INP TOULOUSE PURPAN ÉCOLE D'INGÉNIEURS
Sciences du vivant | Agriculture Agroalimentaire | Marketing | Management

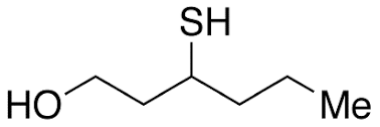
Olivier GEFFROY
Associate professor in viticulture & enology
olivier.geffroy@purpan.fr

Rotundone in red wines

An overview of the impact of plant material, environmental factors and viticultural techniques

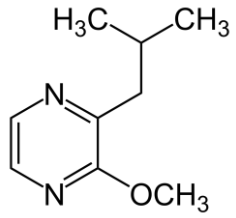
A few introductive words on wine aroma

- More than 800 volatile compounds
- About 10% of them have a sensory impact
- Odorants belong to several chemical families
- Concentration levels from ng/L to hundreds of mg/L
- If the varietal aroma of white wines is quite easy to apprehend (monoterpenols, varietal thiols…)
- Those of red wine remained more mysterious or limited to undesirable molecule such as IBMP….
- Until the discovery of rotundone in 2008 !



Varietal thiol

Ex. 3-sulfanylhexanol

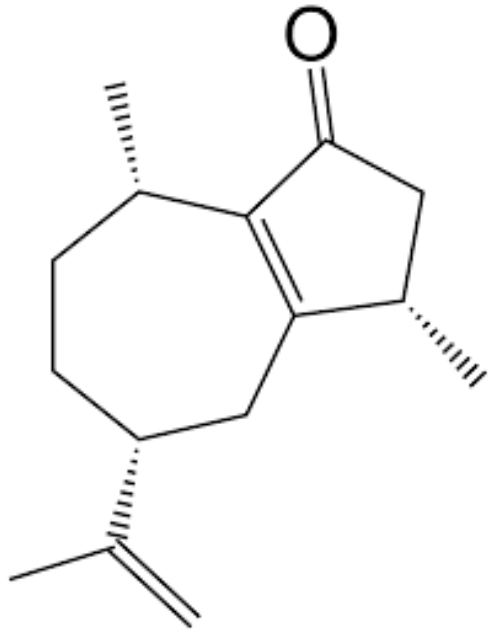


Alkyl-méthoxypyrazines

Ex. IBMP

Interesting facts about rotundone (1/2)

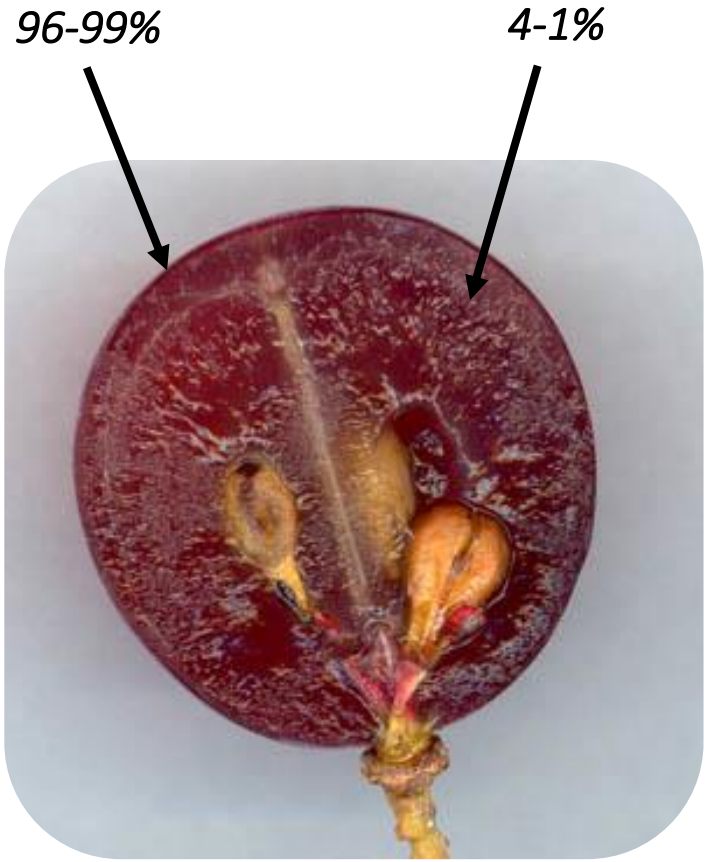
- Sesquiterpènes ($C_{15}H_{22}O$) = active compounds of essential oils
- Found in *Cyperus rotundus*, pepper and aromatic plants
- Odour threshold of 8 ng/L (water) and 16 ng/L (wine)
- Heavy compound less volatile than monoterpenes
- Produced by enzymatic oxydation of α-guaiene
- 20-25% of specific anosmia reported
- Positively perceived except by young wine consumers
- Particularly appreciated by wine connoisseurs who usually spent more than 10 euros for a bottle wine



Wood et al. (2008), JAFC

Interesting facts about rotundone (2/2)

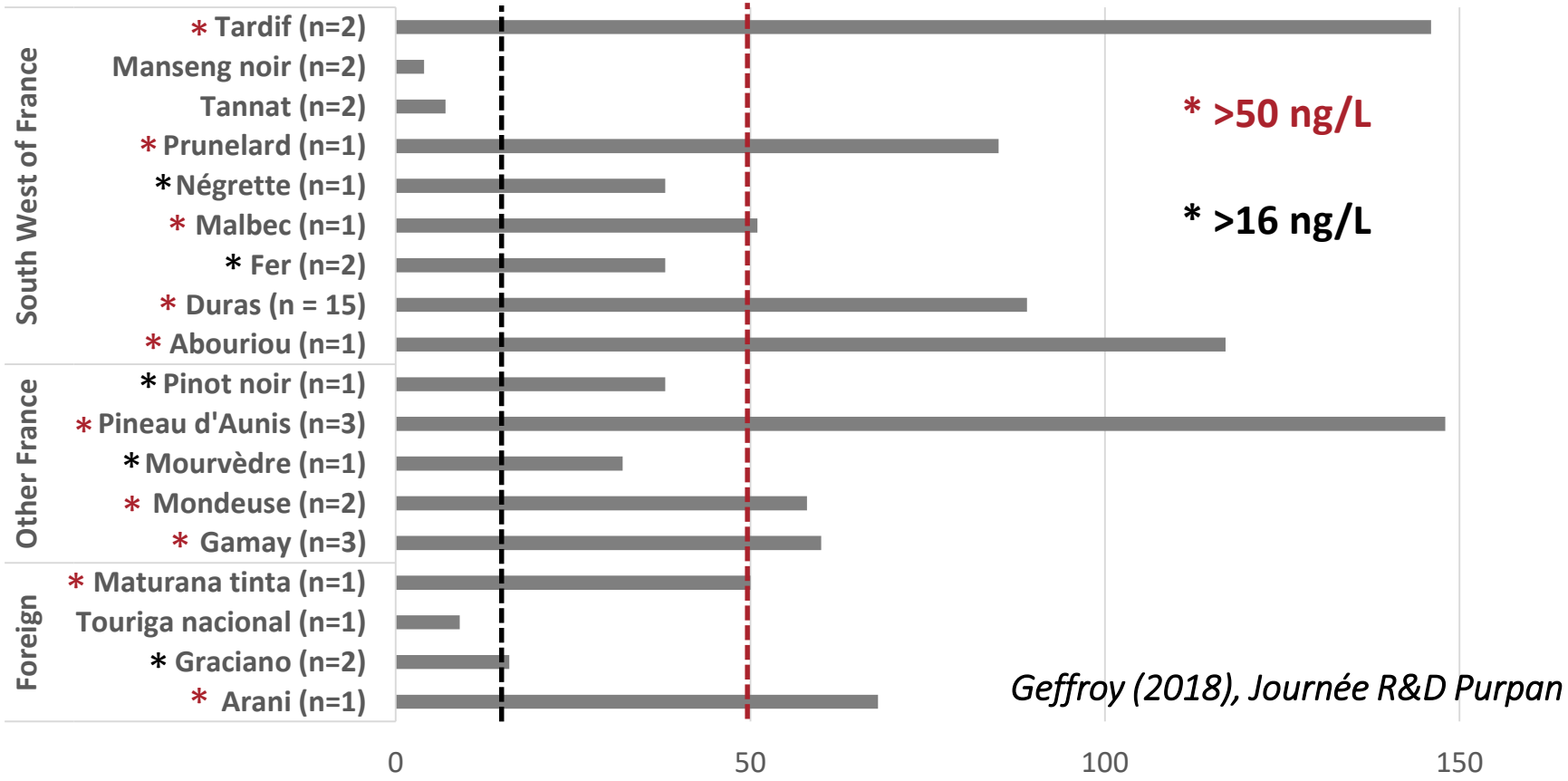
- 96-99% of rotundone is located in the skin
- Hydrophobic compound (≈10% extracted)
- Strong affinity with particles
- Winemaking practices have been identified to lower rotundone in wine (*Saccharomyces uvarum*, carbonic maceration)…
- But not to enhance rotundone, including the increase in maceration temperature and the use of pectolytic enzyme
- Effort to maximize rotundone in wine must be undertaken in vineyard !



Caputi et al. (2011), JAFC

Impact of genotype

Occurrence in wines frequently described as peppery (2008-2015)

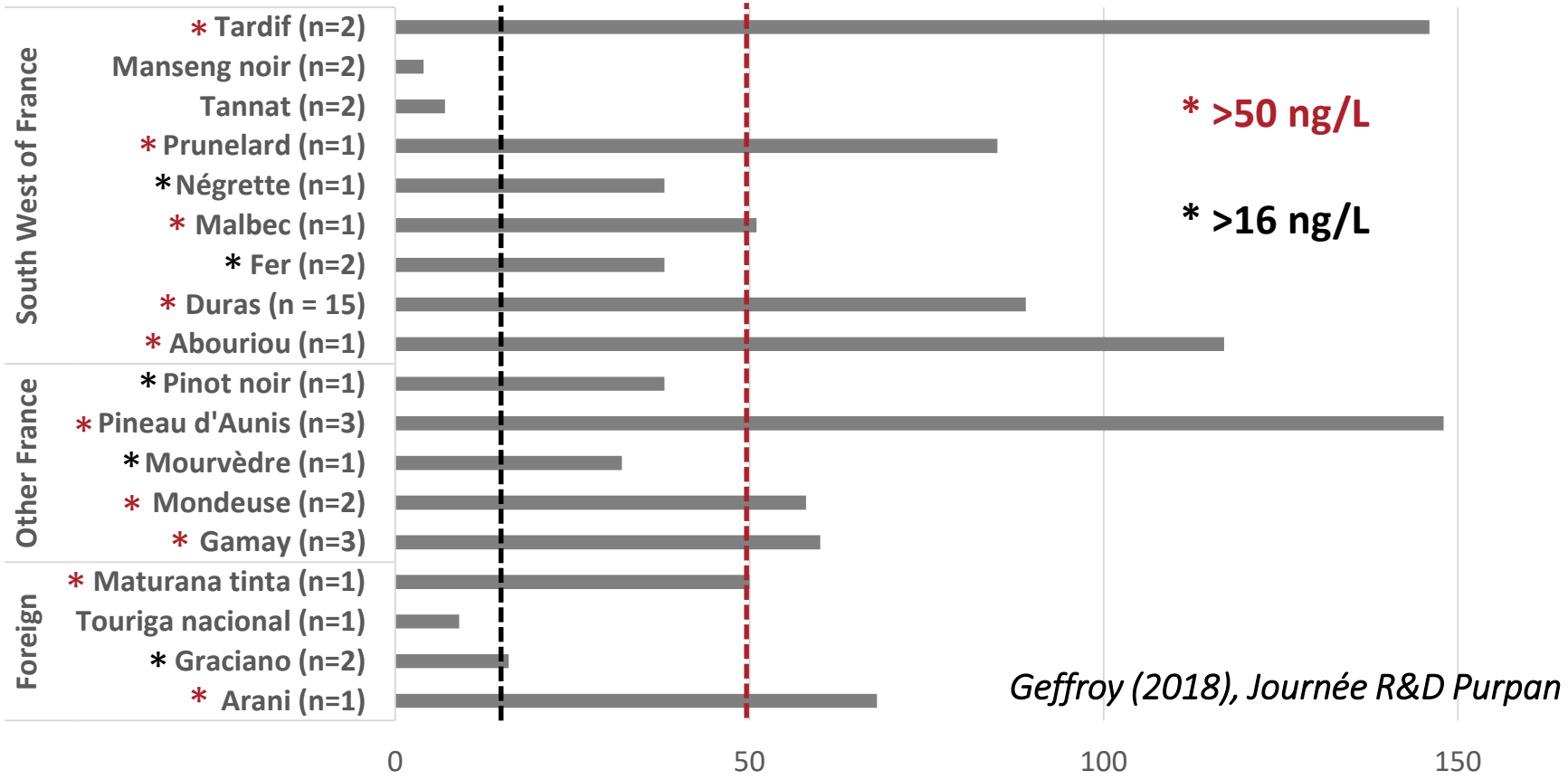


Geffroy (2018), Journée R&D Purpan

Geffroy (2018)

Impact of genotype

Occurrence in wines frequently described as peppery (2008-2015)



Geffroy (2018), Journée R&D Purpan

Geffroy (2018)

Merlot
19-62 ng/kg

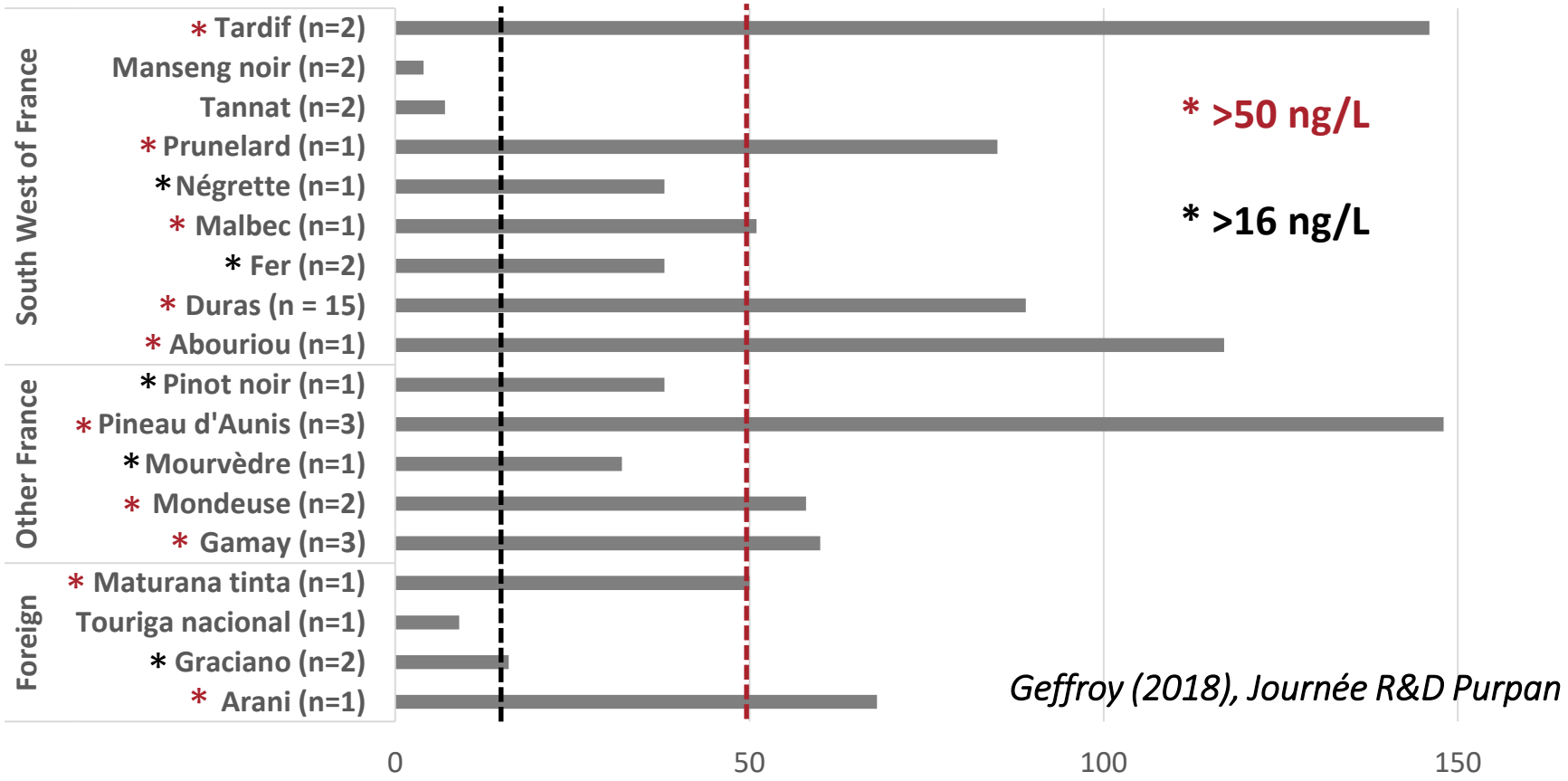
Cabernet Franc
243 ng/kg

Cabernet Sauvignon
21 ng/kg

Takase et al. (2015), AJEV
Logan (2015), Doctoral Thesis

Impact of genotype

Occurrence in wines frequently described as peppery (2008-2015)



Geffroy (2018)

Geffroy (2018), Journée R&D Purpan

Up to 1345 ng/L in spirits (whisky, tequila, rum)

Concentrations increase with barrel aging time

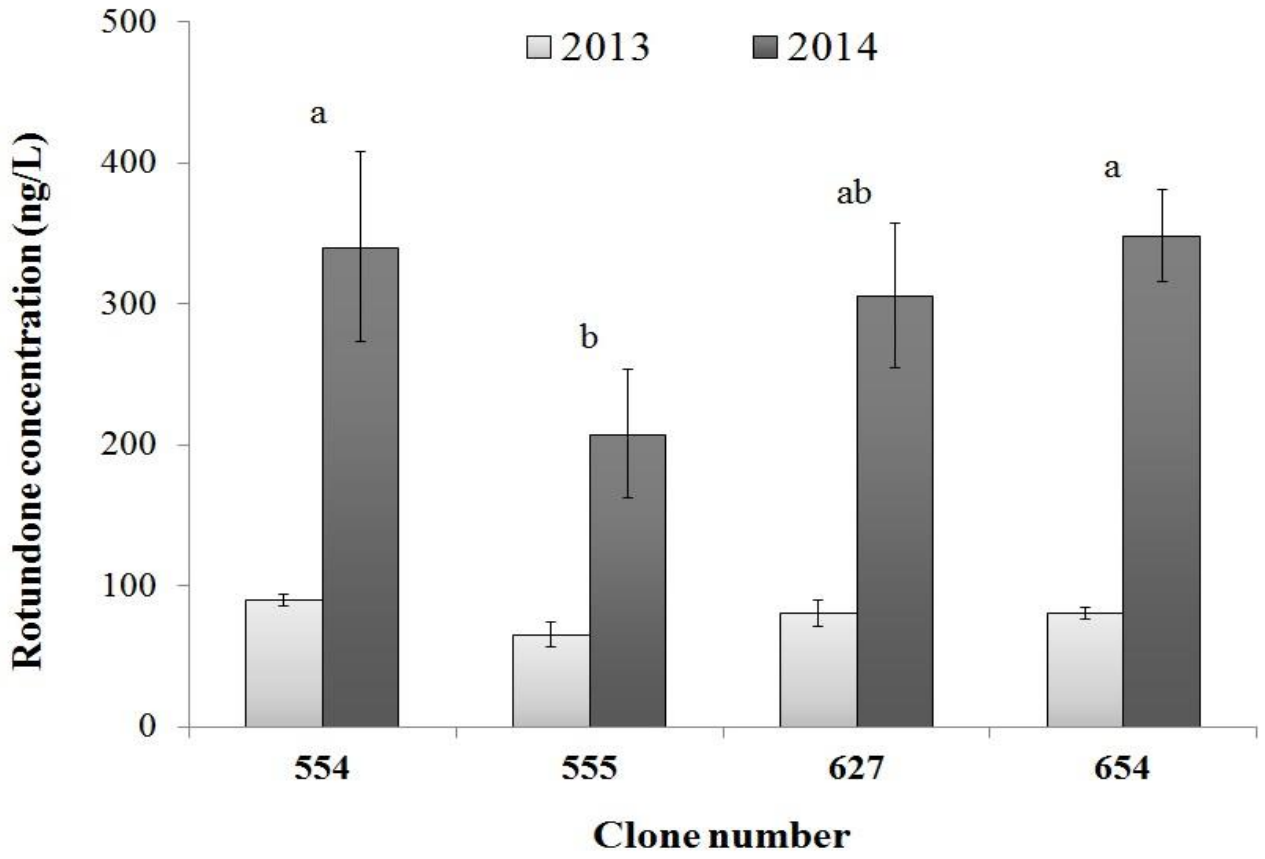
Genthner (2014), Master Thesis

Impact of genotype

Clonal differences observed for Duras

Geffroy et al. (2015a), JISVV

- Clones 554 and 654 showed the greatest concentrations…
- While clone 555 the lowest
- In accordance with other works conducted on Shiraz (Siebert and Solomon 2011) and Grüner Veltliner (Caputi et al. 2011)
- How to explain the extremely high levels for the 2014 vintage ?

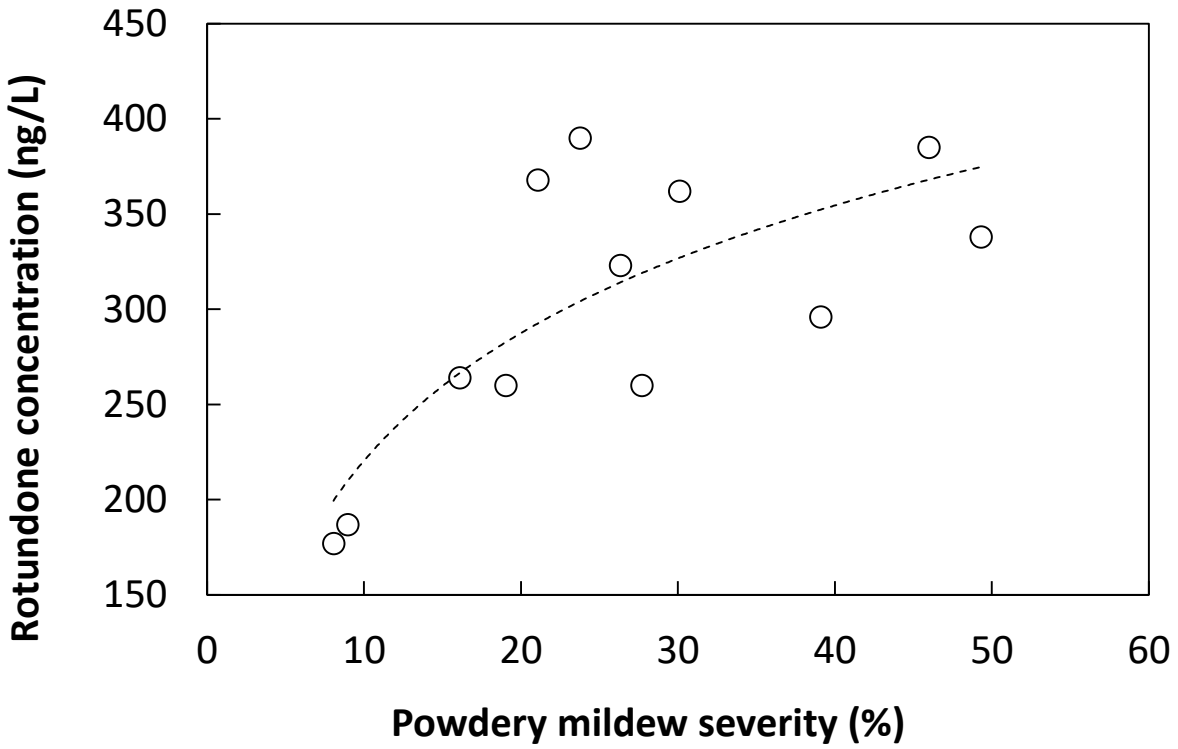


Impact of biotic factors

*Powdery mildew (*Erysiphe necator*)*

- Identification of a positive correlation between PM severity on bunches and rotundone concentration
- Rotundone could be produced in response to PM infection
- Systemic effect as wines were produced from healty berries ?

Geffroy et al. (2015a), JISVV

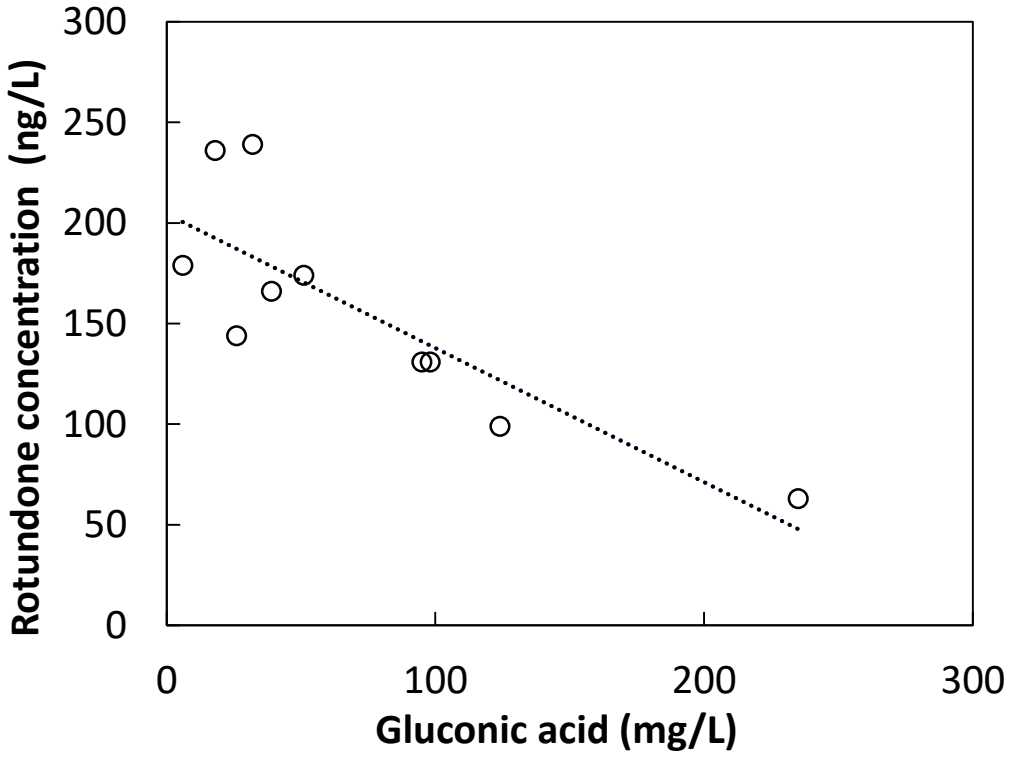


Impact of biotic factors

*Bunch rot (*Botrytis cinerea*)*

- Negative correlation between rotundone concentration and levels of gluconic acid
- Due to the fungus or to its laccase ?
- Rather unexpected as laccase has the ability to convert α-guaiene into rotundone (Schilling et al., 2013)
- However, laccase can neutralize the toxic effect of sesquiterpenes through oxydation (Mayer et Staples, 2002)

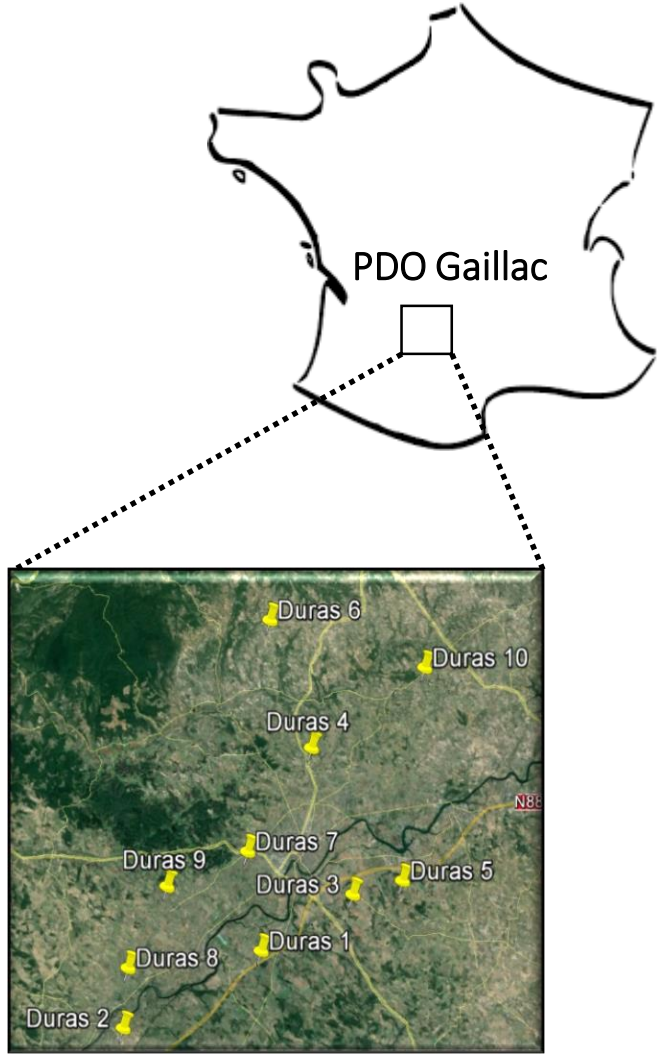
Geffroy et al. (2019a), OENO One



Impact of abiotic factors

Modeling rotundone in Duras wines

- 10 Duras blocks were monitored in 2013 and in 2014
- + 50 variables were collected (fruit, vine, climate) and Ψ_{stem} was modelized
- Rotundone was determined in wines made from microvinification techniques (1L Erlenmeyer flasks)
- PLSR models were built to model rotundone in 2013, 2014 and in both vintages

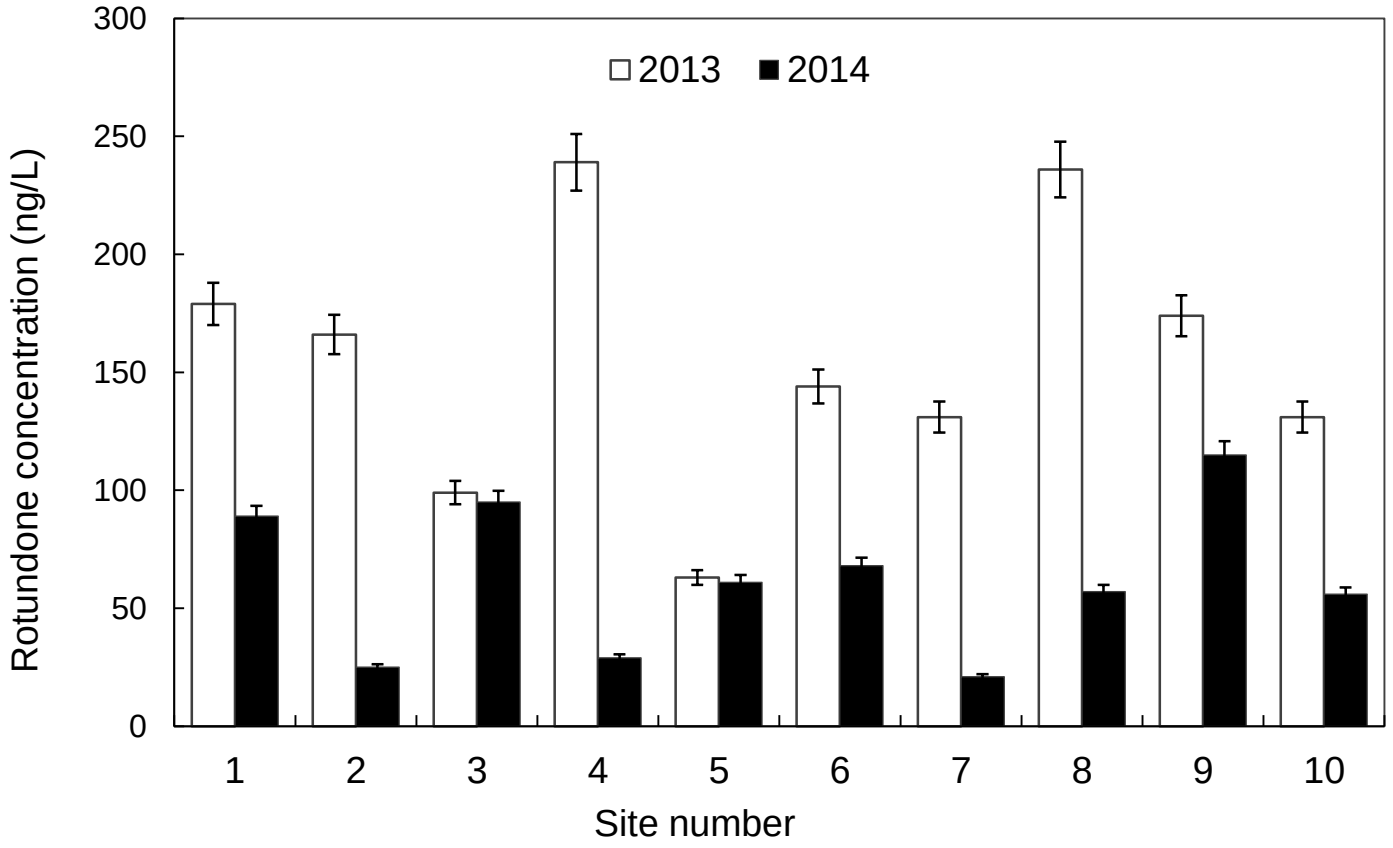


Impact of abiotic factors

Modeling rotundone in Duras wines

Geffroy et al. (2019a), OENO One

- Some blocks with high rotundone levels in 2013 (i.e. n°2 and 4) exhibited low levels in 2014 and conversely (i.e. n°3)
- Fixed variables (topography, plant material…) do not allow to explain the differences between blocks



Impact of abiotic factors

Modeling rotundone in Duras wines

Geffroy et al. (2019a), OENO One

- Positive contribution of cumulative rainfall, daily irradiation and hours of sunshine to the models
- Negative contribution of the Huglin index
- Water supply and light stimulate rotundone production while temperature has a depreciative effect ?

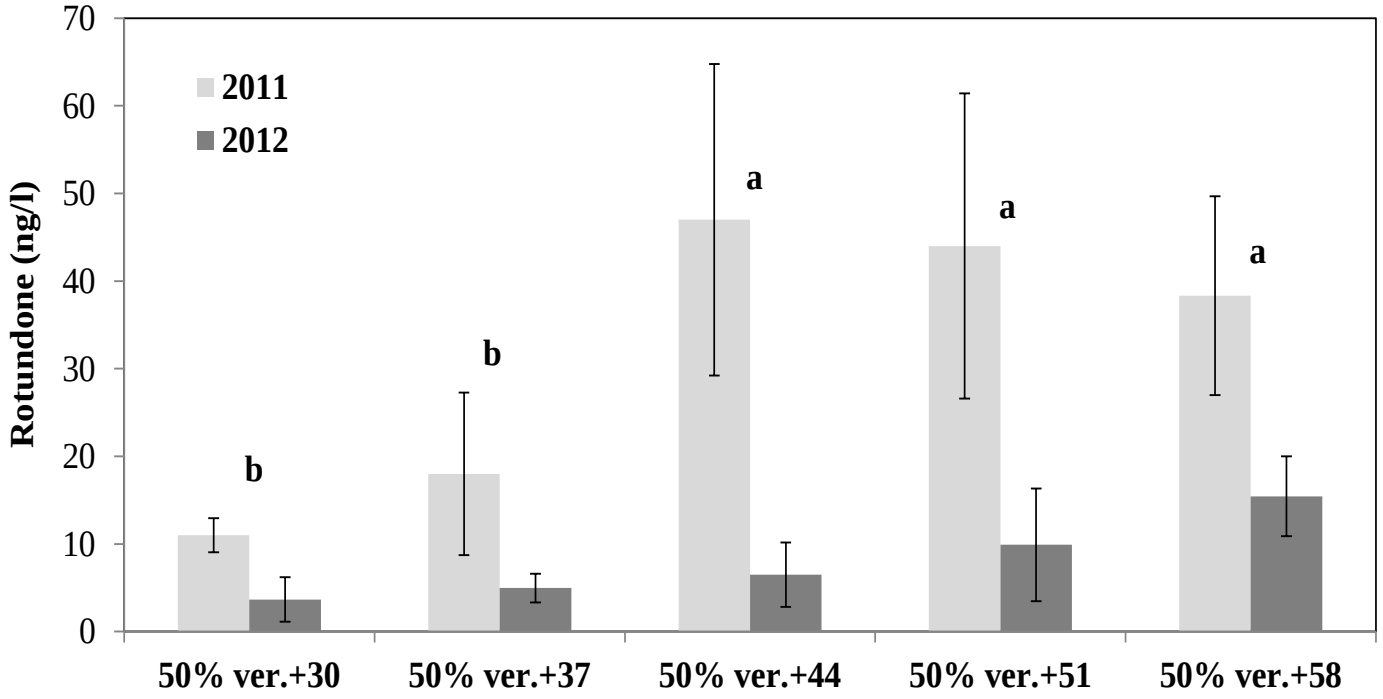
	Variable	Model		
		2013	2014	2013–2014
	Cumulative rainfall, veraison – harvest (mm)	–0.90[a]	NI	NI
+	Hours of sunshine	0.72[a]	NI	0.61[a]
	Gluconic acid concentration (mg/L)	–0.83[a]	NI	–0.001[a]
+	Cumulative rainfall, 1 April – 30 September (mm)	NI	0.85[a]	0.77[a]
–	Huglin index	NI	–0.63[a]	NI
+	Cumulative rainfall, 1 January – 31 December (mm)	NI	NI	0.66[a]
+	Mean daily irradiation, veraison – harvest (W/m^2)	NI	NI	0.59[a]
	No. of latent variables	2	2	2
	Root mean square error	11.4	14.1	28.5
	R^2 (calibration)	0.95	0.78	0.81
	Root mean square error of cross-validation	14.9	20.8	41.3
	R^2 (validation)	0.92	0.53	0.59

How to manipulate rotundone concentration in wine ?

Throught harvesting date

Geffroy et al. (2014), AJGWR

- Kinetic of accumulation slightly differ between the two vintages
- In 2011, fast increase and then reach a plateau
- In 2012, steady increase
- To enhance rotundone, dont pick grapes too early !

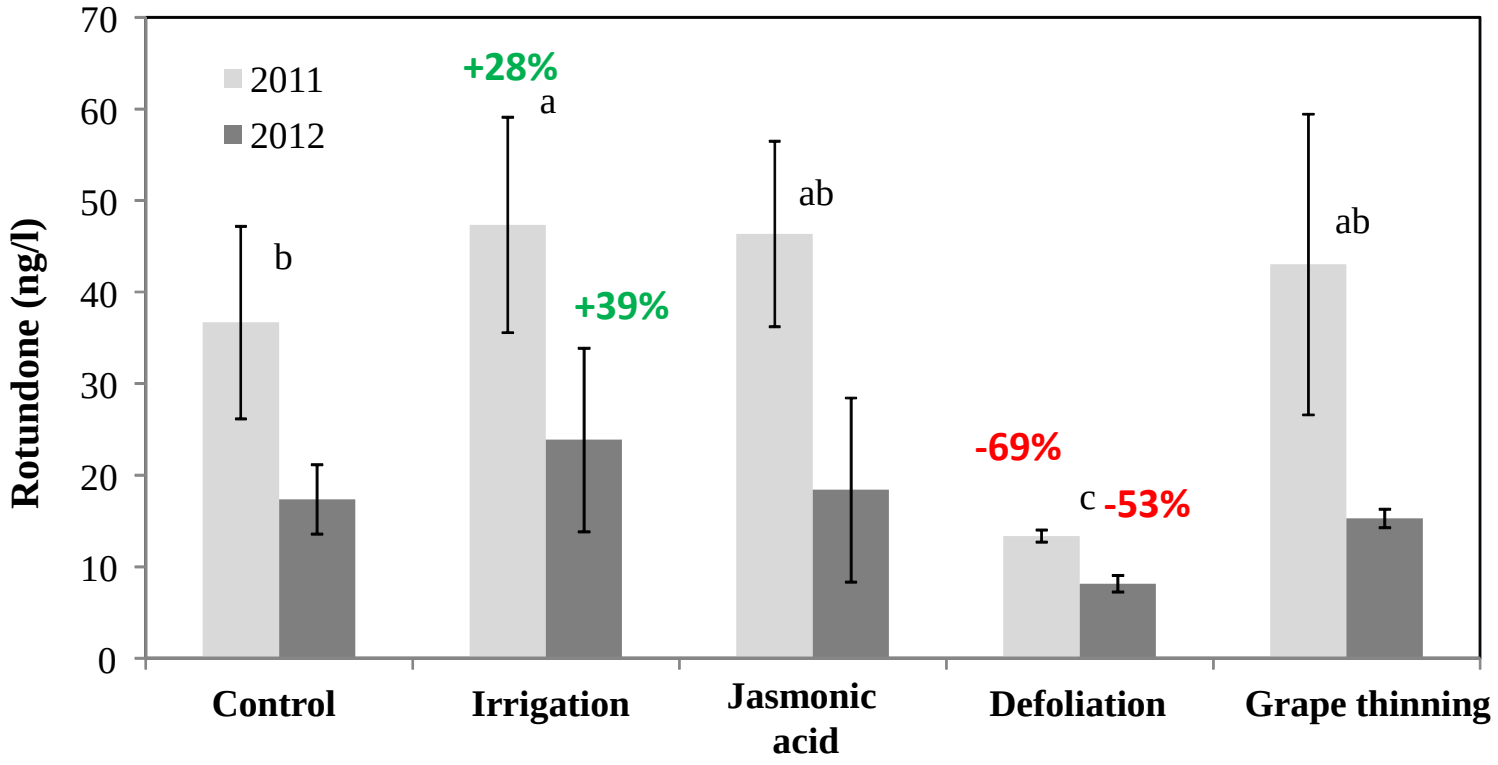


How to manipulate rotundone concentration in wine ?

Throught irrigation and defoliation

Geffroy et al. (2014), AJGWR

- No impact of grape thinning (40%) and jasmonic acid spraying on rotundone
- Positive effect of irrigation (4x10mm before veraison)
- Depreciative effect of defoliation (2 faces at mid-veraison)

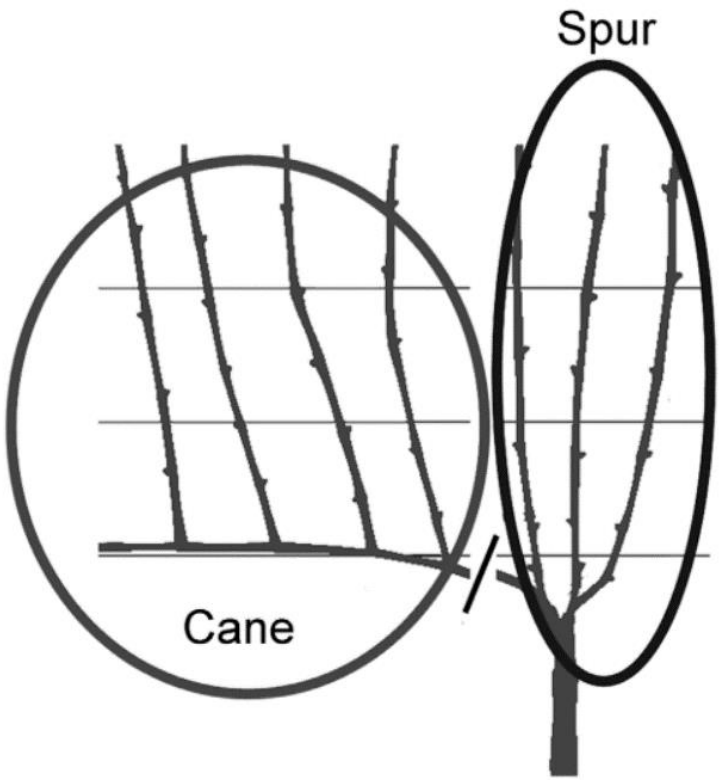


How to manipulate rotundone concentration in wine ?

Enhancing rotundone through irrigation while mitigating the depreciative impact on phenolics

Geffroy et al. (2016), Scientia Horticulturae

- While enhancing rotundone accumulation, irrigation is likely to have a depreciative impact on phenolic compounds (direct and indirect)
- Can a cutting of the fruit bearing cane (PES) 20 days before harvest compensate this loss ?
- We showed in 2013 and in 2014 that PES had a négligeable impact on rotundone accumulation
- In 2014, implementation of a viticultural system combining irrigation (5x14mm) + PES



How to manipulate rotundone concentration in wine ?

Enhancing rotundone through irrigation while mitigating the depreciative impact on phenolics

Parameter	Control	Irrigation + PES	Δ / control
Alcohol (% Vol.)	12.9 b	14.4 b	+1.5 % vol.
Total acidity (g/L tartaric acid)	5.59 b	6.51 a	+0.92 g/L
pH	3.60 a	3.61 a	=
Tartaric acid (g/L)	1.21 a	1.22 a	=
Volatile acidity (g/L acetic acid)	0.47 a	0.55 a	=
Anthocyanins (mg/L)	1061 b	1199 a	+138 mg/L
Total Phenol Index (TPI)	69.6 b	85.0 a	+15.4 points
Yield (kg/vine)	2.12 a	1.78 b	-16%
Rotundone (ng/L)	30 b	44 a	+47%

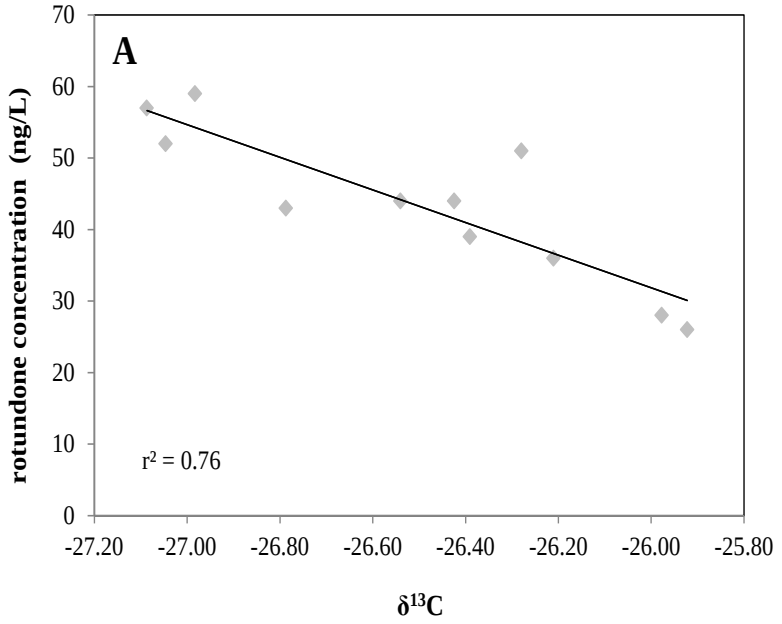
Geffroy et al. (2016), Scientia Horticulturae

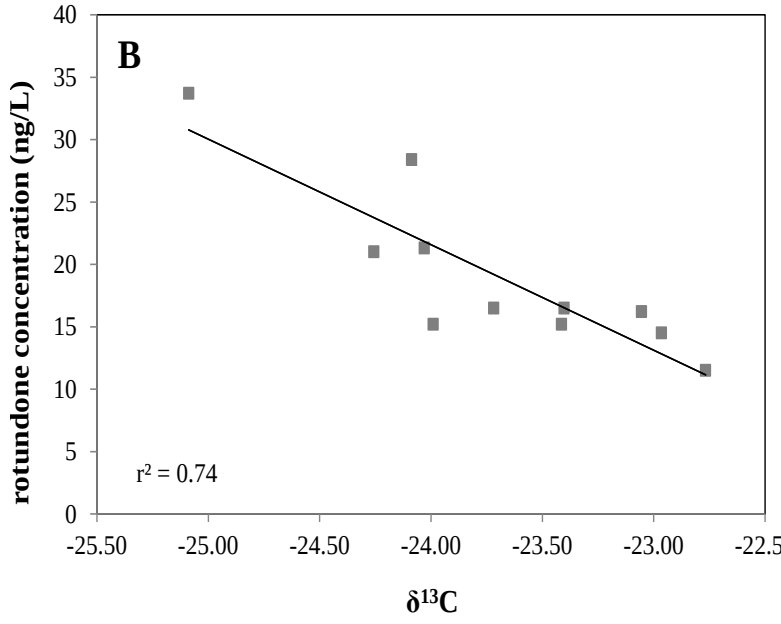
How to manipulate rotundone concentration in wine ?

Throught differential harvest

Geffroy et al. (2014), AJGWR

- Correlation between rotundone and $\delta_{13}C$
- Rotundone is sensitive to weak variation of water constraint
- Possibility to organize differential harvest in order to produce wines with distinct levels of peppery intensity ?



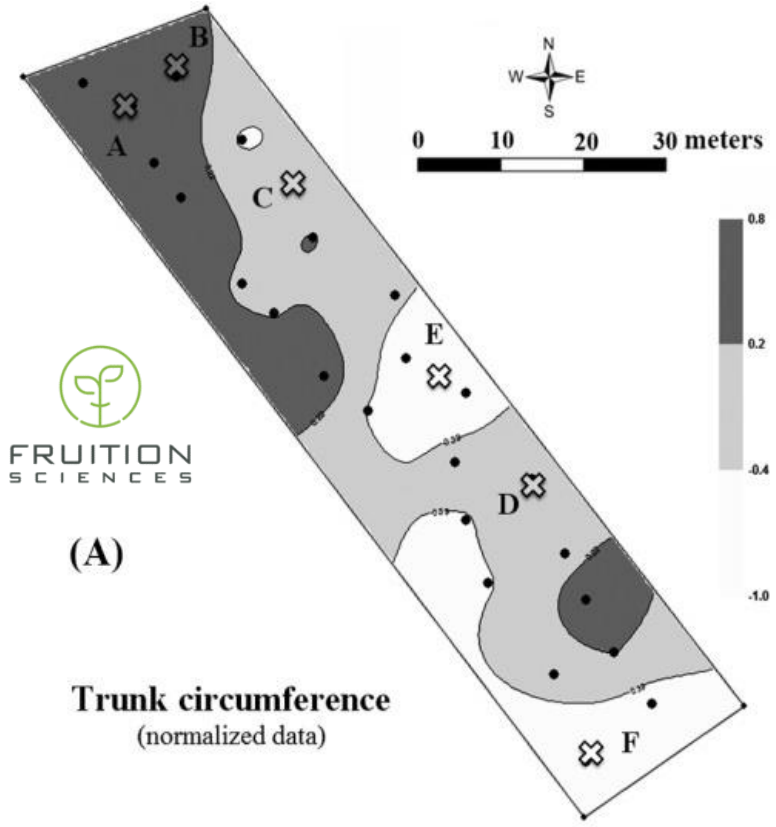


How to manipulate rotundone concentration in wine ?

Throught differential harvest

Geffroy et al. (2015b), GiESCO meeting

- We set up a methodology based on stratified sampling to get access to rotundone spatial distribution
- 25 measurements of Trunk Circumference (TC) on a 0.40-ha block
- Positionning of 6 smart points each one composed of 50 vine plants
- For each smart point, we monitored fruit and plant variables

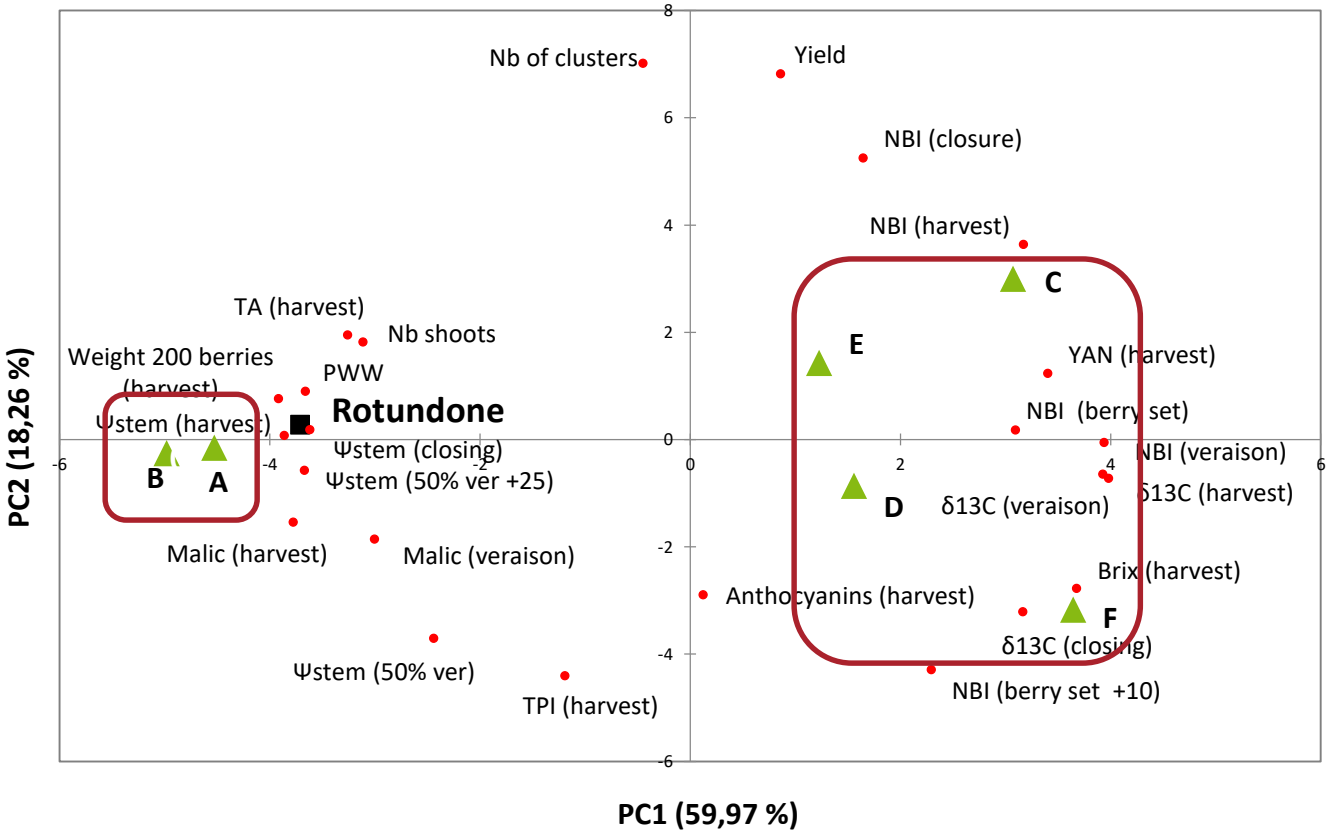


How to manipulate rotundone concentration in wine ?

Throught differential harvest

Geffroy et al. (2015b), GiESCO meeting

- Average TC class has more similarity with the weak TC class and these two classes should be merged
- Rotundone is well correlated with $\delta_{13}C$ at veraison(r2 =0.93) and harvest (r2 = 0.82),
- 94.5 ng/L (large TC), 60.5 and 61 ng/L (average and weak TC)
- TC can be used to map rotundone

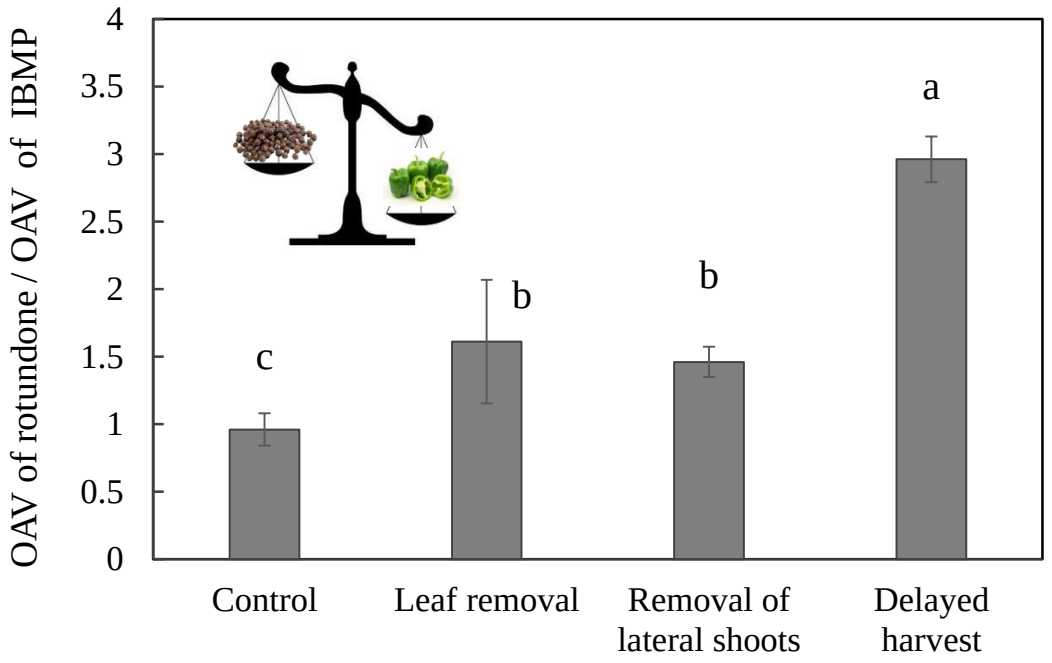


How to manipulate rotundone concentration in wine ?

Enhancing rotundone in Fer wines while decreasing IBMP

Geffroy et al. (2019b), OENO One

- Fer represents ≈ 1500 ha in the SW of France
- Within the PDO Marcillac, Fer wines exhibit intense green and peppery notes imputable to IBMP and rotundone
- Leaf removal, removal of lateral shoots and delayed harvest can be used to modulate the aroma of Fer wines towards an increase in $OAV_{rotundone}$ / OAV_{IBMP} ratio

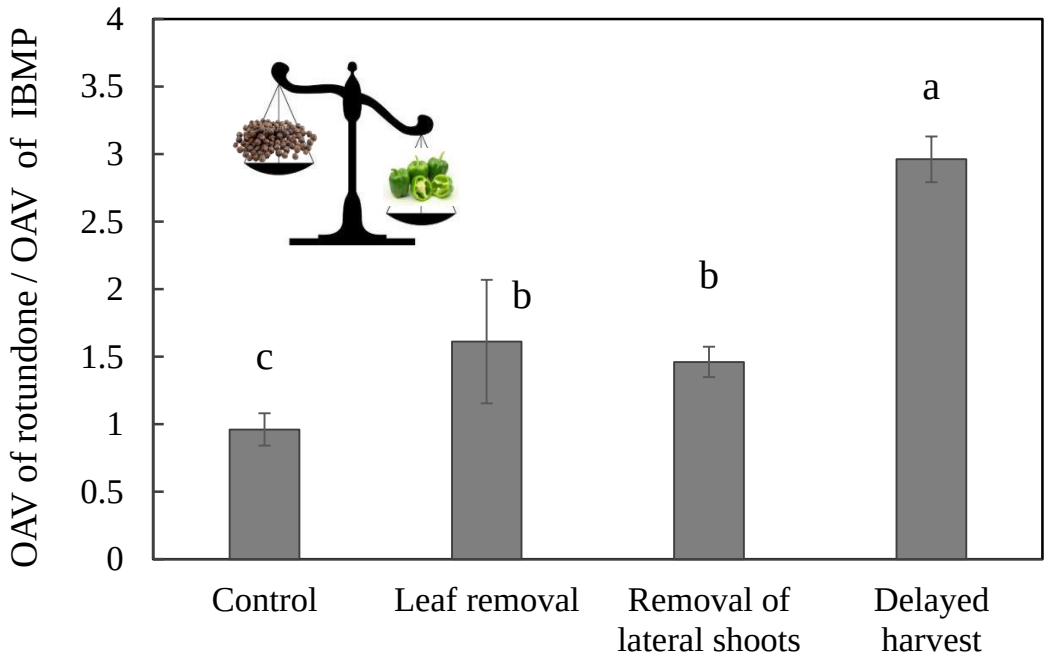


How to manipulate rotundone concentration in wine ?

Enhancing rotundone in Fer wines while decreasing IBMP

Geffroy et al. (2019b), OENO One

- Fer represents ≈ 1500 ha in the SW of France
- Within the PDO Marcillac, Fer wines exhibit intense green and peppery notes imputable to IBMP and rotundone
- Leaf removal, removal of lateral shoots and delayed harvest can be used to modulate the aroma of Fer wines towards an increase in $OAV_{rotundone}$ / OAV_{IBMP} ratio

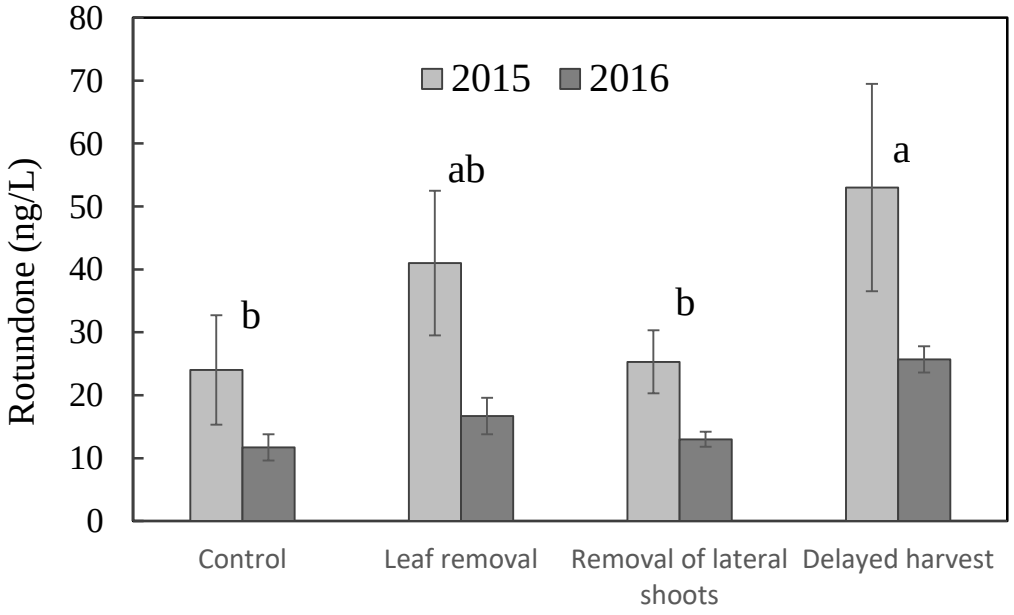


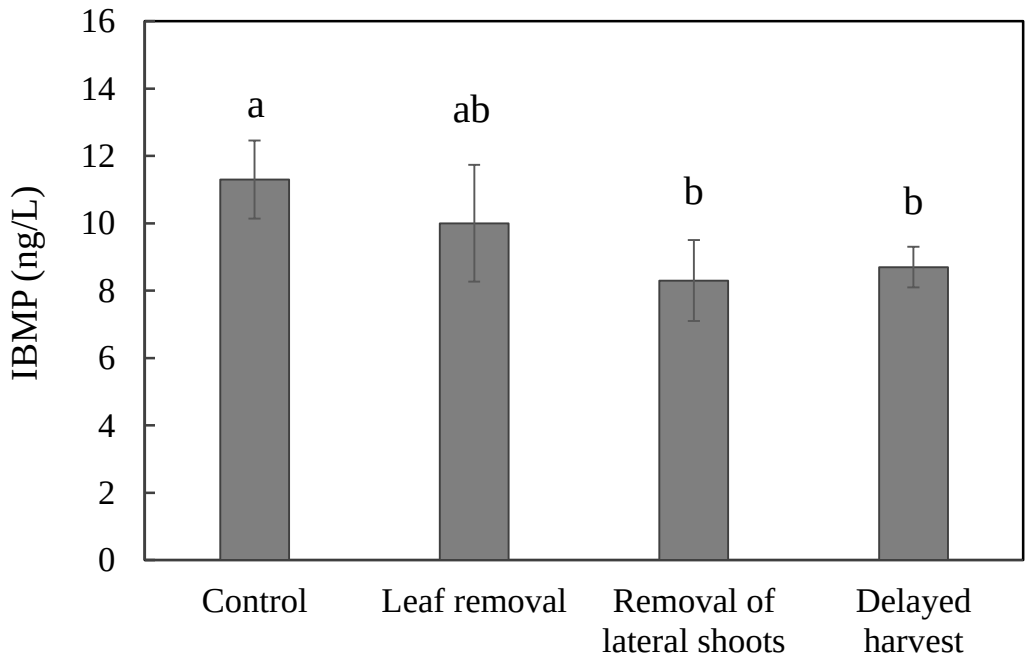
These results might be transposable to Cabernet Franc ?

How to manipulate rotundone concentration in wine ?

Enhancing rotundone in Fer wines while decreasing IBMP

Geffroy et al. (2019b), OENO One





- Significant decrease in IBMP observed for removal of lateral shoots and delayed harvest
- Highest rotundone levels found for delayed harvest while levels for leaf removal were intermediate

Take home message

- Rotundone is a positive aroma compound
- It is a rather ubiquitous molecule
- Certified clones have an impact on rotundone concentration in wine
- The production of rotundone by the plant could be a response to biotic stress (i.e. PM)
- *Botrytis cinerea* has a negative impact on rotundone in wine
- Rotundone accumulation is also affected by abiotic factors (↗with water supply and light, ↘ with temperature)
- The compound is not impacted by grape thinning and crop load
- Harvesting date, irrigation (+PES), defoliation and selective harvest are leverages to manipulate rotundone levels in wines

Thanks to your attention and to the partners

Technical partners

Funding partners

What did I bring for tasting ?

Sample n°1	*Sample n°2*	*Sample n°3*
		
200 ng/L	*≈ 60 ng/L*	*≈ 20 ng/L*
		
Rotundone solution	*Gaillac PDO 100% Duras No defoliation*	*Gaillac PDO 100% Duras Intense defoliation Aged in 2nd hand barrels*