 c	8.1 c	215 b	1.81 b	109
2016	112.2	11.7	11.0	9.5	0.97	2.17 b	10.4 a	225 ab	2.10 a	108
Significance	ns	ns	ns	ns	ns	*	**	*	*	ns
T × Y	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

[a]Means within columns noted by different letters are different by Newman-Student-Keuls test.
[b]*, **, and ns indicate significant differences between treatments and years at $p \leq 0.05$, $p \leq 0.01$, and not significant, respectively.

Table 3 Fruit composition at harvest in 2014, 2015, and 2016 on spur-pruned Sangiovese vines mechanically prepruned in February and subjected to hand-finishing (HF) at different times: February (SHF, standard HF) and after budburst, when apical shoots on canes retained with prepruning were ~10 cm long (LHF, late HF) or ~20 cm long (VLHF, very late HF).

	Total soluble solids (Brix)	Titratable acidity (g/L)	Must pH	Total anthocyanins (mg/kg)	Total phenols (mg/kg)
Treatment (T)					
SHF	22.1 a[a]	6.66 b	3.40 a	362	2668 b
LHF	21.1 b	7.67 a	3.20 b	402	3158 a
VLHF	22.5 a	7.06 ab	3.31 ab	405	3214 a
Significance	*	*	*	ns	*
Year (Y)[b]					
2014	18.8 c	7.83 a	3.28	290 b	2970 b
2015	25.0 a	5.90 b	3.34	525 a	3266 a
2016	22.1 b	7.50 a	3.36	354 b	3348 a
Significance	**	*	ns	*	*
T × Y	*	ns	ns	ns	ns

[a]Means within columns noted by different letters are different by Newman-Student-Keuls test.
[b]*, **, and ns indicate significant differences between treatments and years at $p \leq 0.05$, $p \leq 0.01$, and not significant, respectively.

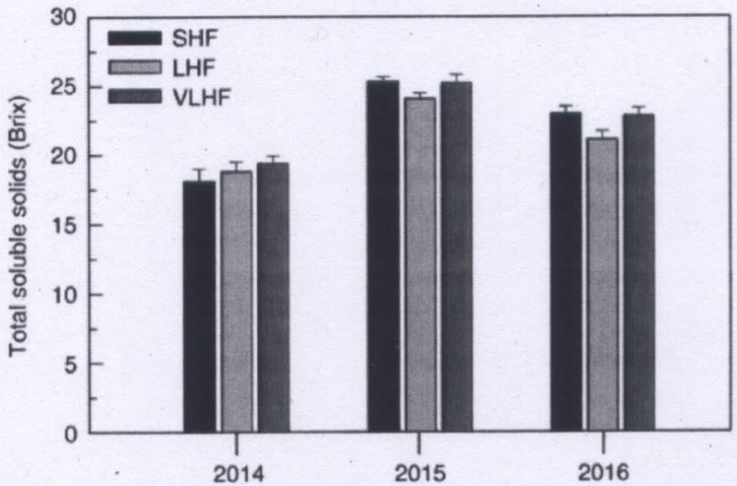


Figure 5 Interactive treatment × year effects on total soluble solids at harvest. For each treatment × year combination, vertical bar represents SE (n = 5). SHF, standard hand-finishing, LHF, late hand-finishing, VLHF, very late hand-finishing.

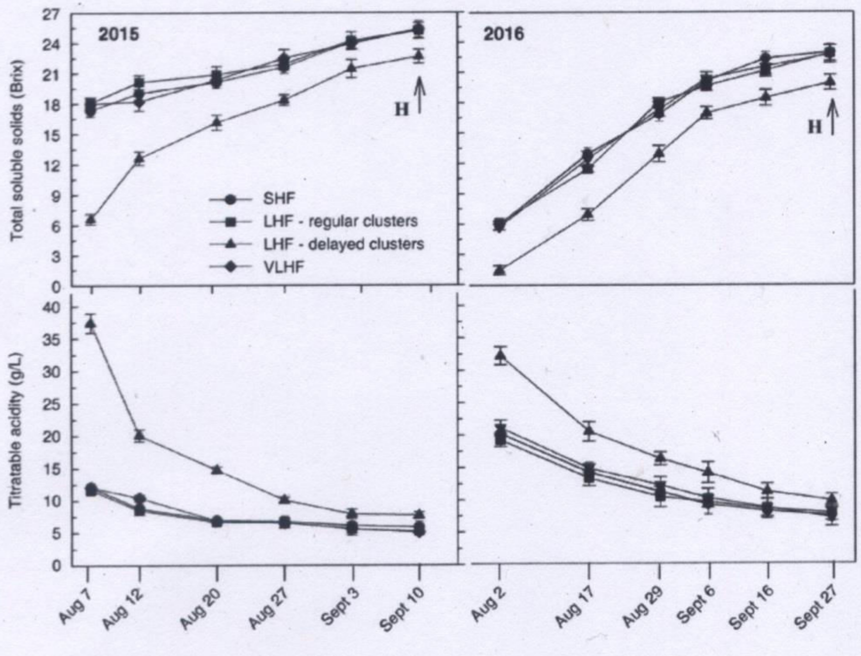


Figure 6 Seasonal changes of total soluble solids and titratable acidity in 2015 and 2016 on spur-pruned Sangiovese vines mechanically prepruned in February and subjected to hand-finishing (HF) at different times: February (SHF, standard HF) and after budburst, when apical shoots on canes retained with prepruning operation were ~10 cm long (LHF, late HF) or ~20 cm long (VLHF, very late HF). Data points are means of three replicates of 50-berry samples. Vertical bars represent SE. H indicates harvest date.

Table 4 Leaf area characteristics, winter pruning weight, and balance indices in 2014, 2015, and 2016 for spur-pruned Sangiovese vines mechanically prepruned in February and subjected to hand-finishing (HF) at different times: February (SHF, standard HF) and after budburst, when apical shoots on canes retained with prepruning were ~10 cm long (LHF, late HF) or ~20 cm long (VLHF, very late HF).

	Leaf area removed with HF (m^2/vine)	Total leaf area (m^2/vine)	Lateral leaf area (m^2/vine)	Leaf-to-fruit ratio (m^2/kg)	Pruning wt (kg/vine)	Yield/pruning wt (kg/kg)
Treatment (T)						
SHF	0	3.06[a]	0.77	1.14 b	0.60	4.60 a
LHF	0.21	2.86	0.71	1.31 b	0.54	3.98 a
VLHF	0.43	2.88	0.75	1.78 a	0.55	2.90 b
Significance[b]	*	ns	ns	*	ns	*
Year (Y)						
2014	0.21	3.08 a	0.74	1.23 b	0.60 a	4.41 a
2015	0.17	2.50 b	0.68	1.46 a	0.49 b	3.48 b
2016	0.22	3.14 a	0.79	1.54 a	0.58 a	3.59 b
Significance	ns	*	ns	*	*	ns
T × Y	ns	ns	ns	ns	ns	ns

[a]Means within columns noted by different letters are different by Newman-Student-Keuls test.
[b]* and ns indicate significant differences between treatments and years at $p \leq 0.05$ and not significant, respectively.

Table 5 Cane and root reserves and total nitrogen at the end of January 2015 and 2016 on spur-pruned Sangiovese vines mechanically prepruned in February 2014 and subjected to hand-finishing (HF) at different times: February (SHF, standard HF) and after budburst, when apical shoots on canes retained with prepruning were ~10 cm long (LHF, late HF) or ~20 cm long (VLHF, very late HF). DW, dry weight.

	Cane wood			Roots		
	Soluble sugars (mg/g DW)	Starch (mg/g DW)	Total nitrogen (% DW)	Soluble sugars (mg/g DW)	Starch (mg/g DW)	Total nitrogen (% DW)
Treatment (T)						
SHF	93.8	97.4	0.46	80.8	134.4	0.76
LHF	99.0	108.4	0.43	86.6	129.3	0.77
VLHF	94.4	96.0	0.50	79.8	125.3	0.80
Significance[a]	ns	ns	ns	ns	ns	ns
Year (Y)						
2015	94.2	99.2	0.48	82.2	132.0	0.78
2016	95.7	105.9	0.45	90.1	127.9	0.81
Significance	ns	ns	ns	ns	ns	ns
T × Y	ns	ns	ns	ns	ns	ns

[a]ns indicates nonsignificant differences between treatments at $p \leq 0.05$.

Table 6 Wine composition in 2015 in spur-pruned Sangiovese vines mechanically prepruned in February 2014 and 2015 and subjected to hand-finishing (HF) at different times: February (SHF, standard HF) and after budburst, when apical shoots on canes retained with prepruning were ~10 cm long (LHF, late HF). Grape batches from very late HF could not be vinified due to too-low yield per vine.

Parameters	SHF	LHF	Signif.[a]
Alcohol (% vol.)	14.6	13.9	*
Total acidity (g/L)	6.5	6.6	ns
pH	3.39	3.44	ns
Total dry extract (g/L)	23.5	22.7	ns
Anthocyanins (g/L)	0.278	0.258	ns
Total phenols (g/L)	1.49	1.75	*
Color intensity ($OD_{420nm} + OD_{520nm}$)	8.6	8.2	ns
Color hue (OD_{420nm}/OD_{520nm})	0.54	0.60	ns

[a] *, ns indicate significant differences between treatments at $p \leq 0.05$ or not significant, respectively.

Ritardo della maturazione

- Meno zuccheri
- Migliori metaboliti secondari

Rispondere al cambio climatico adattando e modificando le varietà:

Tradizione vs. innovazione

Antinomia?

la viticoltura oggi nella UE

- La viticoltura è un'attività agricola tra le più impattanti sull'ambiente
- in Europa occupa il 3 % della superfice agricola e impiega il 65% di tutti i fungicidi usati in agricoltura (68.000 t/anno) (EURTOSTAT 2007)
- La vite è una delle poche specie su cui il miglioramento genetico ha potuto operare in maniera limitata

Le tappe del progetto di Udine

1998	raccolta di materiali e avvio incroci c/o l'azienda agraria sperimentale «A. Servadei»
2002	avvio degli studi di genetica sulle resistenze (mappe genetiche, selezione assistita …)
2005	avvio dell'attività di selezione agronomica
2006	costituzione dell'IGA sequenziamento del genoma della vite
2007	inizio delle nano-vinificazioni e valutazione dei vini
2011	completamento del 1° ciclo di selezione e valutazione delle prime selezioni in campi dimostrativi
2013	presentazione dei dossier al MiPAAF per la registrazione di 10 varietà (5 a bacca bianca e 5 a bacca rossa)
2015	registrazione delle 10 varietà in Europa (CPVO) e in Italia

L’attività e i numeri del progetto

800+ accessioni di vite introdotte in collezione
406 combinazioni di incrocio
24.000+ piante ottenute per incrocio in valutazione
400+ nano- e micro-vinificazioni c/o UIV e VCR
10 nuove varietà selezionate per la resistenza a malattie, caratteristiche agronomiche e qualità dei vini




l'incrocio e l'allevamento dei semenzali

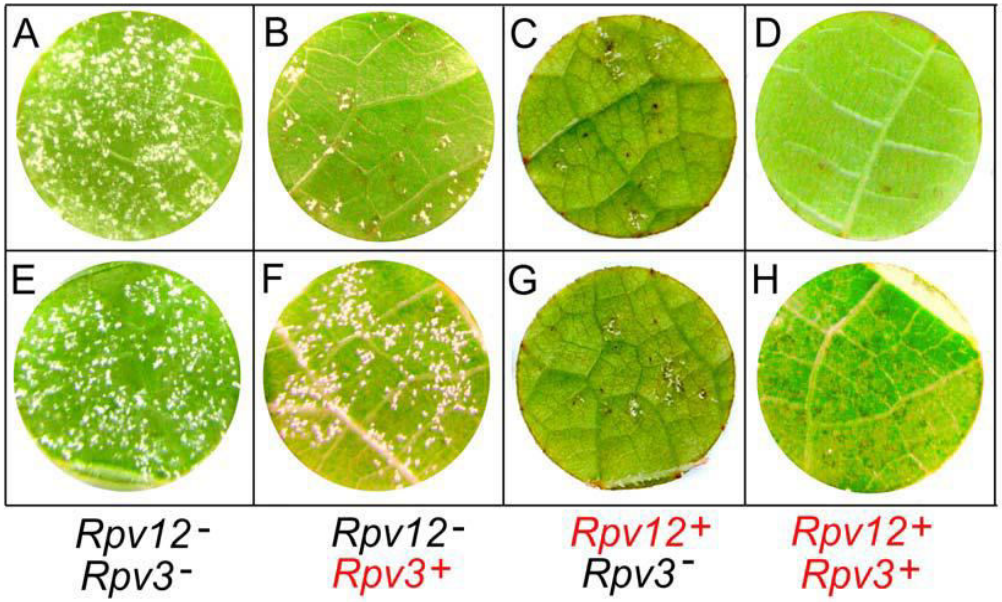
la selezione per la resistenza

Zarja severa
(Rpv12)
↓
20-3

Villard blanc
(Rpv13)
↓
Bianca, Regent

Severnyi
(Rpv10)
↓
Bronner, Solaris

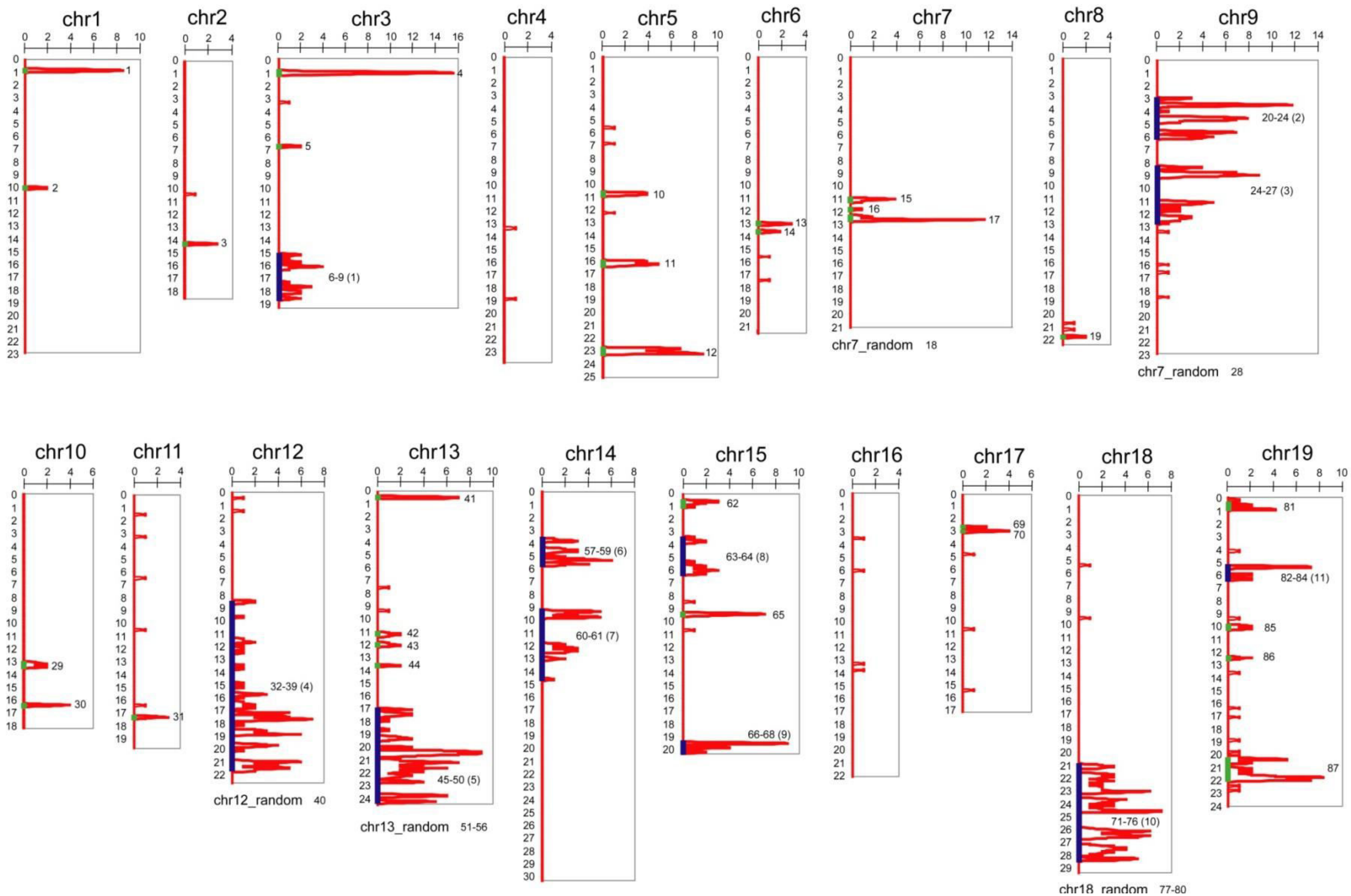
perché combinare resistenze



ceppo rude
avrRpv3+/avrRpv12+

ceppo 127
avrRpv3-/avrRpv12+

Il genoma della vite ha più di 500 geni di resistenza, ma *V. vinifera* non è resistente a peronospora e oidio



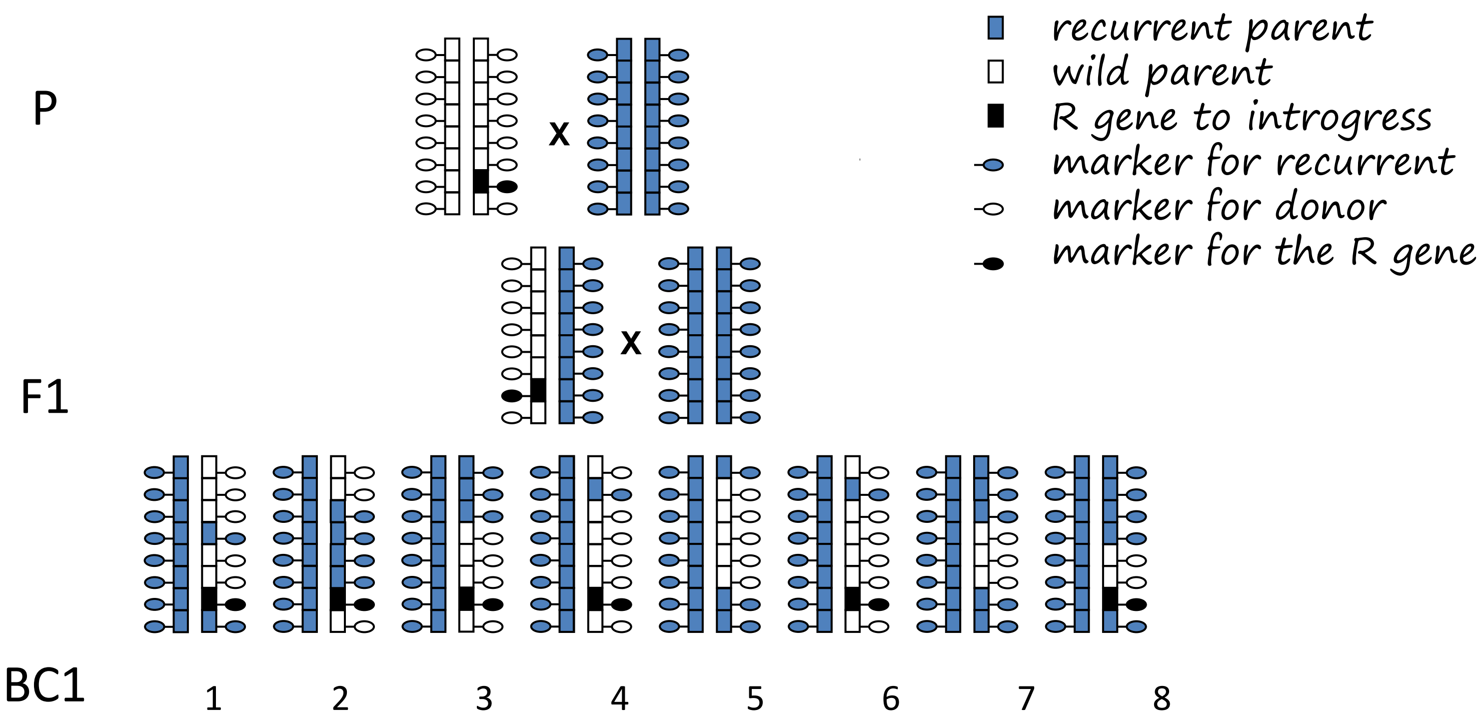
3. the resistance to downy & powdery mildew

Pathogen	Gene	Chromosome	Source	Reference
Plasmopara	*Rpv1*	*12*	*M. rotundifolia*	Blanc *et al* 2012
	Rpv2	*18*	*M. rotundifolia*	Blanc *et al* 2012
	Rpv3	*18*	*V. rupestris*	Di Gaspero *et al* 2011
	Rpv8	*14*	*V. amurensis*	Blasi *et al* 2011
	Rpv10	*9*	*V. amurensis*	Schwander *et al* 2011
	Rpv12	*14*	*V. amurensis*	Venuti *et al* 2013
Oidium	*Run1*	*12*	*M. rotundifolia*	Pauquet *et al* 2001
	Run2	*18*	*M. rotundifolia*	Riaz *et al* 2011
	Ren1	***13***	***V. vinifera***	**Coleman *et al* 2011**
	Ren4	*18*	*V. romanetii*	Mahanil *et al* 2011
	Ren5	*14*	*M. rotundifolia*	Blanc *et al* 2012

most disease-resistance genes come from wild American and Asian species, but the *Ren1* gene, that confers resistance to powdery mildew, has been found in *V. vinifera* cv Kishmish vatkana. Resistance to downy mildew was also found in a *vinifera* variety Mgaloblishvili from Georgia (Caucasus).

2. the presence of DNA from non-vinifera species

- at each backcross to *V. vinifera*, part of the *non-vinifera* genome can be lost
- but … the percentage is unpredictable



in the first back-cross generation (BC1) the chromosome inherited from F1 by the 8 individuals contains a variable percentage of the original wild parent (from 7/8 of individual 4 to 3/8 of the individual 8)

la scelta dei parentali

suscettibili (S)
Chardonnay
Cabernet S.
Merlot
Sauvignon
Sangiovese
Tocai friulano
...

resistenti (R)
Bianca
20/3
Regent
Seyval
Pannonia
SK-00-1/2
...

la selezione per i caratteri agronomici

vigoria
(media)

produttività
(media)

grappolo
(tendenzialmente spargolo)

dall’archivio del progetto

la selezione per i caratteri enologici

463 nano-vinificazioni fatte fino al 2010 c/o UIV e poi c/o VCR

microvinificazioni

analisi HPLC & GC-MS

assaggi di esperti

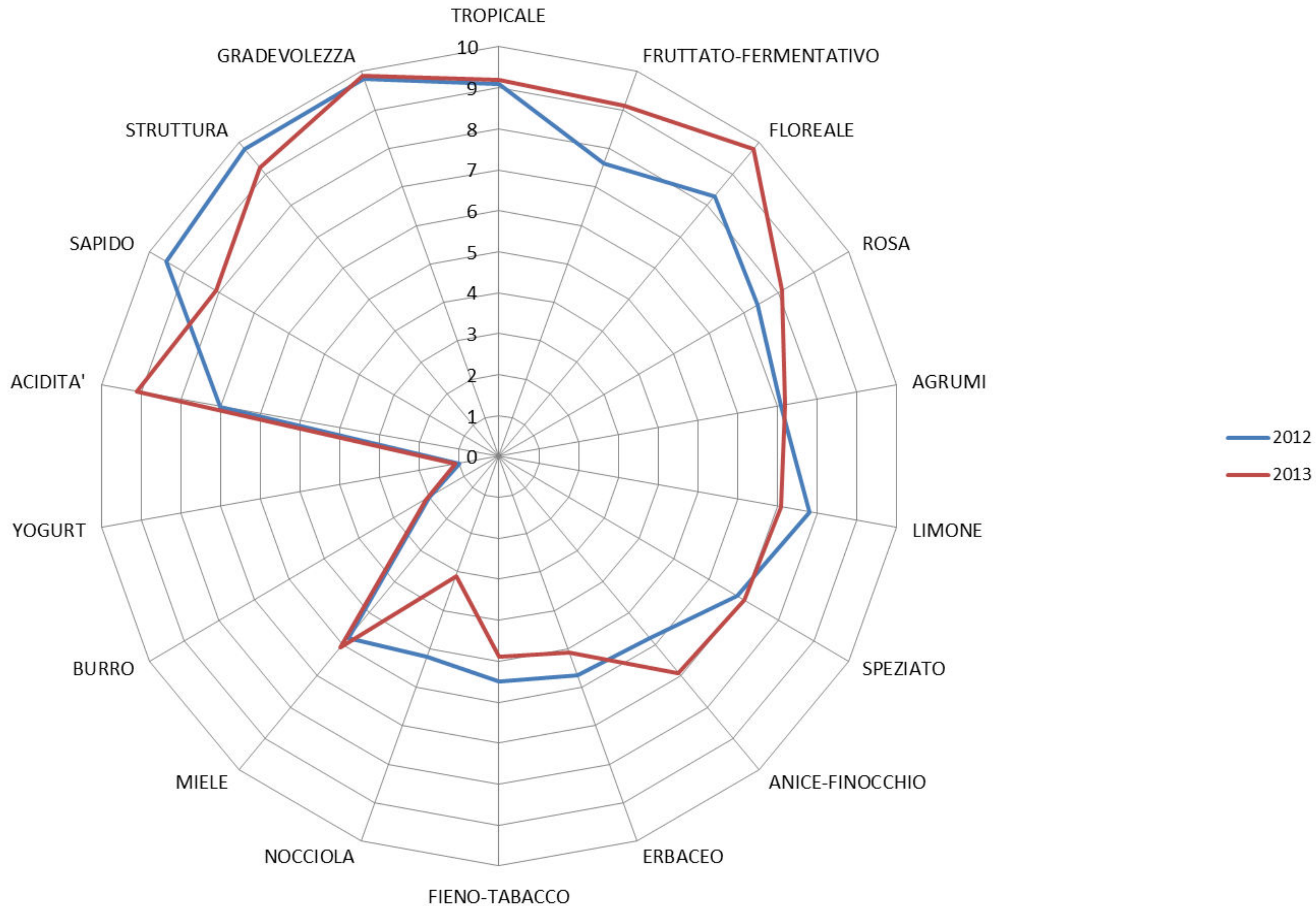
SAUVIGNON RYTOS

Sauvignon x Bianca

55.100

VENDEMMIA	ACIDITA' gr/lt	ESTRATTO SECCO gr/lt	ALCOOL %
2012	6,28	22,9	14
2013	6,05	19,6	14
2014	5,2	18,1	12,2

SAUVIGNON RYTOS

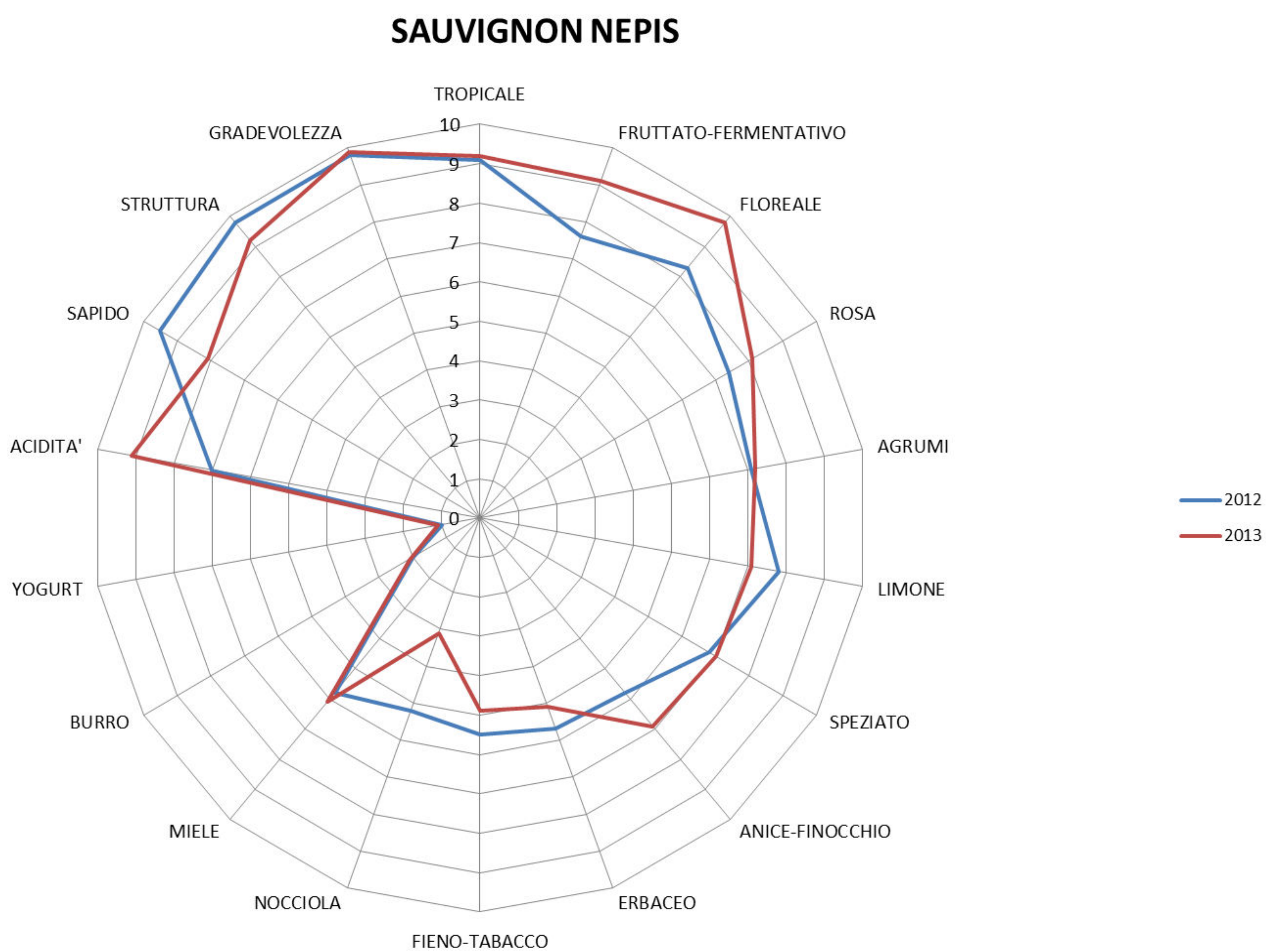


SAUVIGNON NEPIS

Sauvignon x Bianca

55.098

VENDEMMIA	ACIDITA' TOT. gr/lt	ESTRATTO SECCO gr/lt	ALCOOL %
2012	6,13	18,1	11,9
2013	5,62	19,3	13,5
2014	6,6	21,1	12,4


SAUVIGNON NEPIS
TROPICALE
FRUTTATO-FERMENTATIVO
FLOREALE
ROSA
AGRUMI
LIMONE
SPEZIATO
ANICE-FINOCCHIO
ERBACEO
FIENO-TABACCO
NOCCIOLA
MIELE
BURRO
YOGURT
ACIDITA'
SAPIDO
STRUTTURA
GRADEVOLEZZA
10
9
8
7
6
5
4
3
2
1
0
2012
2013

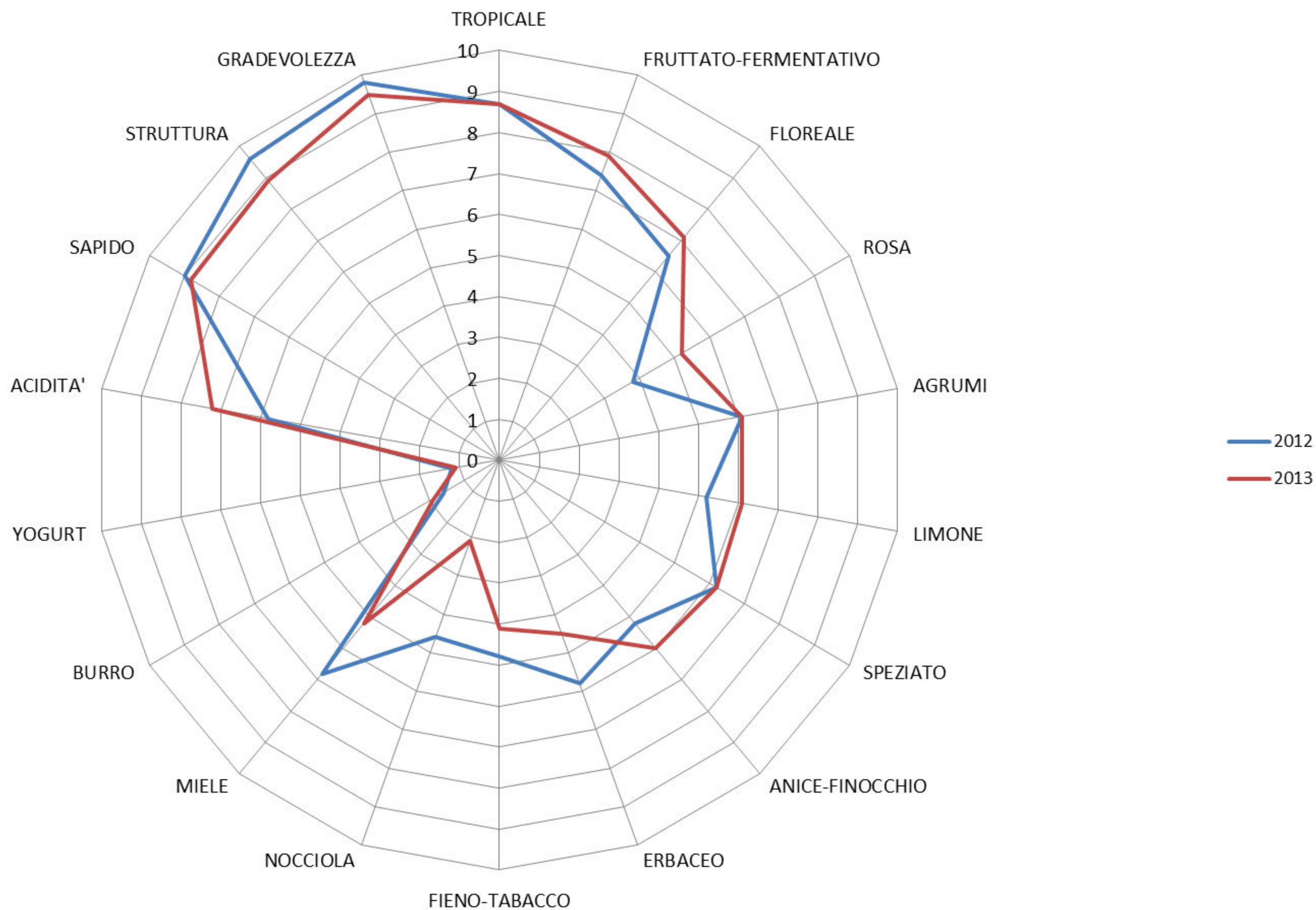
SAUVIGNON KRETOS

Sauvignon x 20-3

76.026

VENDEMMIA	ACIDITA' TOT. gr/lt	ESTRATTO SECCO gr/lt	ALCOOL %
2012	5,66	22,5	14,2
2013	5,66	17,5	13,8
2014	6,6	19,5	12,3

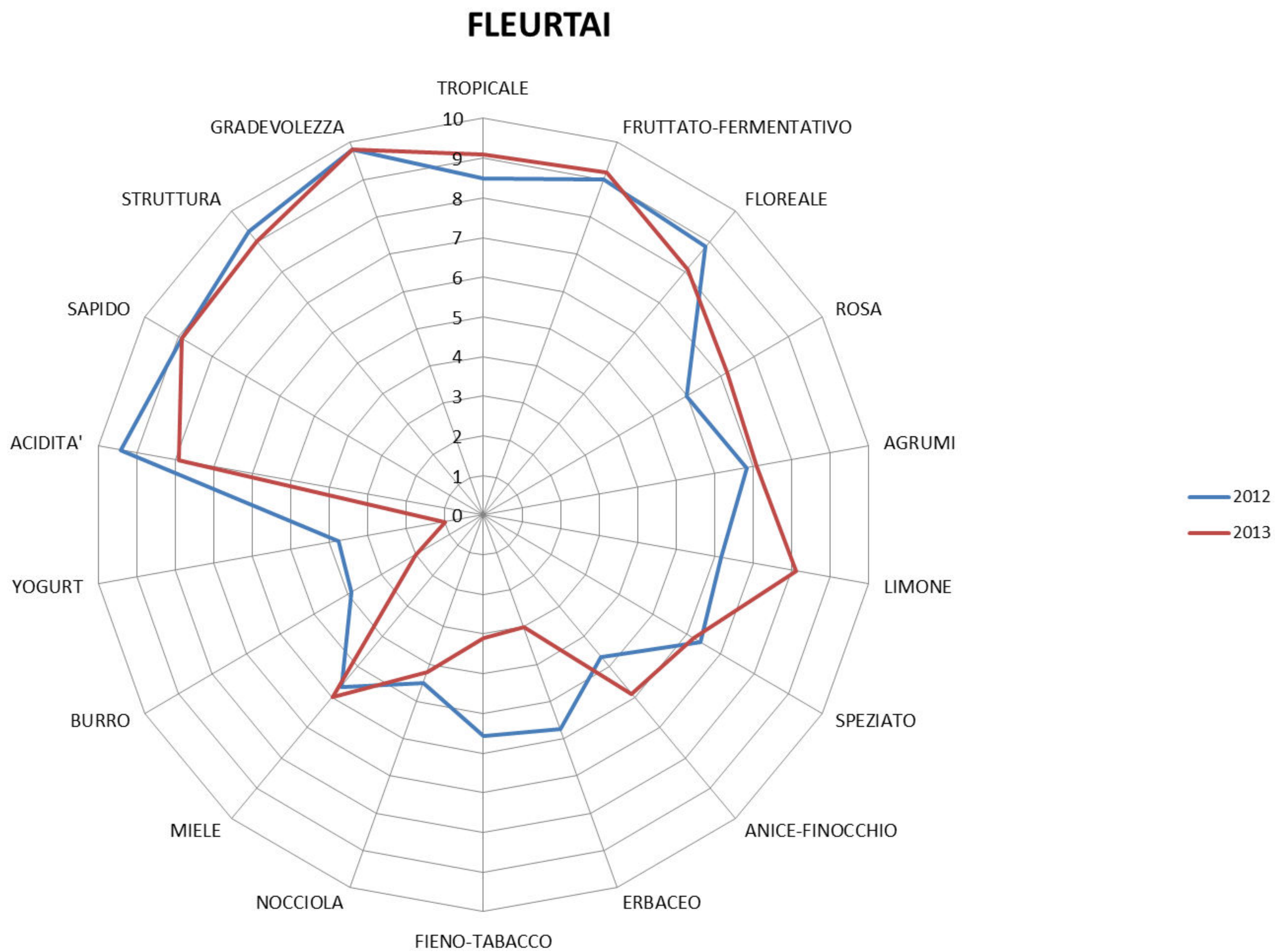
SAUVIGNON KRETOS



FLEURTAI

Tocai Friulano x 20-3 (34.111)

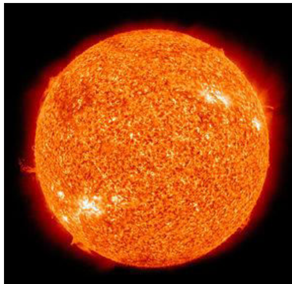
VENDEMMIA	ACIDITA' TOT. gr/lt	ESTRATTO SECCO gr/lt	ALCOOL %
2012	5,6	20,9	14,1
2013	5,6	18,5	13,9
2014	5,8	18,4	12,3


FLEURTAI
TROPICALE
FRUTTATO-FERMENTATIVO
FLOREALE
ROSA
AGRUMI
LIMONE
SPEZIATO
ANICE-FINOCCHIO
ERBACEO
FIENO-TABACCO
NOCCIOLA
MIELE
BURRO
YOGURT
ACIDITA'
SAPIDO
STRUTTURA
GRADEVOLEZZA
10
9
8
7
6
5
4
3
2
1
0
2012
2013

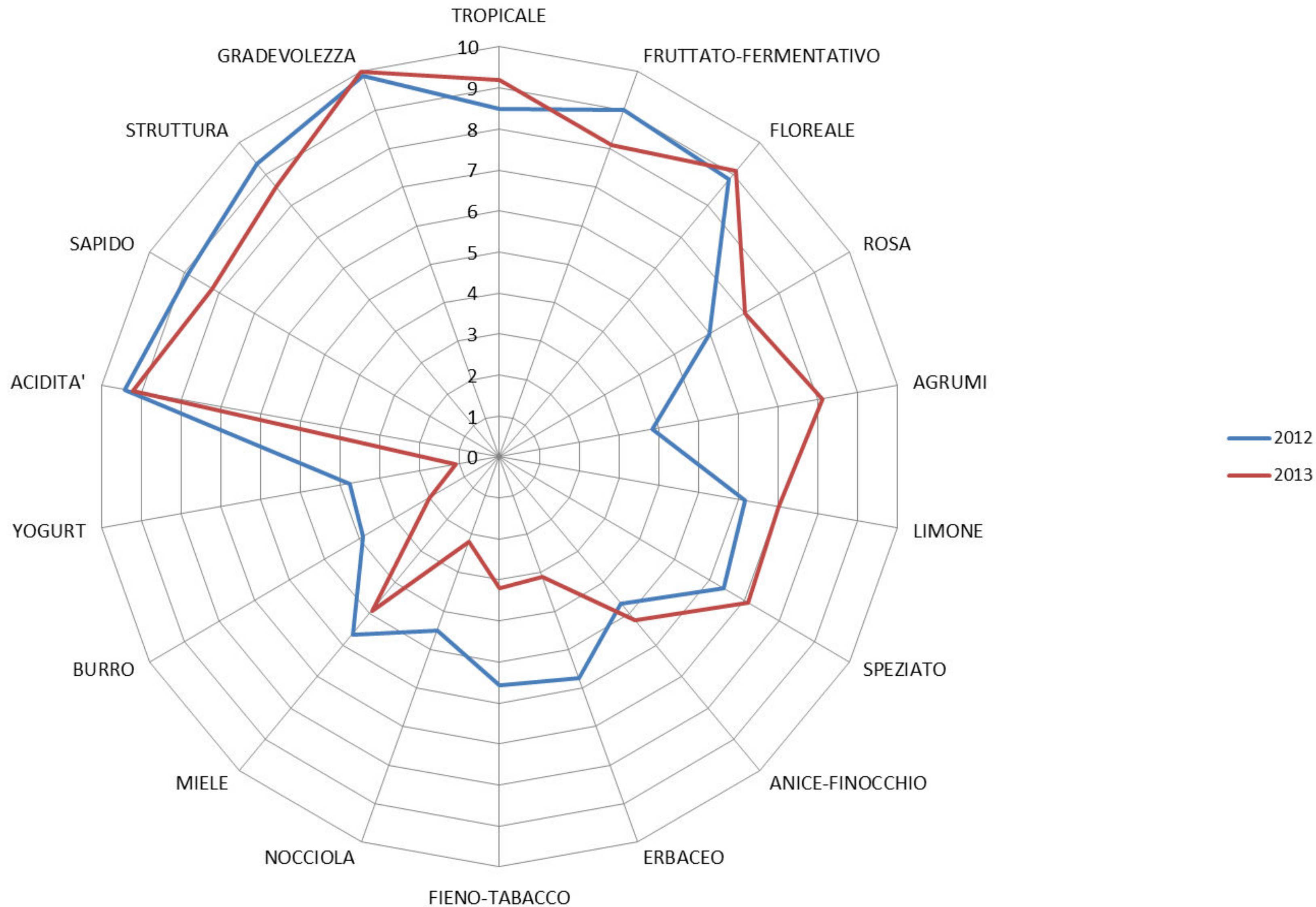
SORELI

Tocai Friulano x 20-3 (34.113)

VENDEMMIA	ACIDITA' TOT. gr/lt	ESTRATTO SECCO gr/lt	ALCOOL %
2012	5,67	19,9	13,1
2013	5,61	18,7	13,6
2014	5,5	18,2	12,3



SORELI



TROPICALE
FRUTTATO-FERMENTATIVO
FLOREALE
ROSA
AGRUMI
LIMONE
SPEZIATO
ANICE-FINOCCHIO
ERBACEO
FIENO-TABACCO
NOCCIOLA
MIELE
BURRO
YOGURT
ACIDITA'
SAPIDO
STRUTTURA
GRADEVOLEZZA
10
9
8
7
6
5
4
3
2
1
0
2012
2013

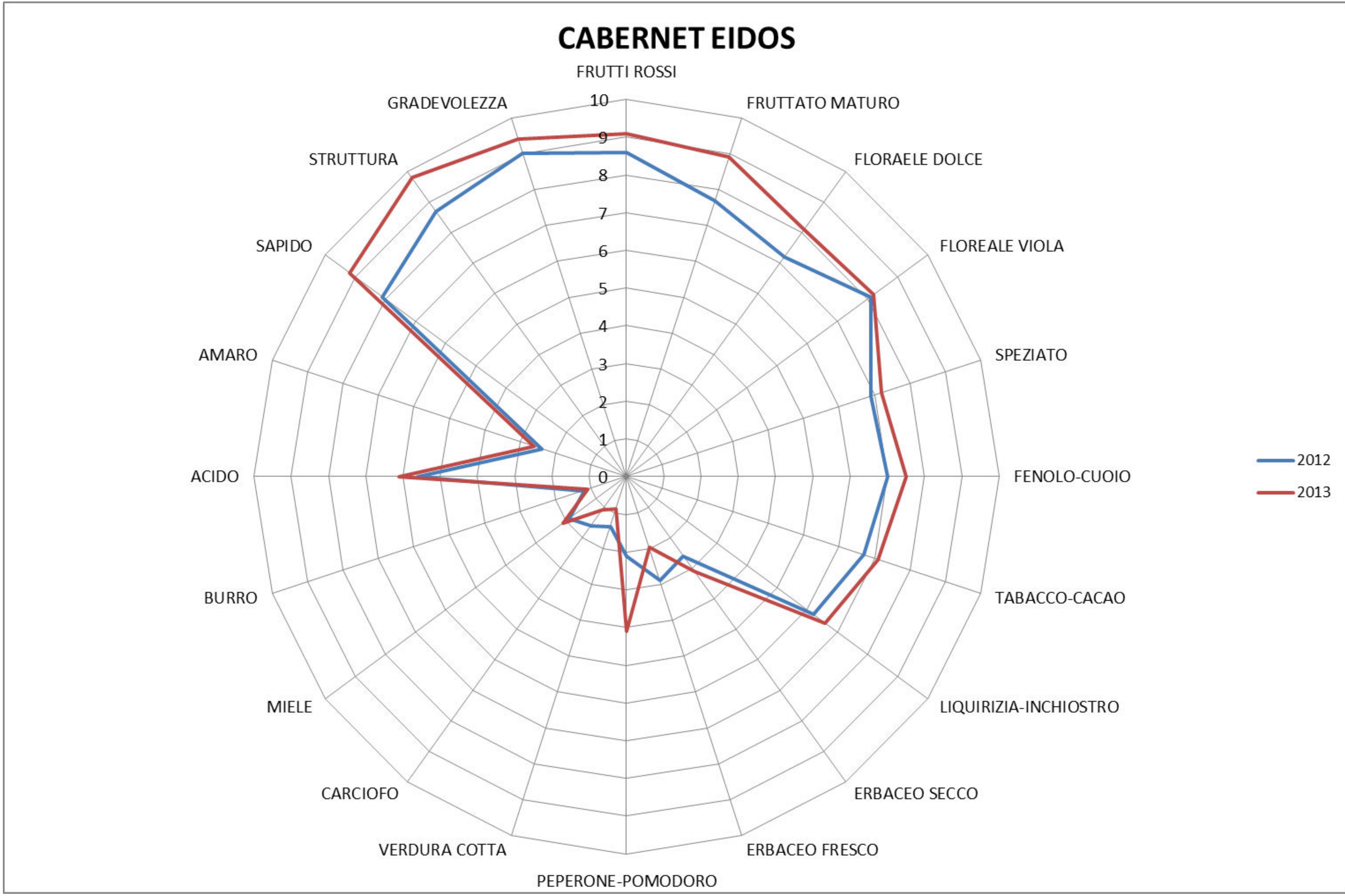
QUADRO RIASSUNTIVO DELLE CARATTERISTICHE RELATIVE AI COMPOSTI AROMATICI DEI VINI BIANCHI

PARAMETRO			TOCAI X 20-3		SAUVIGNON X 20-3	SAUVIGNON X BIANCA	
			FLUERTAI 34-111	SORELI 34-113	SAUV. KRETOS 76-026	SAUV. NEPIS 55-098	SAUV. RYTOS 55-100
LIBERI	**Intensità aromatica** per vini giovani (contenuto totale dei composti volatili liberi)		+	-	+	+	++
	Ampiezza (contenuto in linalolo e geraniolo)		-	-	-	++	+
GLICOSIDATI	**Intensità aromatica** per vini affinati (contenuto totale dei composti volatili glicosidati)		+	-	+	++	+
	Ampiezza (n° composti positivi delle famiglie di odori)	**Floreale**	-	-	-	++	++
		Fruttato	+	-	++	+	-
		Speziato	+	-	+	+	-

++ valori sopra la media, **+** valori medi, **-** valori sotto la media

CABERNET EIDOS
Cabernet SauvignonxBianca
(58.083)

VENDEMMIA	ACIDITA' TOT. gr/lt	ESTRATTO SEC. gr/lt	ALCOOL %	ANTOCIANI mg/lt	POLIFEN. mg/lt
2012	5,4	28,3	12,4	800	3030
2013	5,5	32,4	13,4	1031	3691
2014	5,0	25,9	12,7	599	2209

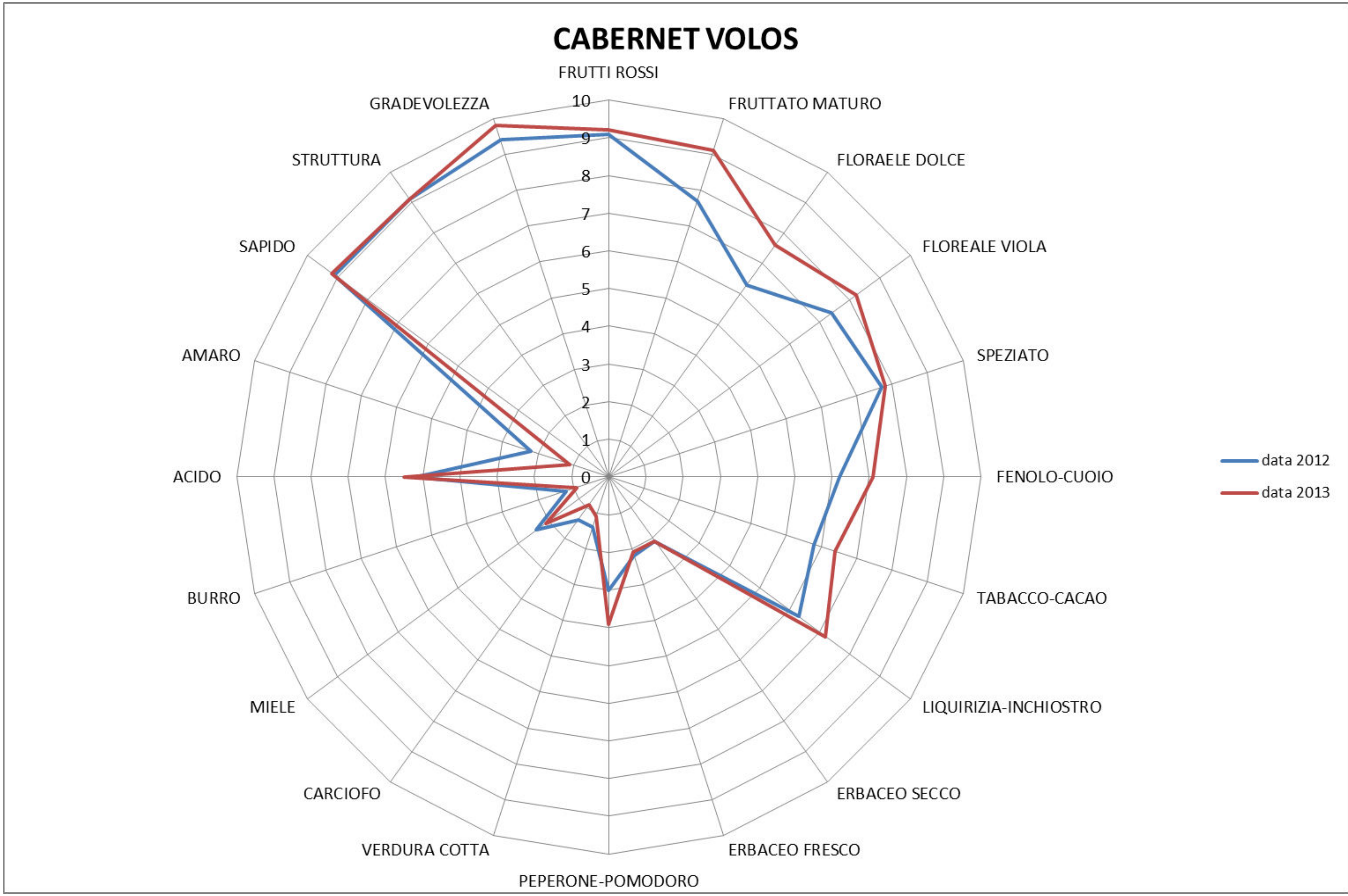


- da consumo giovane

CABERNET VOLOS

Cabernet Sauvignonx20-3 (32.078)

VENDEMMIA	ACIDITA' TOT. gr/lt	ESTRATTO SEC. gr/lt	ALCOOL %	ANTOCIANI mg/lt	POLIFEN. mg/lt
2012	5,5	32,2	13,9	1267	4300
2013	5,5	31,6	12,9	1213	3751
2014	5,2	30,3	12,8	648	2497

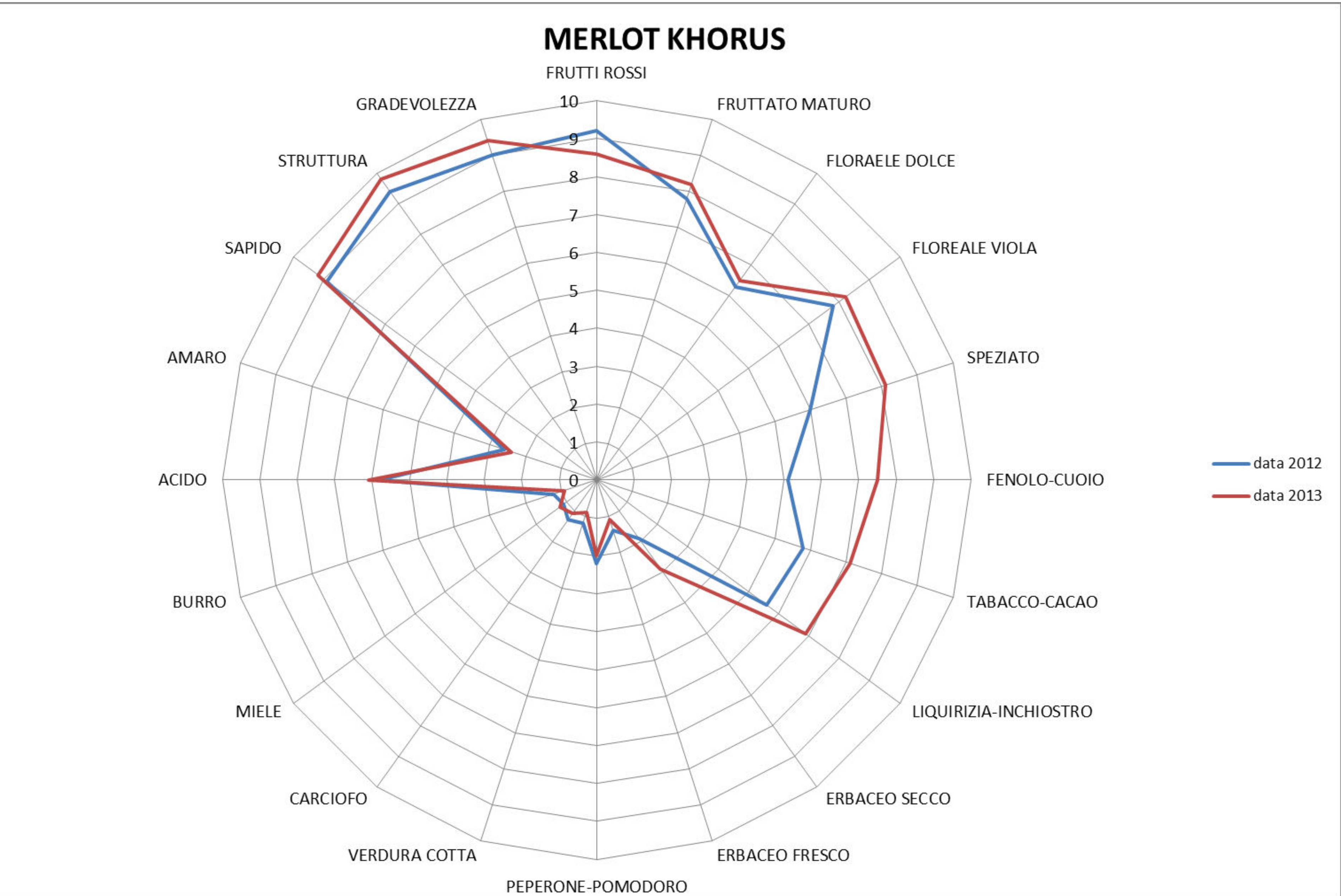


- da invecchiamento

MERLOT KHORUS

Merlot x 20-3 (31.125)

VENDEMMIA	ACIDITA' TOT. gr/lt	ESTRATTO SEC. gr/lt	ALCOOL %	ANTOCIANI mg/lt	POLIFEN. mg/lt
2012	5,2	38,6	14,2	1080	3650
2013	5,4	35,7	14,0	958	4203
2014	5,2	34,7	13,3	879	3131

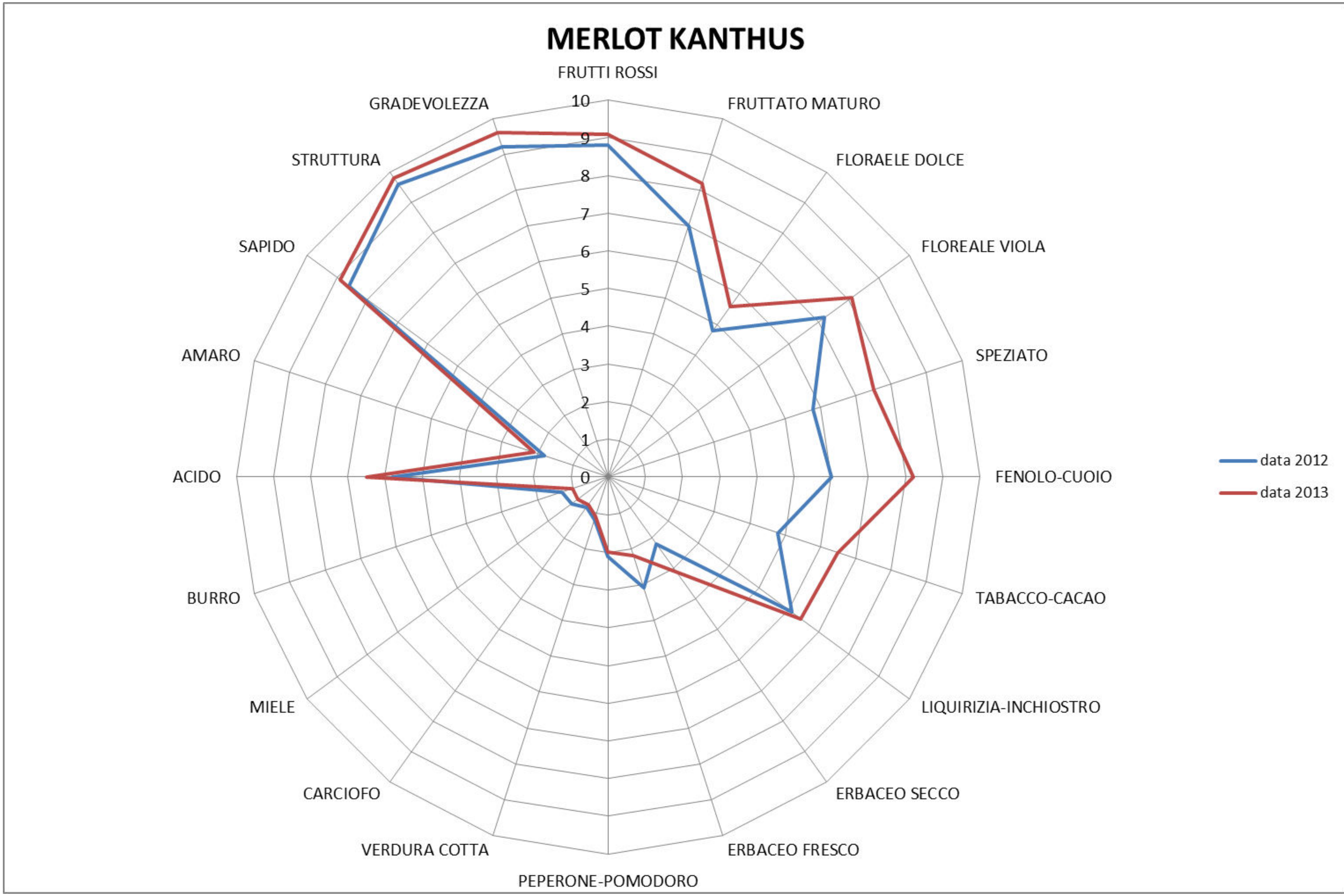


- da invecchiamento (barrique)

MERLOT KANTHUS

Merlot x 20-3 (31.122)

VENDEMMIA	ACIDITA' TOT. gr/lt	ESTRATTO SEC. gr/lt	ALCOOL %	ANTOCIANI mg/lt	POLIFEN. mg/lt
2012	5,5	28,9	12,1	830	3970
2013	5,4	31,1	13,9	1133	3476
2014	5,2	27,1	12,9	656	2226

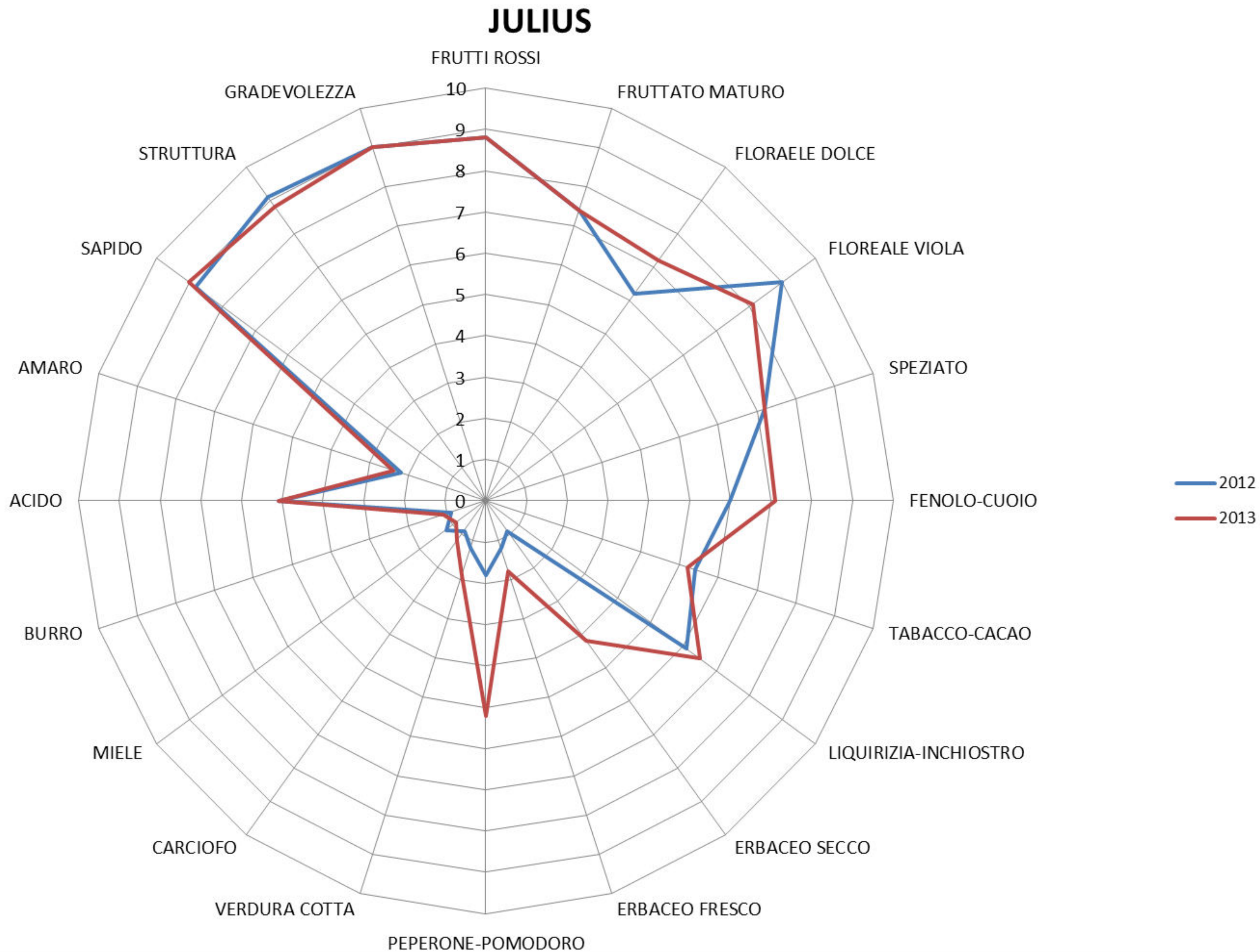


- da invecchiamento

JULIUS

Regent x 20-3 (36.030)

VENDEMMIA	ACIDITA' TOT. gr/lt	ESTRATTO SEC. gr/lt	ALCOOL %	ANTOCIANI mg/lt	POLIFEN. mg/lt
2012	5,5	31,2	13,5	720	3900
2013	5,5	31,7	13,3	927	3231
2014	5,2	30,7	13,2	689	2708



- da invecchiamento

QUADRO RIASSUNTIVO DELLE CARATTERISTICHE RELATIVE AI COMPOSTI AROMATICI DEI VINI ROSSI

PARAMETRO			CABERNET SAUVIGNON X BIANCA		MERLOT X 20-3		REGENT X 20-3
			CAB. EIDOS 58-083	CAB. VOLOS 32-078	MERLOT KHORUS 31-125	MERLOT KANTHUS 31-122	JULIUS 36-030
LIBERI	**Intensità aromatica** per vini giovani (contenuto totale dei composti volatili liberi)		+	++	++	+	-
LIBERI	**Ampiezza** (contenuto in linalolo e geraniolo)		+	-	+	-	++
GLICOSIDATI	**Intensità aromatica** per vini affinati (contenuto totale dei composti volatili glicosidati)		+	+	++	-	++
GLICOSIDATI	**Ampiezza** (n° composti positivi delle famiglie di odori)	**Floreale**	+	-	+	-	++
GLICOSIDATI	**Ampiezza** (n° composti positivi delle famiglie di odori)	**Fruttato**	-	+	+	-	++
GLICOSIDATI	**Ampiezza** (n° composti positivi delle famiglie di odori)	**Speziato**	+	+	++	-	+

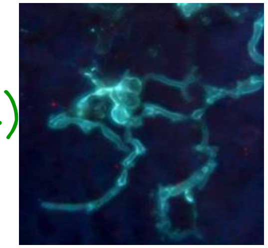
++ valori sopra la media, **+** valori medi, **-** valori sotto la media

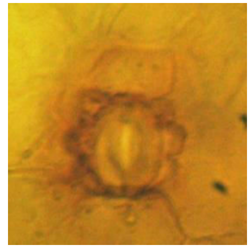
QUADRO RIASSUNTIVO DELLE CARATTERISTICHE RELATIVE AI PARAMETRI POLIFENOLICI DEI CINQUE VINI ROSSI

PARAMETRO	CABERNET SAUVIGNON X BIANCA		MERLOT X 20-3		REGENT X 20-3
	CAB. EIDOS 58-083	CAB. VOLOS 32-078	MERLOT KHORUS 31-125	MERLOT KANTHUS 31-122	JULIUS 36-030
Contenuto Polifenolico (Polifenoli e Flavonoidi totali, Flavonoidi non antocianici)	+	++	++	++	+
Intensità colorante	++	++	++	++	-
Tonalità	++	+	+	++	-
Antociani (totali e monomeri)	++	++	++	+	+
Stabilità del colore (dTAT%)	++	++	+	++	-
Tannini astringenti (Flavani reattivi alla vanillina)	-	++	+	++	+

++ valori sopra la media, **+** valori medi, **-** valori sotto la media

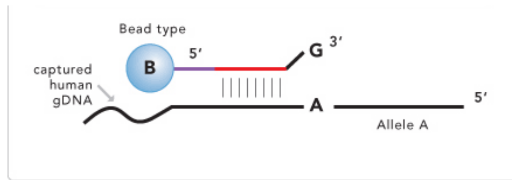
sviluppi futuri

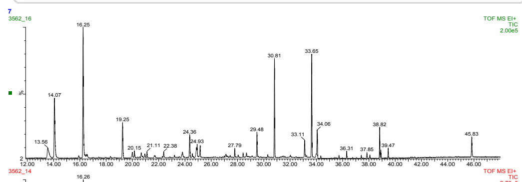




combinare resistenze
- 3 resistenze a peronospora (rpv3, rpv10, rpv12)
- 2 resistenze a oidio (ren1, run1)
- altre resistenze

differenziare il prodotto
- base spumante
- vini da invecchiamento
- vini da dessert
- uve da tavola
- ...

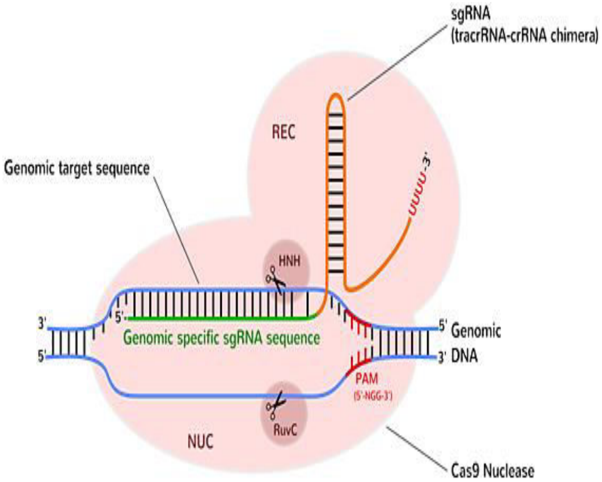




nuovi strumenti per la selezione
- selezione assistita dalla sequenza del genoma
- analisi dei profili metabolici dei mosti

LE VIE PER RENDERE LE VITI RESISTENTI AI PATOGENI

selezione di mutanti naturali
incrocio e selezione
cis-genesi (viti GM)
genome editing



- l'incrocio crea nuovi tipi (ricombinanti) mai visti prima
- «cis-genesi» e «genome editing» modificano varietà esistenti

nuovi strumenti di selezione

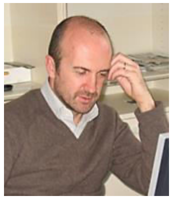
selezione assistita da informazioni sul genoma

- MAS Marker-assisted selection
- Selezione per blocchi aplotipici
- GWEBV genome-wide estimate of breeding value

selezione basata sull'analisi dei profili metabolici

- es. profili aromatici del mosto al GC-MS

hanno collaborato al progetto

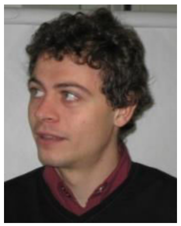
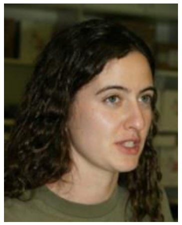


Michele Enrico Raffaele



Guido Gabriele Simone



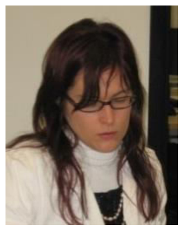





Diana Elisa Luigi Courtney Dario Serena Renato Giorgio






Paolo Barbara Orietta Silvia Moreno .... Michela

Francesco

Collaborazioni con Istituzioni

- Institute of Viticulture, Pécs, Hungary
- Missouri State University, USA
- INRA, Colmar, France
- Université de Strasbourg, France
- Genoscope, Paris, France
- Institut für Rebenzüchtung, Geilweilerhof, Germany
- Hochschule Geisenheim University, Germany
- UIV, Unione Italiana Vini, Verona, Italy
- Università di Verona, Italy
- CRA Istituto di Viticoltura, Conegliano, Italy
- University of Novi Sad, Serbia

Sostenitori

- Università di Udine / Azienda agraria «A. Servadei»
- Regione Friuli Venezia Giulia
- MiPAF Progetti Vigna & Vigneto
- MiUR progetti nazionali PRIN
- Vivai Cooperativi di Rauscedo
- Banche di Credito Cooperativo del FVG
- Fondazioni bancarie CRUP, CRT, CARIGO
- Consorzio Collio
- Vignaioli: Felluga L, Felluga M, Zamò, Venica & Venica

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le resistenze note e disponibili

Patogeno	Gene	Cromosoma	Fonte	Riferimento
peronospora	*Rpv1*	*12*	*M. rotundifolia*	Blanc *et al* 2012
	Rpv2	*18*	*M. rotundifolia*	Blanc *et al* 2012
	Rpv3	*18*	*V. rupestris* (a)	Di Gaspero *et al* 2011
	Rpv8	*14*	*V. amurensis*	Blasi *et al* 2011
	Rpv10	*9*	*V. amurensis*	Schwander *et al* 2011
	Rpv12	*14*	*V. amurensis*	Venuti *et al* 2013
oidio	*Run1*	*12*	*M. rotundifolia*	Pauquet *et al* 2001
	Run2	*18*	*M. rotundifolia*	Riaz *et al* 2011
	Ren1	*13*	*V. vinifera*	Coleman *et al* 2011
	Ren4	*18*	*V. romanetii*	Mahanil *et al* 2011
	Ren5	*14*	*M. rotundifolia*	Blanc *et al* 2012

(a) Rpv3 è una regione del cromosoma 18 non ancora risolta. Contiene un cluster di geni di resistenza che possono avere avuto origine anche da specie diverse da *V. rupestris*, come *V. riparia*, *V. lincecumii* e *V. labrusca*.