June 16, 2022

Description of the relationship between GTDs and meteorological conditions, irrigations and physiological response

Pr FONTAINE Florence

Management?

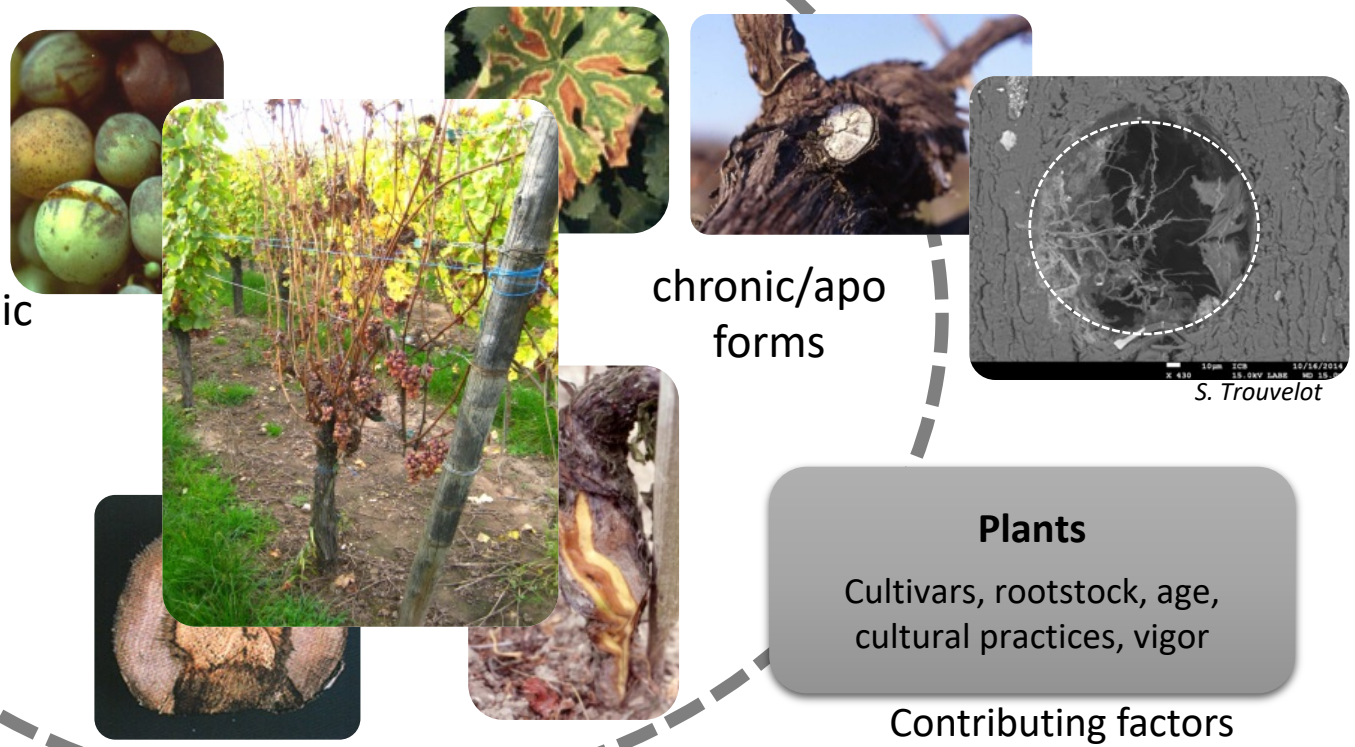
Prophylactic, biocontrol, no chemicals

Pathogens

Complexe of fungi

Predisposing factors

Saveguard of vineyard



Economic losses

chronic/apo forms

S. Trouvelot

Environment

Soil, climat, …

Aggravating factors

Plants

Cultivars, rootstock, age, cultural practices, vigor

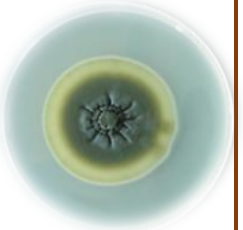
Contributing factors

Herlemont, 1995, Mugnai *et al.* 1999, Bertsch *et al. 2012,* Mondello *et al.* 2018, Fischer & Peighami 2019

Fungal diseases

Several fungi

Different families



Wood decay fungi

Enzymes to degrade the wood

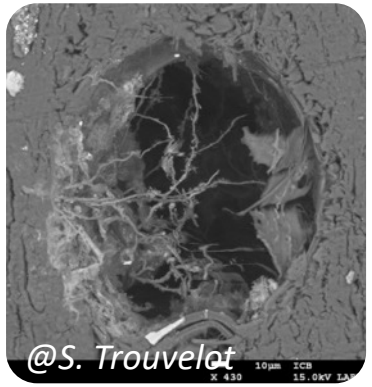
Produce phytotoxic molecules

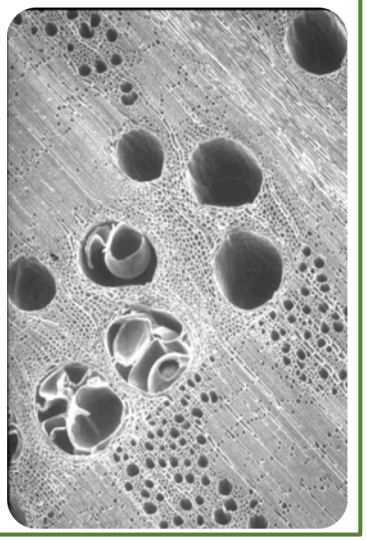
Grapevine

Necroses in wood

Specificity according to fungi

Xylem

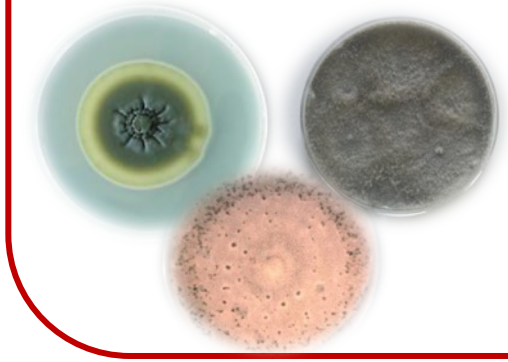




1st plant response:
gummosis, tyloses

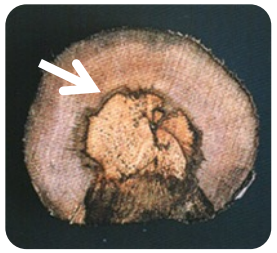
Grapevine **Trunk** Diseases

arsenal of fungi



infection

Pruning wound
(winter, spring)



necrosis
in wood

1, 2, 3…10…

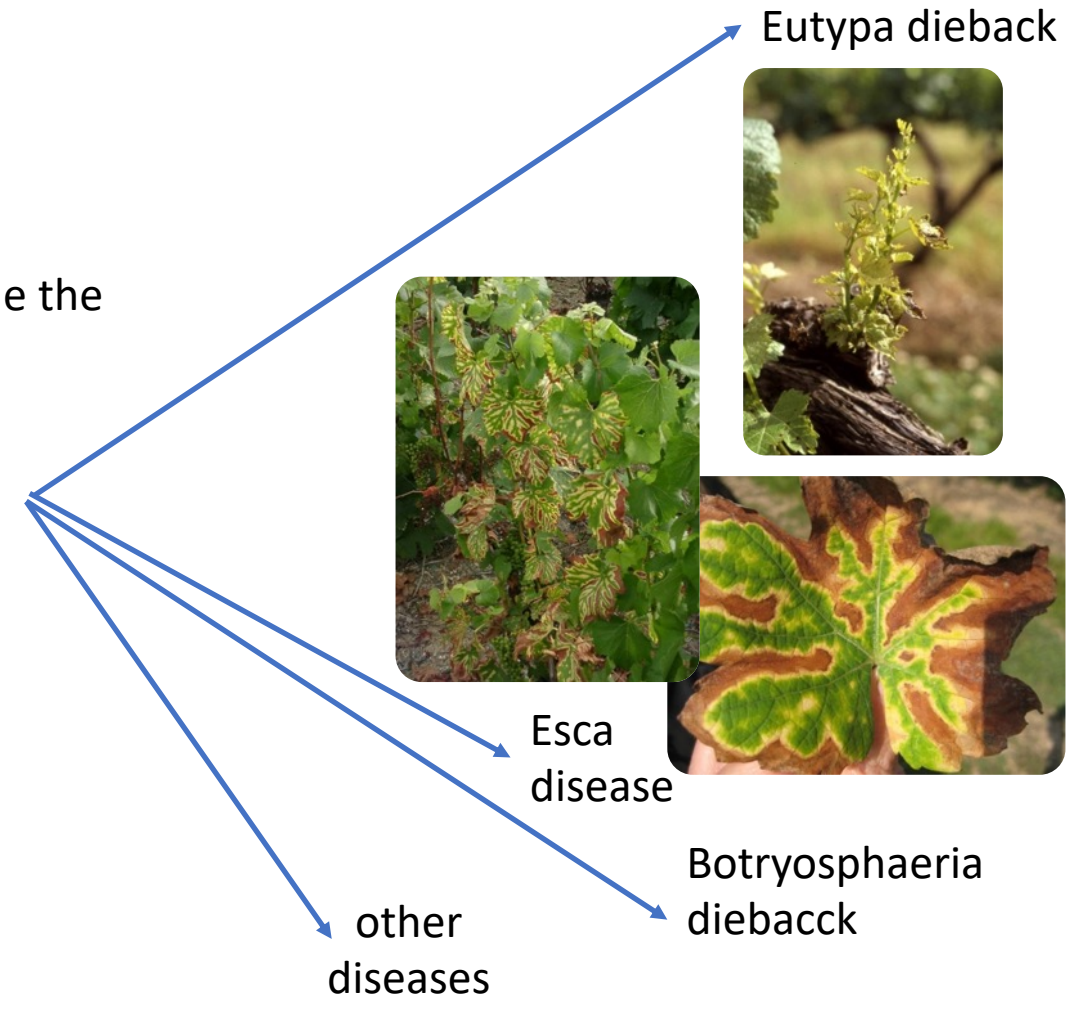
years later

expression of
symptoms:
leaves & berries

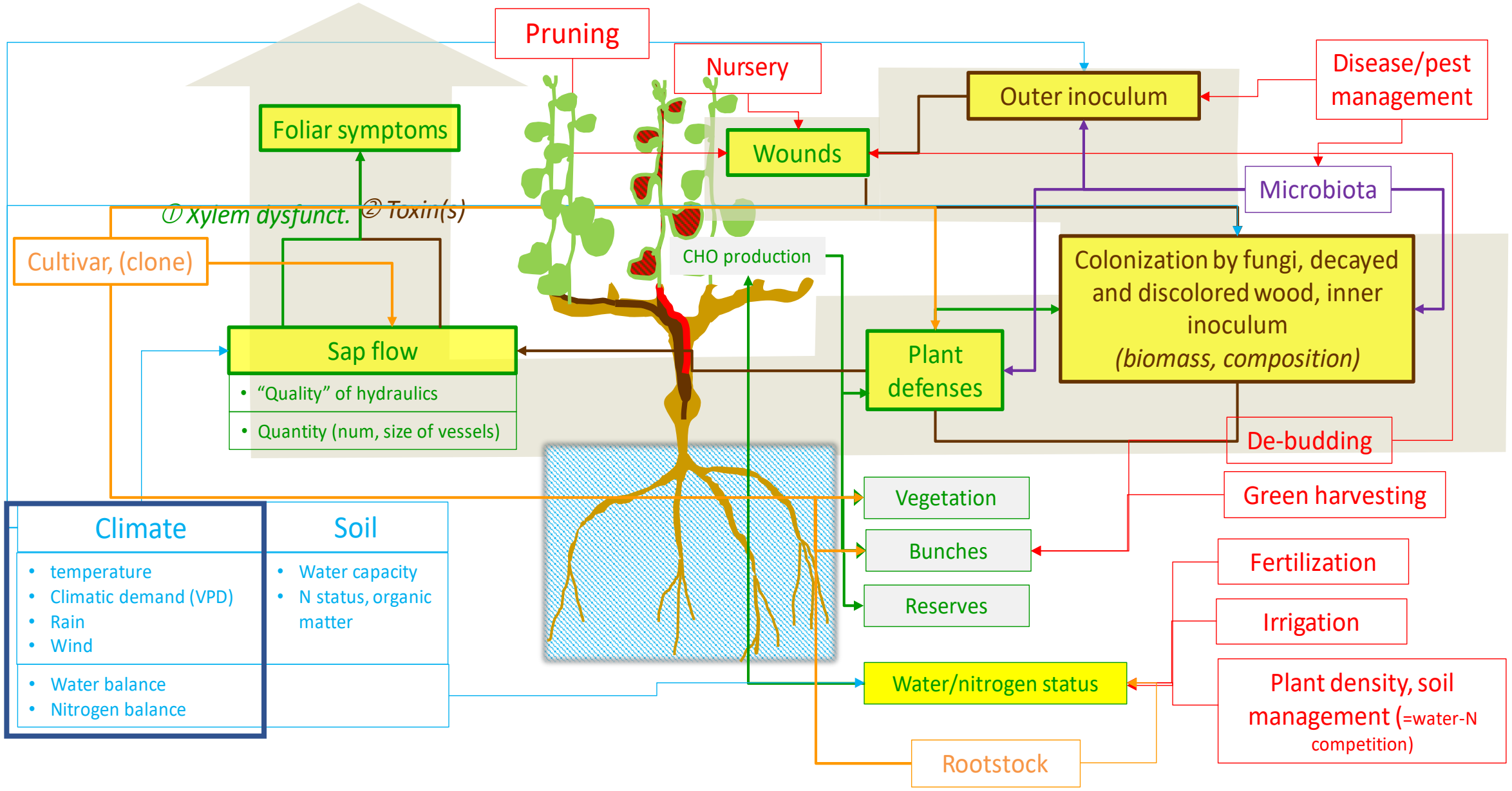
death of the
vine

Decrease of yield
&
Sustainability of vineyard

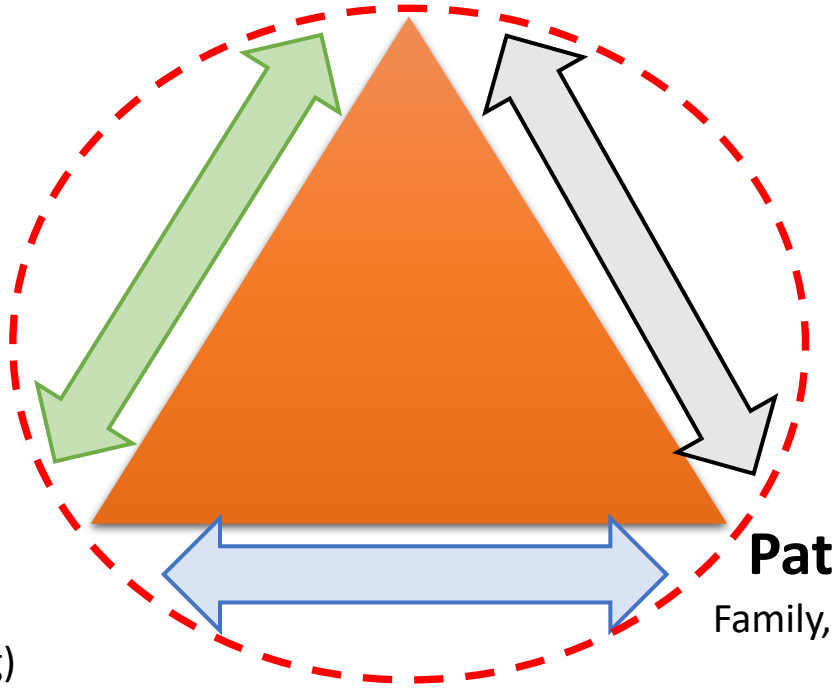
Diversity of fungi inside the vine



- **Which diseases?**
- **Discontinuity** of foliar symptoms expression from one year to the next



Claverie et al. 2020



Vine

cultivars, rootstock, clone, age

Climate

Heat & Water stress
(intensity, duration, timing)

Pathogenes

Family, Species, Strain

Songy *et al.* 2019, Fischer & Peighami 2019

Temperature & Virulence

Table 1. Mean lesion length caused by *Botyrosphaeriaceae* species on detached dormant Chardonnay canes (Clone I10V5) under different incubation temperatures in vitro.

Species	Accession number[2]	Mean lesion length (mm) ±SE[1]		
		25°C	30°C	35°C
Diplodia seriata	DAR79990	8.10±2.36 ab	15.60±4.40 bc	17.40±4.59 b
D. seriata	DAR79998	9.11±3.60 ab	20.20±4.32 cd	9.00±2.47 ab
D. seriata	DAR80002	5.75±3.05 ab	5.80±2.81 ab	8.57±3.93 ab
Neofusicoccum parvum	DAR77821	41.11±7.53 c	61.90±7.58 f	72.28±2.48 d
N. parvum	DAR77823	38.40±9.29 c	64.60±4.46 f	18.10±7.41 b
N. parvum	DAR77822	41.60±3.87 c	59.10±5.88 ef	49.40±10.09 c

Water stress & Virulence

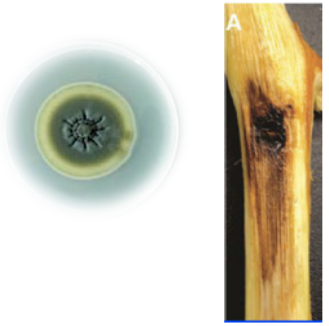


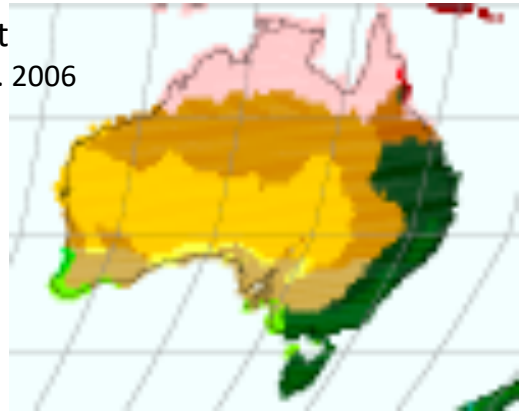
Table 2. Mean lesion length caused by *Botyrosphaeriaceae* species on 2-year-old potted Chardonnay grapevines (Clone I10V5) subjected to normal and restricted-watering regime in a glasshouse.

Species	Accession number[2]	Mean lesion length (mm) ±SE[1]	
		Non-water stress	Water stress
Diplodia seriata	DAR79990	21.00±2.45 ab	54.50±14.09 cde
D. seriata	DAR79998	21.25±4.37 ab	21.25±5.45 b
D. seriata	DAR80002	38.50±9.87 bcd	36.00±11.48 bc
Neofusicoccum parvum	DAR77821	71.75±14.53 d	92.50±19.63 e
N. parvum	DAR77823	26.00±5.02 b	39.00±8.91 bcd
N. parvum	DAR77822	34.25±11.63 bc	85.00±8.57 e

Qiu *et al*. 2016

Prediction – location of Botryo. & climate

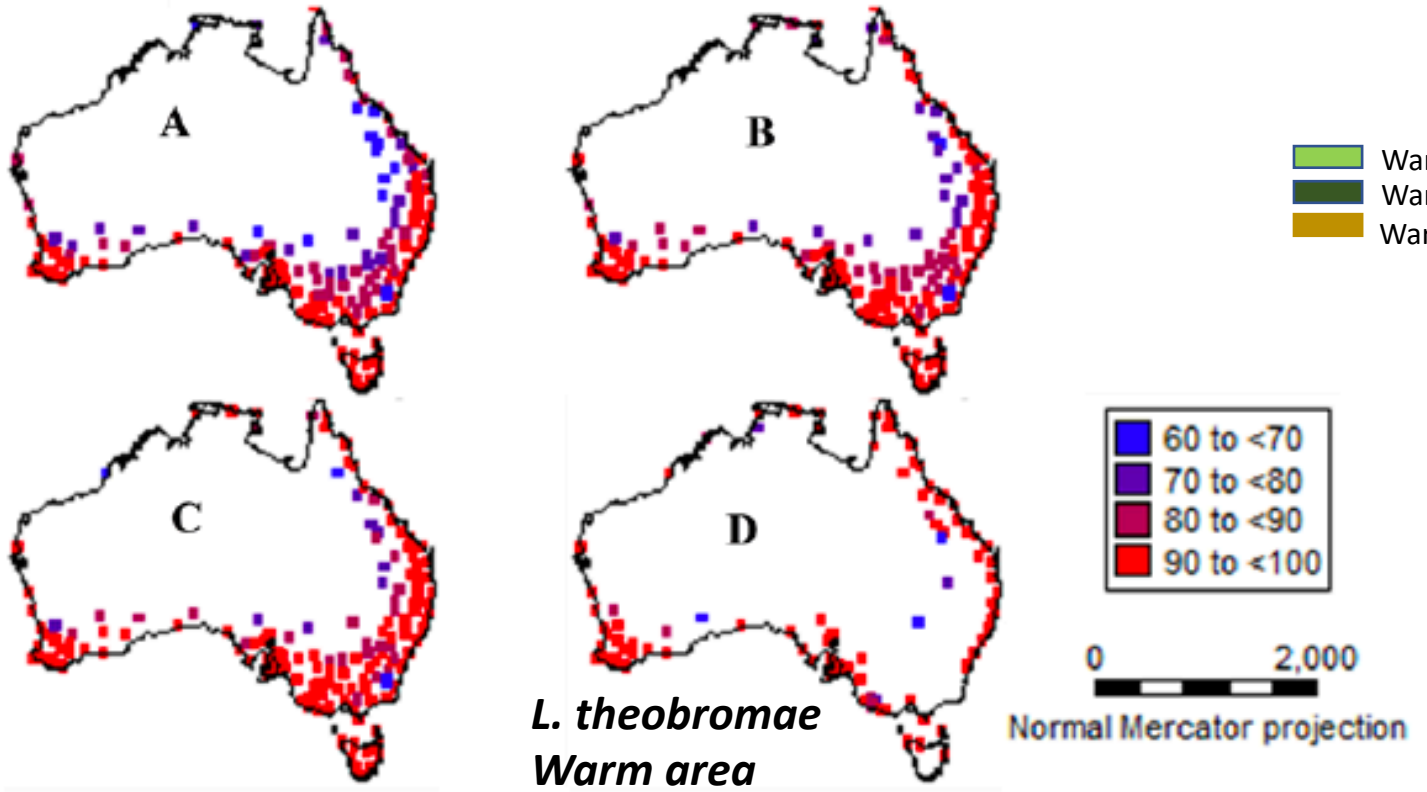
Climat
Kottet *et al*. 2006



Warm temperature, steppe, hot-warm summer
Warm temperature, fully humide
Warm temperature, winter dry, warm summer

D. seriata
wide distribution

N. parvum



L. theobromae
Warm area

Figure 2. Estimated suitable geographical locations for four *Botryosphaeriaceae* species in Australia. A: *Diplodia seriata*, B: *Neofusicoccum parvum*, C: *Botryosphaeria Dothidea* and D: *Lasiodiplodia theobromae*, based on the analysis of CLIMEX using cardinal temperatures of these species. Legend: Ecoclimatic Index (EI).

Qiu *et al.* 2016

Vine & Water stress

Physiological & biochemical changes

Plant species (as cited in respective research papers)	Physio-biochemical changes	Reference
Acer platanoides, *Populus tremula*, etc.	Stomatal closure	Aasamaa *et al.*, 2001
Juglans regiax×nigra		Cochard *et al.*, 2002
Betula alleghaniensis, *B. davurica*, etc.		Gu and Rom, 2007
Vitis vinifera		Letousey *et al.*, 2010
Zea mays	Changes in photosynthetic rate and Carbon reserves	Westgate and Boyer, 1985
V. vinifera		Christen *et al.*, 2007
Arabidopsis thaliana		Hummel *et al.*, 2010
Pinus edulis		Sevanto *et al.*, 2014
V. vinifera	Enhanced respiration	Schultz, 2000
A. saccharum, *Thuja occidentalis*, etc.	Lower shoot hydraulic conductance and leaf specific conductivity	Tyree and Sperry, 1988
V. vinifera	Lower transectional areas in xylem vessels	Lovisolo and Schubert, 1998
Eucalyptus globulus	Impaired function of phloem	Pate and Arthur, 1998
Vitis sp.	Aquaporin gene expression	Galmes *et al.*, 2007
V. vinifera	Growth reduction	Shellie and Brown, 2012
Melissa officinalis	Chlorophyll loss	Munne-Bosch and Alegre, 1999
Z. mays	Alteration in root structure and function	Zhang *et al.*, 1995
V. berlandieri×V. rupestris		Dry *et al.*, 2000
Lycopersicom esculentum		Mingo *et al.*, 2004
Glycine max	ABA-responsive signaling pathway, e.g. the activation of JA-related defense genes, alteration in PAL activity, etc.	Ward *et al.*, 1989
Z. mays		Zhang and Davies, 1990
G. max		McDonald and Cahill, 1999
L. esculentum		Audenaert *et al.*, 2002
A. thaliana		Kariola *et al.*, 2006
A. thaliana		Adie *et al.*, 2007
V. vinifera		Grimplet *et al.*, 2007
Solanum lycopersicum		Asselbergh *et al.*, 2008
V. vinifera		Deluc *et al.*, 2009
Vitis sp.		Lovisolo *et al.*, 2010
S. lycopersicum	Cytokinin production	Kudoyarova *et al.*, 2007
Z. mays		Alvarez *et al.*, 2008
V. vinifera	Sugar accumulation	Castellarin *et al.*, 2007
V. vinifera		Deluc *et al.*, 2009
V. vinifera		Koundouras *et al.*, 2009
Ocimum sp.	Accumulation of amino acids, *e.g.* proline	Khalid, 2006
V. vinifera		Deluc *et al.*, 2009
V. vinifera		Berdeja *et al.*, 2014

Photosynthesis
Carbon / Vigor
Respiration

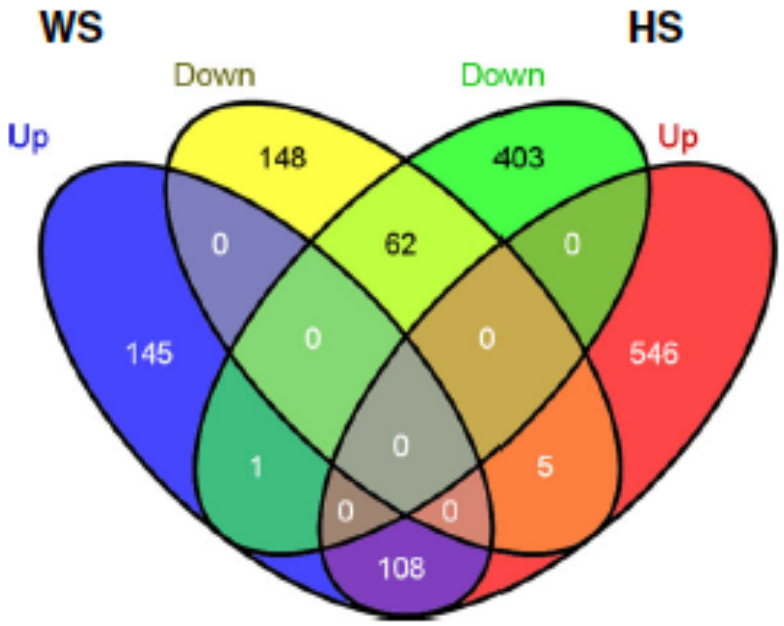
Growth / vigor
Transport

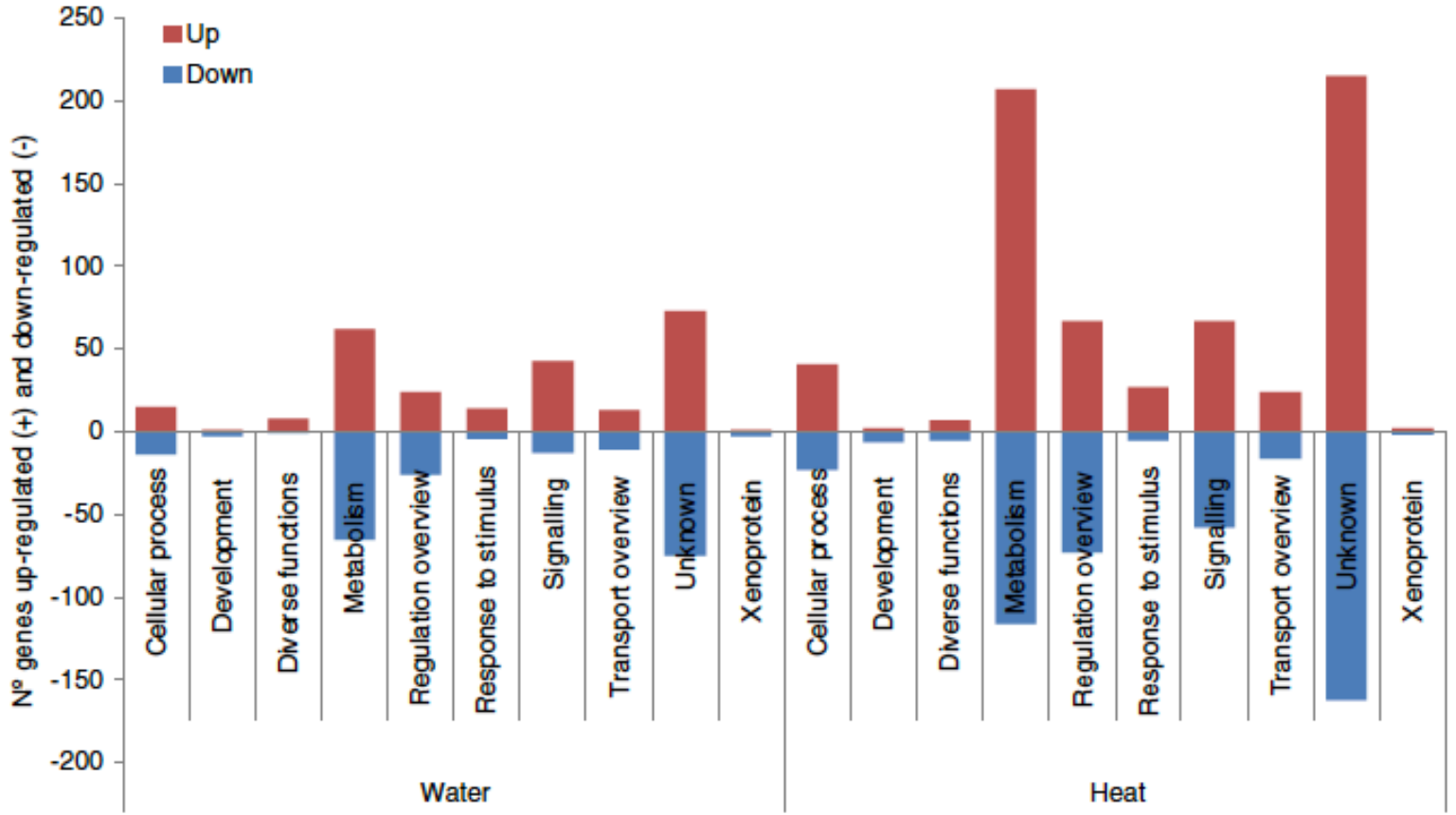
Hormones

Fischer & Peighami 2019
Songy *et al.* 2019

Vine & Heat(HS) or Water (WS) Stress

Aragonez
Transcriptomic changes





Commun
&
Specific
Responses HS / WS

Rocheta *et al*. 2014
Carvalho *et al.* 2015
Songy *et al.* 2019

Cultivars | **Water** | **Heat**

A. Cultivars		Tolerance to GTD	Tolerance to Water stress	Tolerance to Heat stress
Red cultivars				
Cabernet Franc	BDA	**Int** (Travadon et al., 2013)	-	**High-Int** (Jones 2007) **Low** (Xu et al. 2014)
	Esca	**Low** (Travadon et al., 2013)		
	Eutypa	**High** (Travadon et al., 2013)		
Cabernet Sauvignon	BDA	**Int** (Travadon et al., 2013)	**High-Int** (Tramontini et al. 2013) **Int** (Tomás et al., 2012)	**High** (Jones, 2007; Xu et al., 2014)
	Esca	**High** (Feliciano et al. 2004) ; Travadon et al., 2013) **Int** (Pouzoulet et al. 2014) **Low** (Borgo et al., 2016)		
	Eutypa	**High** (Travadon et al., 2013) **Low** (Péros and Berger 1994 ; Rolshausen et al., 2008)		
Grenache	Esca	**High** (Feliciano et al., 2004) **Int** (Borgo et al., 2016)	**High** (Vandeleur et al. 2009; Tomás et al. 2012; Tramontini et al. 2013; Martorell et al. 2015) **Int-Low** (Prieto et al. 2010)	**High** (Jones, 2007)
	Eutypa	**High** (Péros & Berger, 1994) **Low** (Sosnowski et al., 2007)		
Merlot	BDA	**High-Int** (Travadon et al., 2013)	**Low** (Tramontini et al., 2013)	**High** (Jones, 2007) **Low** (Xu et al., 2014)
	Esca	**High** (Borgo et al., 2016) **Int** (Murolo & Romanazzi, 2014; Travadon et al., 2013) **Low** (Pouzoulet et al., 2014)		
	Eutypa	**High** (Travadon et al., 2013 ; Sosnowski et al., 2007 ; Rolshausen et al., 2008)		
Mourvèdre	BDA	**Low** (Spagnolo et al., 2014)	**Int-Low** (Prieto et al. 2010)	**High** (Wolkovich et al., 2018)
	Esca	**High** (Travadon et al., 2016)		
Pinot Noir	Esca	**High** (Borgo et al., 2016)	**Low** (Tomás et al., 2012)	**Low** (Jones, 2007)
Sangiovese	Esca	**High** (Surico et al., 2000a) **Int** (Borgo et al., 2016)	**Int** (Poni et al., 2007)	**High** (Jones, 2007)
Syrah	Esca	**High** (Borgo et al., 2016) **Low** (Travadon et al., 2016)	**High** (Prieto et al., 2010) **Int** (Tramontini et al., 2013)	**High** (Jones, 2007)
Tempranillo (syn. Aragonez)		**Low** (Elena et al. 2015)	**Low** (Martorell et al., 2015; Tomás et al., 2012)	**High-Int** (Jones, 2007)
White cultivars				
Chardonnay	BDA	**High** (Travadon et al., 2013) **Low** (Spagnolo et al., 2014)	**Int** (Gomez del Campo et al., 2003; Vandeleur et al., 2009)	**Int** (Jones, 2007; Xu et al., 2014)
	Esca	**High** (Marchi et al., 2001)		

Songy *et al*. 2019

Rootstock

Water

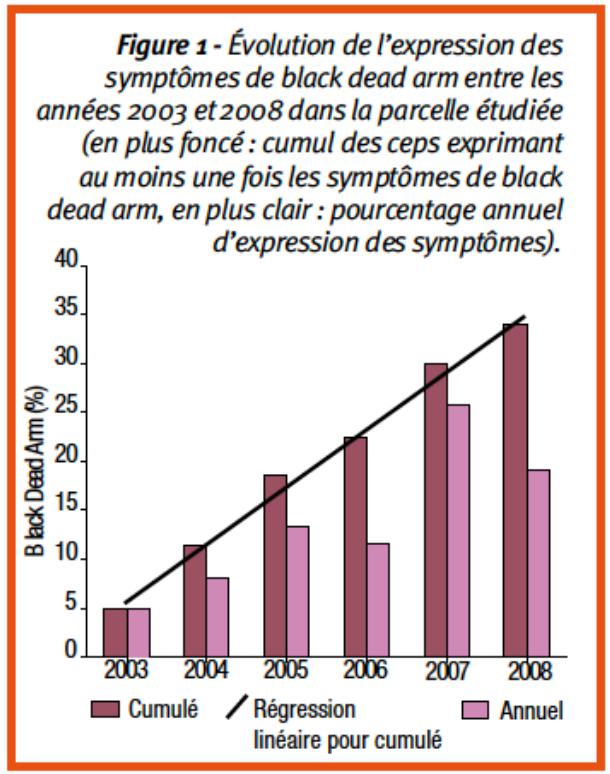
Heat

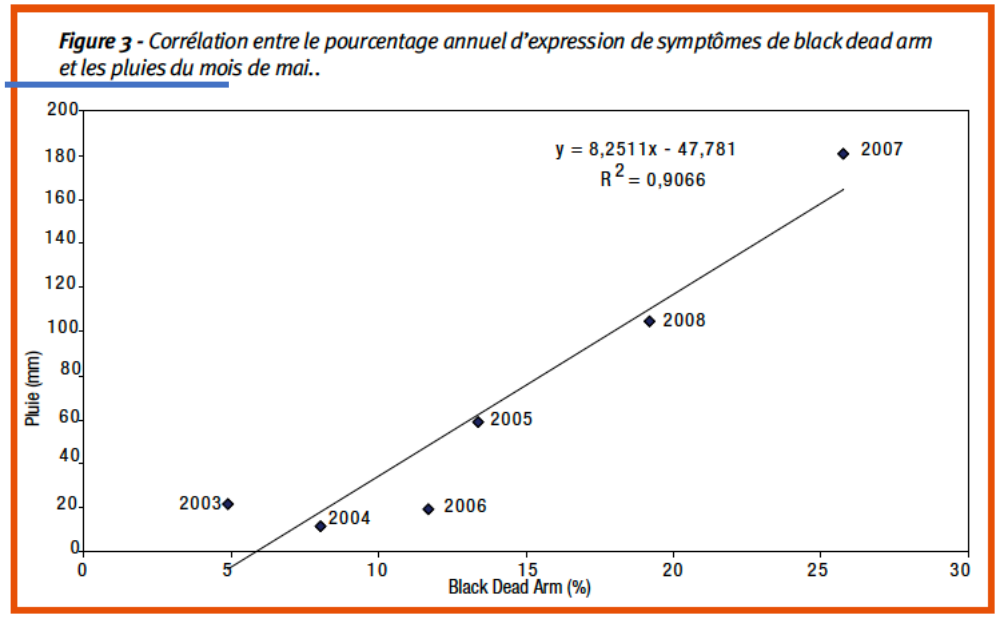
B. Roostocks		Tolerance to GTD	Tolerance to WS	Tolerance to HS
Kober 5BB	Esca	**Low** (Marchi et al., 2001)	**Int** (Marchi et al., 2001) **Low** (Lovisolo et al., 2016)	**Low** (Xu et al., 2014)
Riparia Gloire de Montpellier	Esca	**Low** (Eskalen et al., 2001)	**Low** (Lovisolo et al., 2016)	-
Schawrzmann	Esca	**High** (Eskalen et al., 2001)	**Int** (Lovisolo et al., 2016)	-
SO4	Esca	**High** (Marchi et al., 2001; Murolo & Romanazzi, 2014) **Low** (Eskalen et al., 2001)	**Low – Int** (Lovisolo et al., 2016) **Low** (Koundouras et al., 2008 ; Marchi et al., 2001; Murolo & Romanazzi, 2014)	**High** (Xu et al., 2014)
Teleki 5C	Esca	**High** (Eskalen et al., 2001)	**Low** (Lovisolo et al., 2016)	**High** (Xu et al., 2014)
110 R (Richter)	Esca	**Low** (Gramaje et al., 2010; Eskalen et al., 2001)	**High** (Lovisolo et al., 2016)	-
1103 P (Paulsen)	Esca	**High** (Eskalen et al., 2001) **Int** (Gramaje et al., 2010; Marchi et al., 2001) **Low** (Murolo & Romanazzi, 2014)	**High** (Lovisolo et al., 2016 ; Koundouras et al., 2008 ; Marchi et al., 2001 ; Murolo & Romanazzi, 2014)	
140 Ru (Ruggeri)	Esca	**Int** (Marchi et al., 2001) **Low** (Eskalen et al., 2001; Gramaje et al., 2010)	**High** (Lovisolo et al., 2016; Marchi et al., 2001)	-
161-49 C (Couderc)	Esca	**High** (Gramaje et al., 2010) **Low** (Eskalen et al., 2001)	**Low** (Lovisolo et al., 2016)	-
3309C (Couderc)	Esca	**High** (Eskalen et al., 2001)	**Low – Int** (Lovisolo et al., 2016)	-
41B (Millardet et de Grasset)	Esca	**Int** (Gramaje et al., 2010)	**Int** (Lovisolo et al., 2016)	-
420A (Millardet et de Grasset)	Esca	**High** (Eskalen et al., 2001) **Low** (Marchi et al., 2001; Eskalen et al., 2001)	**Int** (Marchi et al., 2001) **Low – Int** (Lovisolo et al., 2016)	-

Songy *et al*. 2019

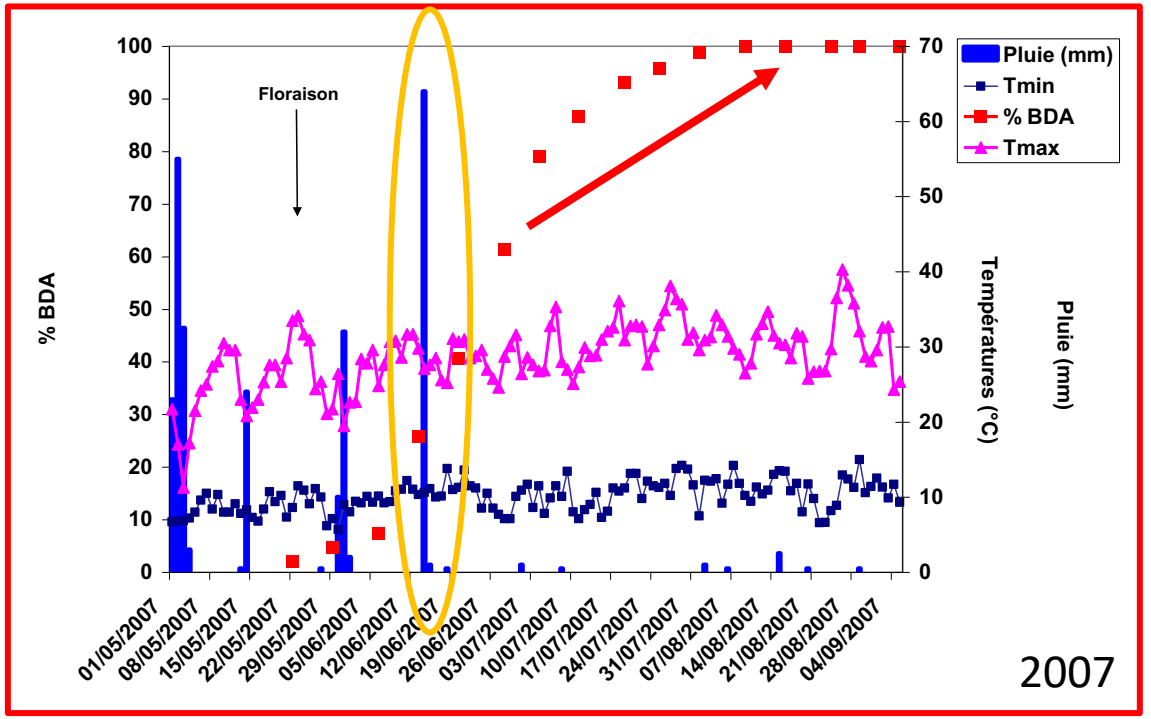
Preliminary observations

Rainfall





Relationship between rainfall & heat 30°C & phenological stage: flowering



annual fluctuation

Favorable conditions :
high rainfall
T ≈ 30°C

Costières de Nîmes
Sauvignon

Larignon 2009

Proposal of a scale by P. Larignon (IFV)

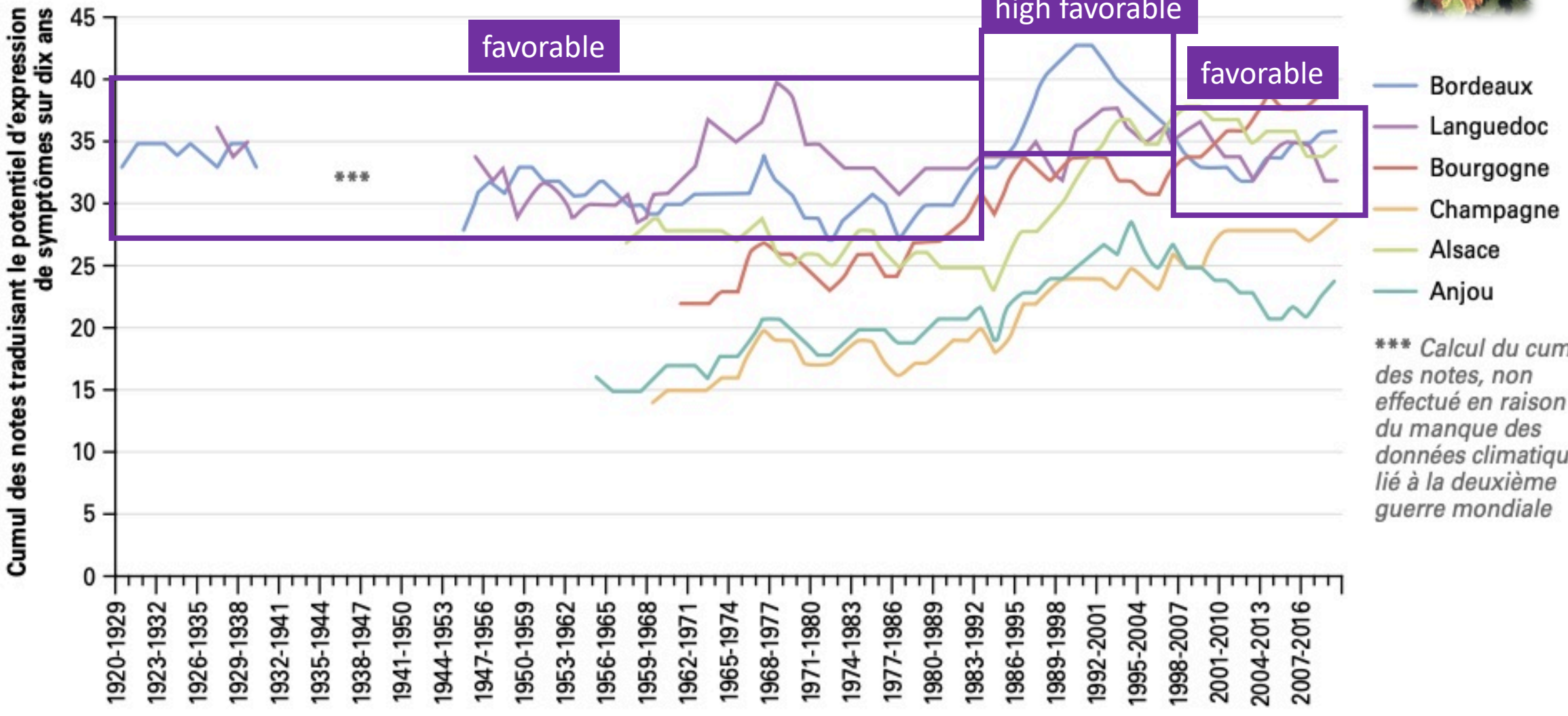
Tableau 1 : Grille d'évaluation du degré potentiel d'expression de symptômes de l'esca/BDA.

Notes	Degré d'expression	Niveau de pluviométrie (mm)	Nombre de jours T max > 30 °C
1	Très défavorable	Indifférent	≤ 2
		< 100	Indifférent
2	Défavorable	Entre 100 et 200	> 2 ≤ 20
		Entre 200 et 300	> 2 ≤ 10
		Entre 300 et 400	> 2 ≤ 5
3	Moyennement	Entre 100 et 200	> 20
		Entre 200 et 300	> 10 ≤ 20
		Entre 300 et 400	> 5 ≤ 10
		> 400	> 2 ≤ 5
4	Favorable	Entre 200 et 300	> 20
		Entre 300 et 400	> 10 ≤ 20
		> 400	> 5 ≤ 10
5	Très favorable	Entre 300 et 400	> 20
		> 400	> 10

Rainfall/Temperature :
1 may to 30 sept. (5 months)

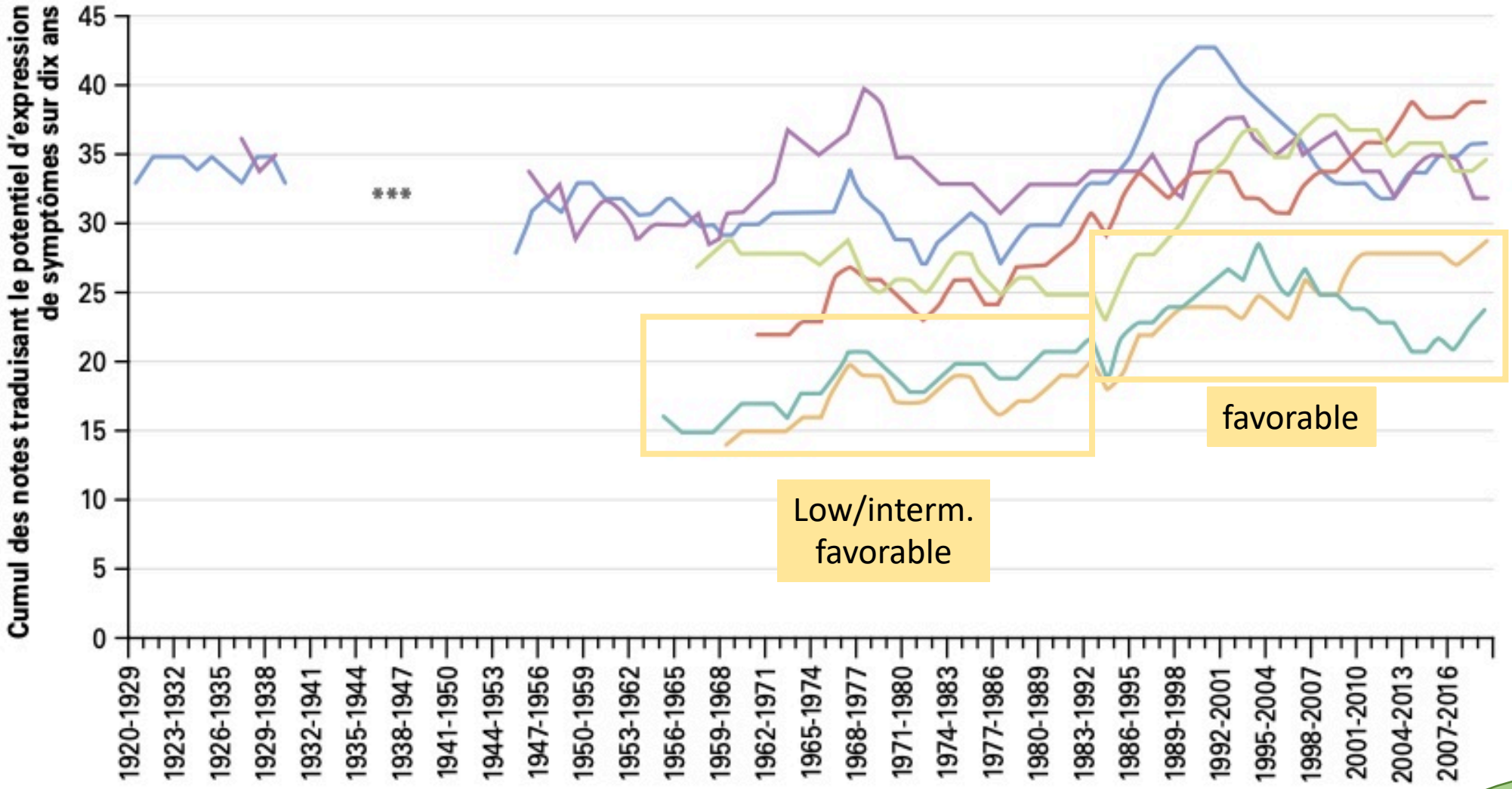
Analyse of data from **1920 to 2016**
in **5 French vineyards**
Bordeaux
Languedoc
Bourgogne
Alsace
Champagne

Figure 1: Évolution du degré potentiel d'expression de symptômes d'esca / BDA dans six vignobles français.



Bordeaux / Languedoc

Figure 1: Évolution du degré potentiel d'expression de symptômes d'esca / BDA dans six vignobles français.



Champagne area

Susceptibility to cultivars

Relationship with the use of Sodium arsenate….

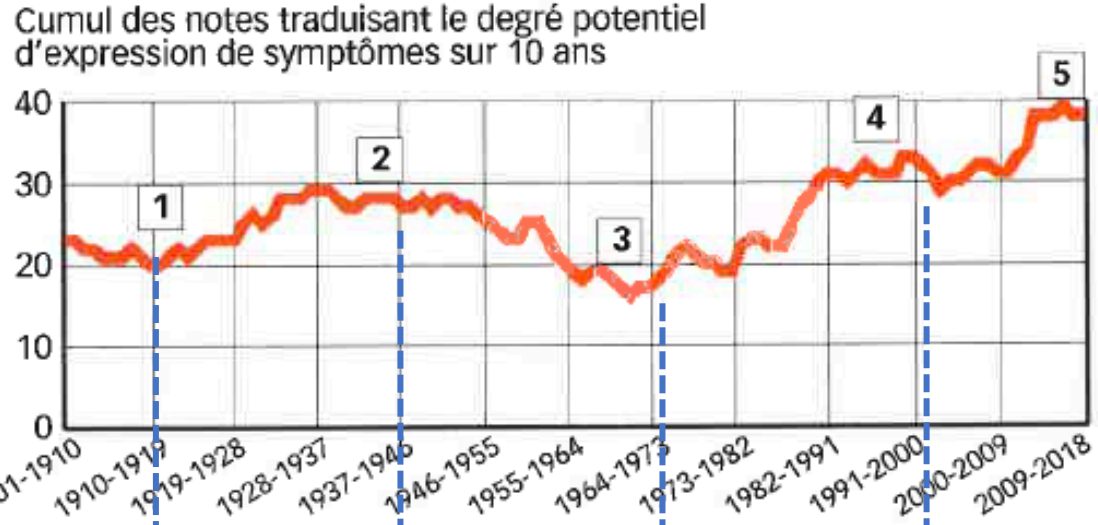
Bourgogne

1 — 5

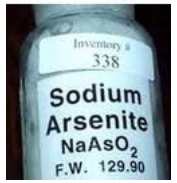
High **unfav**orable — High **fav**orable

Fig. 1 : Évolution des conditions climatiques favorables à l'expression de l'esca et du BDA au cours du XX^e et du début du XXI^e siècle en Bourgogne

Les chiffres 1 à 5 correspondent aux cinq principales étapes d'évolution des conditions favorables aux symptômes.



HWS — unfavo — favo — unfavo — favo — high favo



use

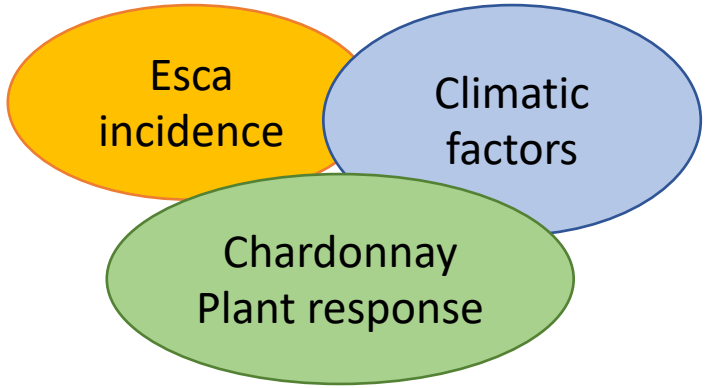
?

expression — low — low — low — low — increase

Literature

Observatoire GTDs

Larignon 2019



vineyard – 3 years (2016-18)
Spain, Barbastro area

Irrigation

Drop, 3.1 – 9.3 Lm^{-2}
May – September
depending on water requirement

Control, no irrigation

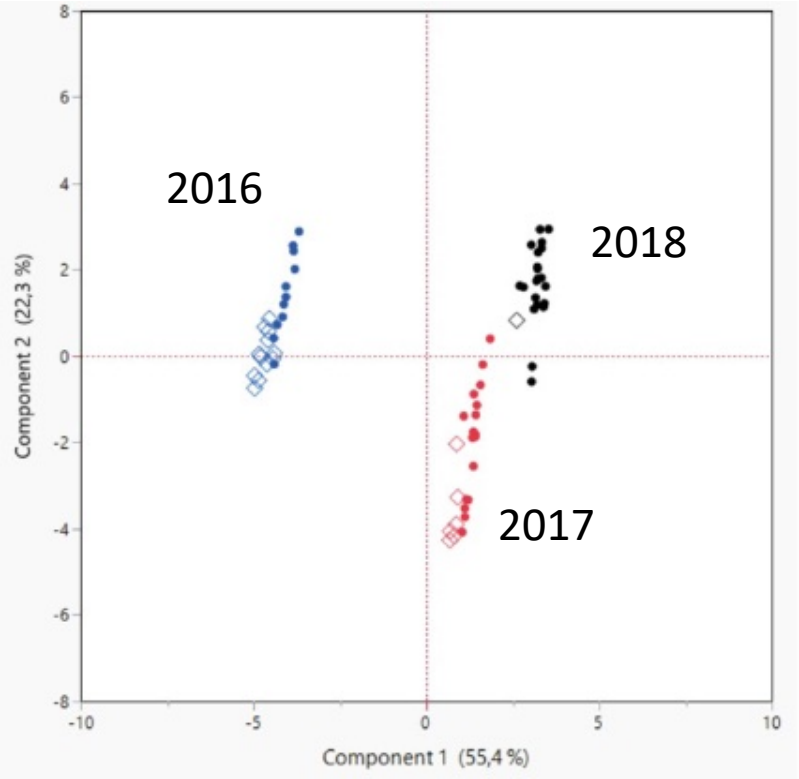
Plant responses

pea-size, pre-veraison, pre-harvest
Water potential
Photosynthesis parameters

Calvo-Garrido et al., 2020

Irrigation system is not comparable to heavy rainfall over a short period

Vintage effect

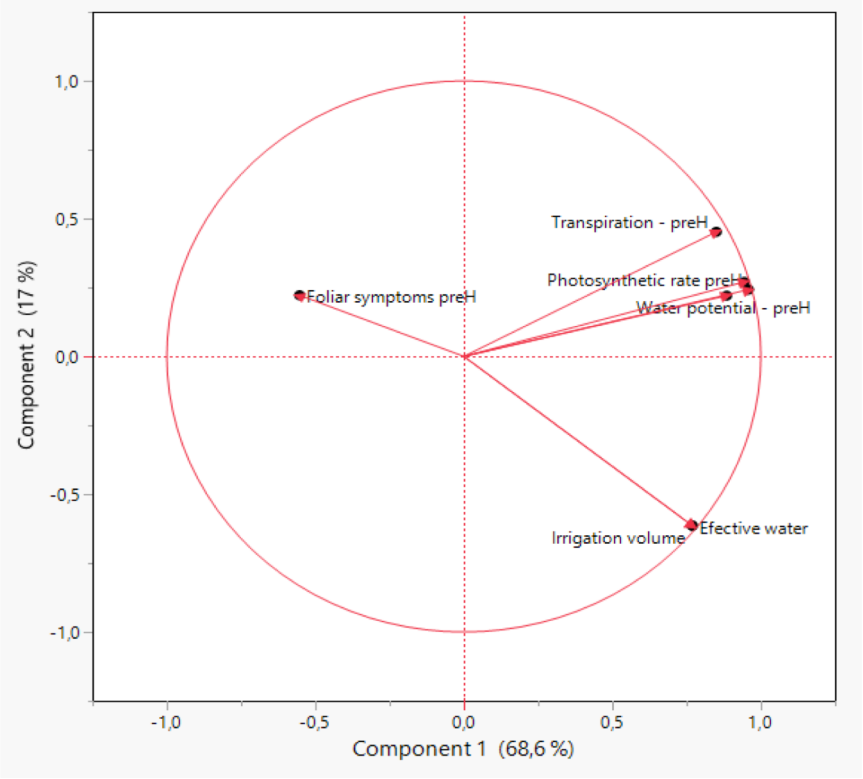


Asymptomatic plants

Esca symptoms

2017 Irrigation effect

Esca incidence Irrigated < control



Relevant parameters

water availability/transpiration rate and period of heat (T°C> 35°C)

Irrigation **before flowering**, increase of water availability for vine, decrease the incidence of Esca

Calvo-Garrido et al., 2020

Projet GTDfree

Climatic data Vineyard

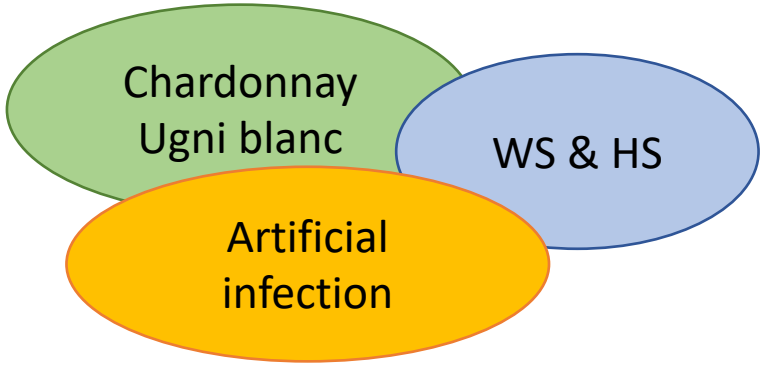
	Years	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006
Cognac	Number of days Tmax ≥ 35°C	1	1	2	3	2	3	3	0	1	8
	Mean Tmin	18,9	18,0	20,1	17,4	20,9	15,6	17,3	-	14,8	19,6
Champagne	Number of days Tmax ≥ 35°C	3	1	1	2	2	0	1	0	0	1
	Mean Tmin	17,9	15,7	17,7	16,1	16,6	-	20,6	-	-	16,6

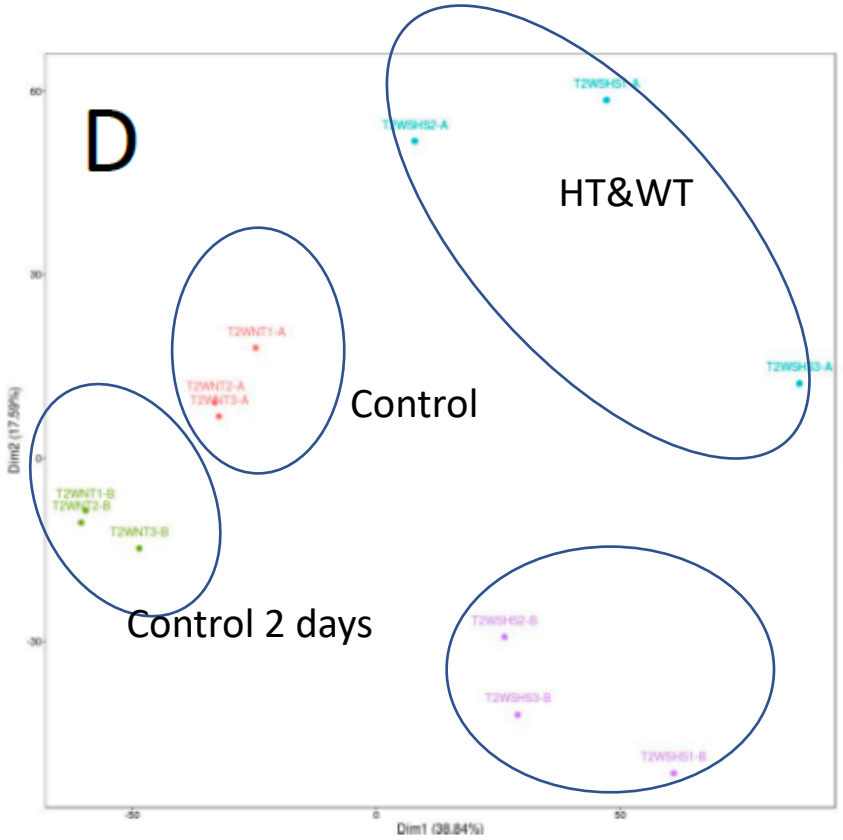
Tolerance of fungi to high temperature

	Optimum temperature for mycelial growth	Tmin and Tmax for mycelial growth	References
Diplodia seriata	27,6°C	4°C - 35°C	Qiu *et al.*, 2016
	25°C	15°C - 36°C	Bellée *et al.*, 2016
	26,8°C	10°C – 35°C	Pitt *et al.*, 2013
	26,8°C	10°C – 40°C	Úrbez-Torres *et al.*, 2006
Neofusicoccum parvum	22-28°C	15°C - 33°C	Bellée *et al.*, 2016
	30,2°C	4°C - 35°C	Qiu *et al.*, 2016
	26,8°C	10°C – 35°C	Pitt *et al.*, 2013
	28,2°C	10°C – 40°C	Úrbez-Torres *et al.*, 2006

HS 35°C day & 18°C night (16h/8h) during **3 days** with **WS 50%**

Projet GYDfree





Differential responses according to the pathogens

Double stress increase the aggressiveness of *D. seriata*

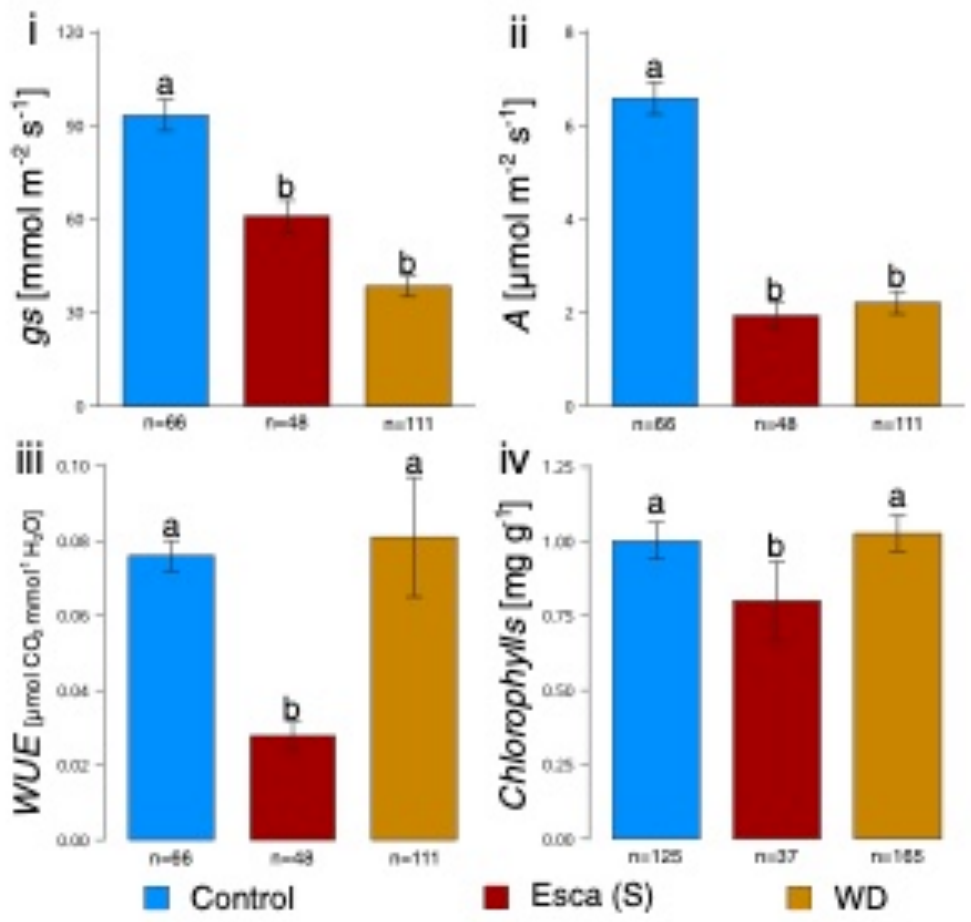
Differential plant responses according to the stress conditions

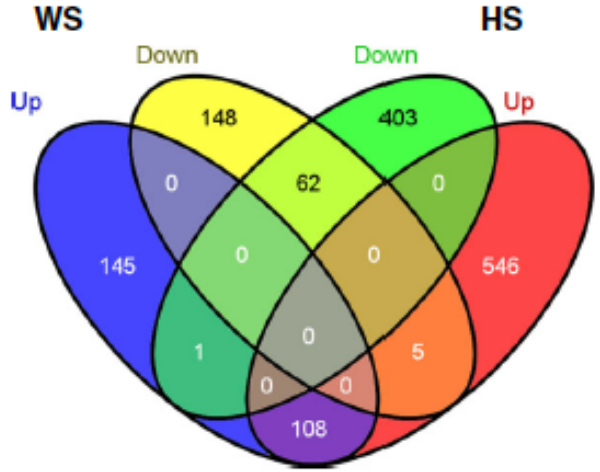
Fernandez et al., in preparation

GTD foliar symptoms expression

Drought stress

Photosynthesis parameters

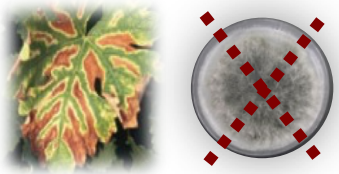


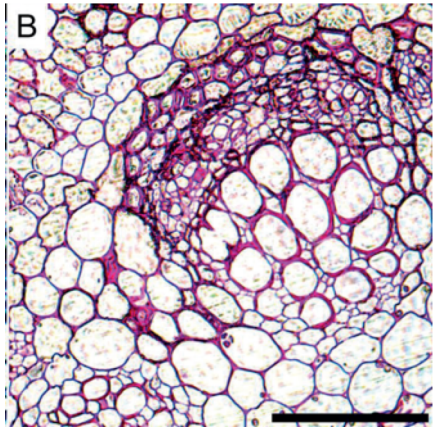


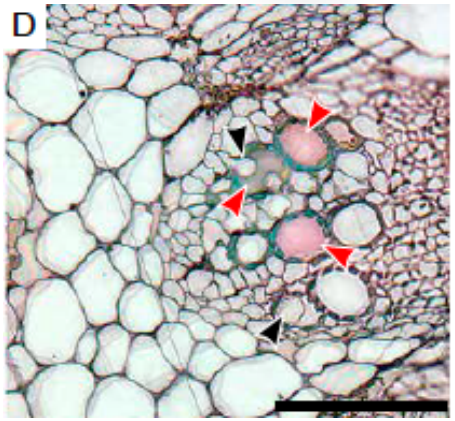
differential responses
WS & HS
Esca & WS
BUT in both
water transport & carbon balance altered

Bortolami *et al.* 2021, Rocheta *et al.* 2014

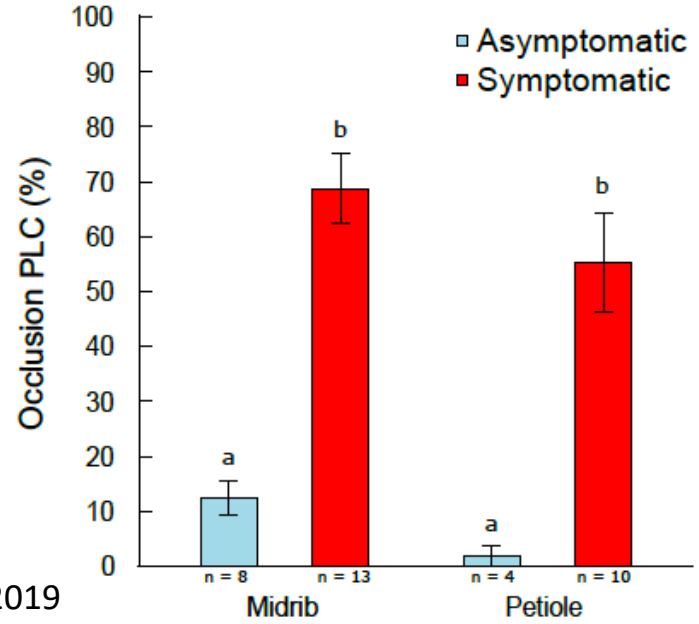
WS is not enough to explain esca expression





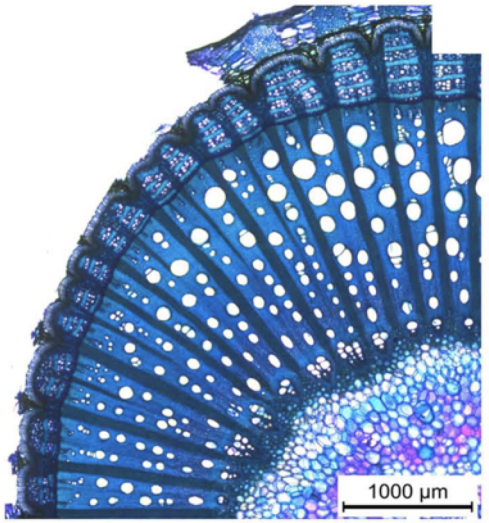


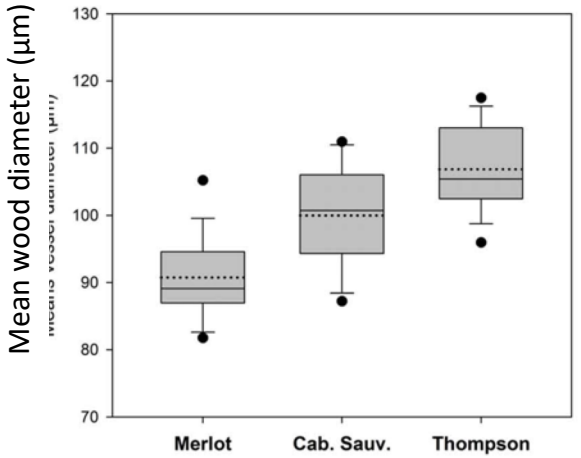
vessel occlusions



Bortolami *et al.* 2019

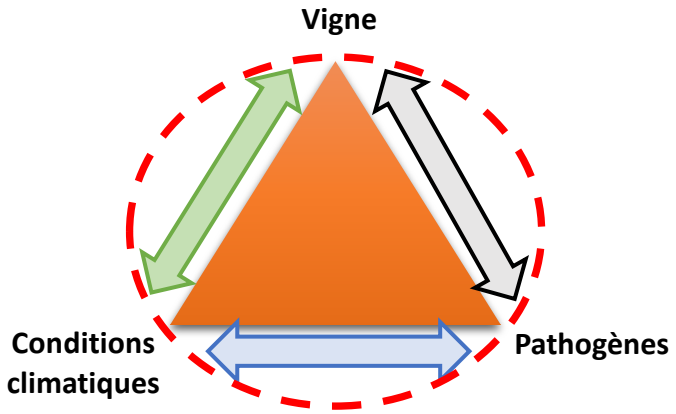
Vessel diameter

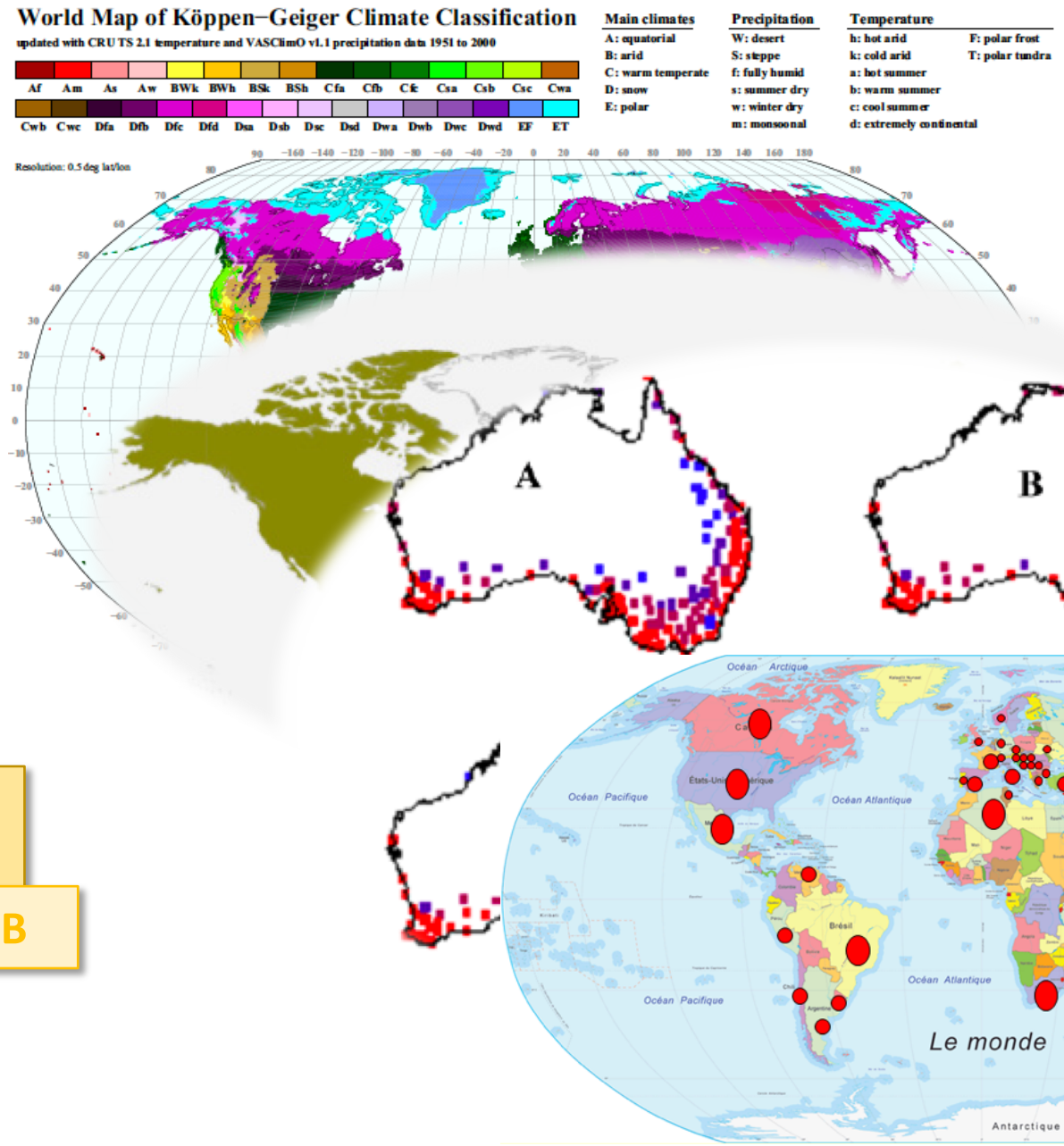




Susceptibility + ++ +++

Pouzoulet *et al*. 2014





Climat

Cépages (Chardonnay)

Pathogènes (Australie)

Incidence des MDB

Kottek et al. 2006, Qiu *et al*. 2016, OIV 2017

A control **irrigation before flowering**,
if necessary, could limit foliar symptom expression (*in Chili, irrigation and few GTDs*)

Water Stress, depending on intensity and timing, is not enough to induce Esca disease

Periods with high rainfall & warm temperature are favorable to Esca disease expression

As it is not possible to control climate,
what we could do to reduce the incidence of GTDs…

What is known on the vineyard GTD management…

Prophylactic methods

Eliminate dead arm, dead vine
Vine training: Guyot better than Cordon (*Eutypa*)
Limit number and size of pruning wounds
Trunk renewal
Re-grafting
Trunk surgery or “Curetage”

Best period to prune? early *versus* late
depend to GTD diseases and climatic conditions

Pruning wound protection

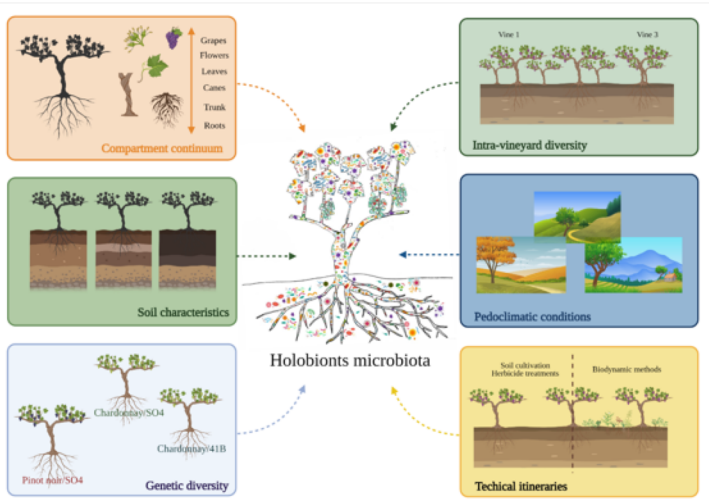
Physical by pastes
BCA - Niche competition

Control the plant vigor

Especially for
Esca & Botryosphaeria dieback
Balance leaves / fruits
(*number of buds*)

What is currently being tested …

Hydrogen peroxide application
Plants extracts
Combination of BCAs
Trunk injection



What is currently being studied … plant & soil microbiome

Mondello et al. 2018, Larigon 2016, Bettenfeld et al., 2021

Acknowledgements

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Projet GYDfree

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Hennessy COGNAC

BORDEAUX SCIENCES AGRO

ISVV INSTITUT DES SCIENCES DE LA VIGNE ET DU VIN BORDEAUX AQUITAINE

INRAE

VITEC PARC TECNOLÒGIC DEL VI

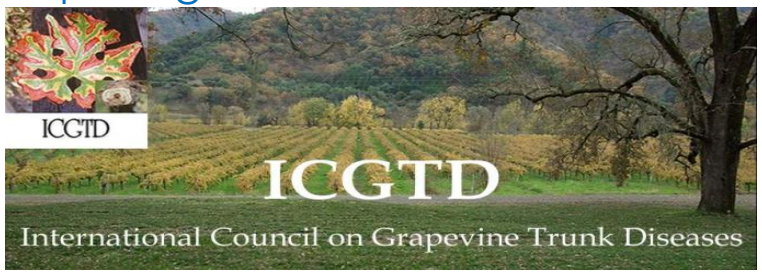
BIOGER

Agroécologie Dijon Unité de Recherche

IFV INSTITUT FRANÇAIS DE LA VIGNE ET DU VIN

International Council of Grapevine Trunk Diseases

http://icgtd.ucr.edu/



Merci à tous

Any questions…..

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