ARCHITECTURE, MICROCLIMATE, VINE REGULATION, GRAPE BERRY and WINE QUALITY : HOW TO CHOOSE THE TRAINING SYSTEM ACCORDING TO THE WINE TYPE ?

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Summary
This synthetic presentation deals with :

- A description of the variability and the main models of grapevine canopy architecture in the world.
- A precision on the model « potential exposed leaf area SFEp », which estimates the potential of net carbon balance of the plant, and shows a regulating effect of high SFEp levels on production decrease.
- A presentation of plant global regulating processes influenced by the training system on the basis of the biological triptych theory : relation between (SFEp) and dry matter production (« puissance ») fitted by vigour ; relation between SFEp and bunch microclimate fitted by leaf exposure/bunch exposure ratio.
- The stability of the microclimatic equilibrium between leaf and bunch due to the architecture, in comparison with general climatic variations (Multicriteria Climatic Classification).
- Some consequences of SFEp and berry microclimate variations on Syrah wine typeness and quality, on the basis of a comparison in a dry « terroir » between the Vertical trellis, the truncated Lyre, the Lyre-volume.
- A general proposal over a 30 year experience of the most suitable training systems according to the objectives of production and quality. A special focus is made on the choice of the training system in function of the wine typeness (ie : « Lyre wine » concept).

1 – Description of the main models of grapevine canopy architecture :

This worldwide general description is presented in the book : Carbonneau Alain et Cargnello Giovanni, 2003.Architectures de la Vigne et systèmes de conduite. Dunod Paris Editeur.
Figure 1 illustrates the 50 basic forms or architecture models, to which are related 250 precise training systems. This is the result of a general classification based on morphological descriptors of the vine structure.
Considering a given training system, it is important to know the main particularities and the architecture model it belongs to, and if another training system belongs or not to the same group.
Figure 2 illustrates the 10 architectures of Cabernet-Sauvignon at INRA Bordeaux which were studied by Carbonneau et al. (1978) and Carbonneau (1980) and produced the basic results which are analyzed in the following.

2 – Precisions on the model of potential exposed leaf area (SFEp) :

SFEp estimates, on the basis of simple measurements of the geometry of the canopy, the potential of net carbon of the plant (Carbonneau, 1995). It is used in more complex models (Carbonneau, 2004).
Figure 3 shows the relationship between SFEp and Dry Matter Production or « puissance » which is the total dry matter produced by the vine and estimated as : 0,5 B (pruning weight) + 0,2 P (harvest weight).

It appears an experimental curve (the general tendency is presented) which clearly indicates an optimum. This tendency is in interaction with vigour or water availability.
The optimum itself is due to a regulating process at high SFEp levels which induces some water limitation in the foliage and thus some limitation of growth and production. This feed back effect is part of the explanation of the concentration of sugars and mostly of major secondary products or polyphenol compounds in the berry.

3 – Plant global regulating processes :

The concept of biological triptych was presented by Carbonneau (1996) and by Carbonneau and Deloire (2001). It is based on the existence of an elementary organization of biological functionning : source – structure – regulating system. Many basic phenomenons have a common regulating system – water limitation – which insures the coherence of plant physiology. This triptych concept concerns different scale levels, from the gene to the whole plant, and different biological fields such as nutrition, growth, development. Figure 4 illustrates this theory.
Figure 5 illustrates 2 kinds of triptychs related to grapevine architecture : SFEp – « puissance » or dry matter production – vigour (which fits SFEp to « puissance ») ; and SFEp – bunch microclimate – leaf exposure/bunch exposure ratio (which fits SFEp to bunch microclimate or sink effect).
Table 1 shows the basic data allowing to build up the corresponding experimental curves (Carbonneau et al., 1978 ; Carbonneau, 1980). Figure 6 is the result of this study. It is important to consider that architectures or training systems must be compared over a range of SFEp in relation to « puissance » or bunch microclimate, and positionned on those graphs according to vigour or to leaf exposure/bunch exposure ratio respectively. Carbonneau (1987, 2001) presented plant regulating phenomenons directly due to water regime.

4 – Leaf exposure / bunch exposure as an invariant of architecture :

According to the Multicriteria Climatic Classification published by Tonietto and Carbonneau (2004), it appears that :
- Dryness index (IS) varies from 1 to 4 (condidering center of classes) ;
- Heliothermal index (IH) from 1 to 2 ;
- Night Cold index (IF) from 1 to 2.

Looking at microclimatic variations among architectures (Carbonneau, 1980 ; table 1), it appears that :
- Leaf light microclimate (SFEp, PAR) vary roughly from 1 to 2 ;
- Light bunch or berry microclimate varies roughly from 1 to 4 ;
- Leaf exposure/bunch exposure ratio varies roughly from 1 to 3, and is rather independant of absolute values of energy level intercepted by leaves or bunches.

Thus, architecture plays an important role on microclimate and variations are as important as these due to general climate concerning light variables. It is not so important for temperature or water microclimate, even if those variations are significant.
Besides, the ratio leaf exposure/bunch exposure can be considered as an invariant of vine architecture. This could explain that some results coming from some architectures or training systems are shared around the viticultural world (ie : fruity characters, aroma complexity, equilibrated polyphenol structure of « Lyre » wines).

5 – Syrah wine typeness and quality according to Vertical trellis, truncated Lyre or Lyre-volume (Audrey Jolivot, Alain Samson, Hernan Ojeda : INRA Pech Rouge):

Figure 7 presents the result of a multivariable statistical analysis of sensorial analysis of experimental Syrah wines. Vines are grown at INRA Pech Rouge experimental unit, in a dry « terroir » particularly since end of phase 1 of berry development. The comparison is between the Vertical trellis (« Espalier »), the truncated Lyre and the Lyre-volume. Planting density is also crossed with architecture in a factorial designed.
The truncated Lyre is different from the 2 others by having more SFEp per unit of production.

It appears that all wines from those architectures or training systems are rich in structure and colour ; they present aromas of mature red fruits or jam, and very often of liquorice. But the wines are clearly distinguished by other characters, and the effect of architecture is more important that the planting density effect. Additional data show that those results are quite stable over vintages (2001, 2002, 2003).
Precisely analyzing, the wines from those 3 training systems reveal few but particular, dominant and frequent characters of typeness, which allows for instance to speak about « Lyre wines » :

- Vertical trellis : black pepper (frequent), density and some desequilibrium (often) ;
- Truncated Lyre : violet (frequent), colour intensity (often), density and equilibrium (often) ;
- Lyre-volume : more close to truncated Lyre than to Vertical trellis, with some vegetable aroma (often).

NB : From other experiments, such as the Syrah network of Agro Montpellier / INRA, and from worldwide observations of Lyre wines also, it appears that the results fit well the above characteristics.

6) Choice of the training system in function of objectives of production and quality, and of wine typeness.

Our 30 year experience of canopy management on the basis of Ecophysiology and applied Viticulture, allows to present the following synthetic choices (Carbonneau et Cargnello, 2003).

- ***General principles*** *for efficient training :*
- *SFEp must always exceed a minimum value ;*
- *SFEp must be related to production P (dry matter or yield) ;*
- *An optimum equilibrium is between « SFEp – P – V (vigour or water availability) » ;*
- *Bunches and berries must have an optimal exposure avoiding any excess or dense shade ;*
- *Volume of old wood or reserves must be promoted accortding to the production capacity.*

- *Technical choices of training systems when* ***quantity*** *is a priority :*
- *table grapes :* ***open Lyre****, (« Roof » shapes) ;*
- *grapes for brandies :* ***Minimal Pruning (high vigour)*** *;*
- *wine grapes for entrance and centre of quality range :* ***Minimal Pruning (medium vigour), open Minimal Pruning, Lys, foldable Lyre.***

- *Technical choices of training systems when* ***quality*** *and* ***typeness*** *are priorities :*
- *characterization of the Basic Terroir Unit – UTB (mesoclimate x soil) ;*
- *definition of the Viticultural Terroir Unit – UTV (UTB x variety x technics) ;*
- *precise adaptation of architecture and training system in the UTV context, looking for a moderate water limitation (Carbonneau, 1987, 2001);*
- *wine grapes for top of quality range, for « crus » :* ***Lyre (open, truncated, foldable)*** *;*

NB. Tradition is a priority : ***conventional or historical trainings (ie : high density Espalier) ;***
Complementary choices according to vineyard : ***Lys, Niofcasarsa, erected Vase, Arpava.***

BIODIVERSITY concerns architectures and training systems too, and must be optimized !

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Legends of figures :

- *Figure 1(a and b) : 50 basic forms or architecture models rassembling 250 worldwide training systems.*
- *Figure 2 : 10 architectures of Cabernet-Sauvignon vines studied at INRA Bordeaux.*
- *Figure 3 : Theoretical relationships between SFEp and Dry Matter Production. The central curve is the general tendency drawn from vineyard observations.*

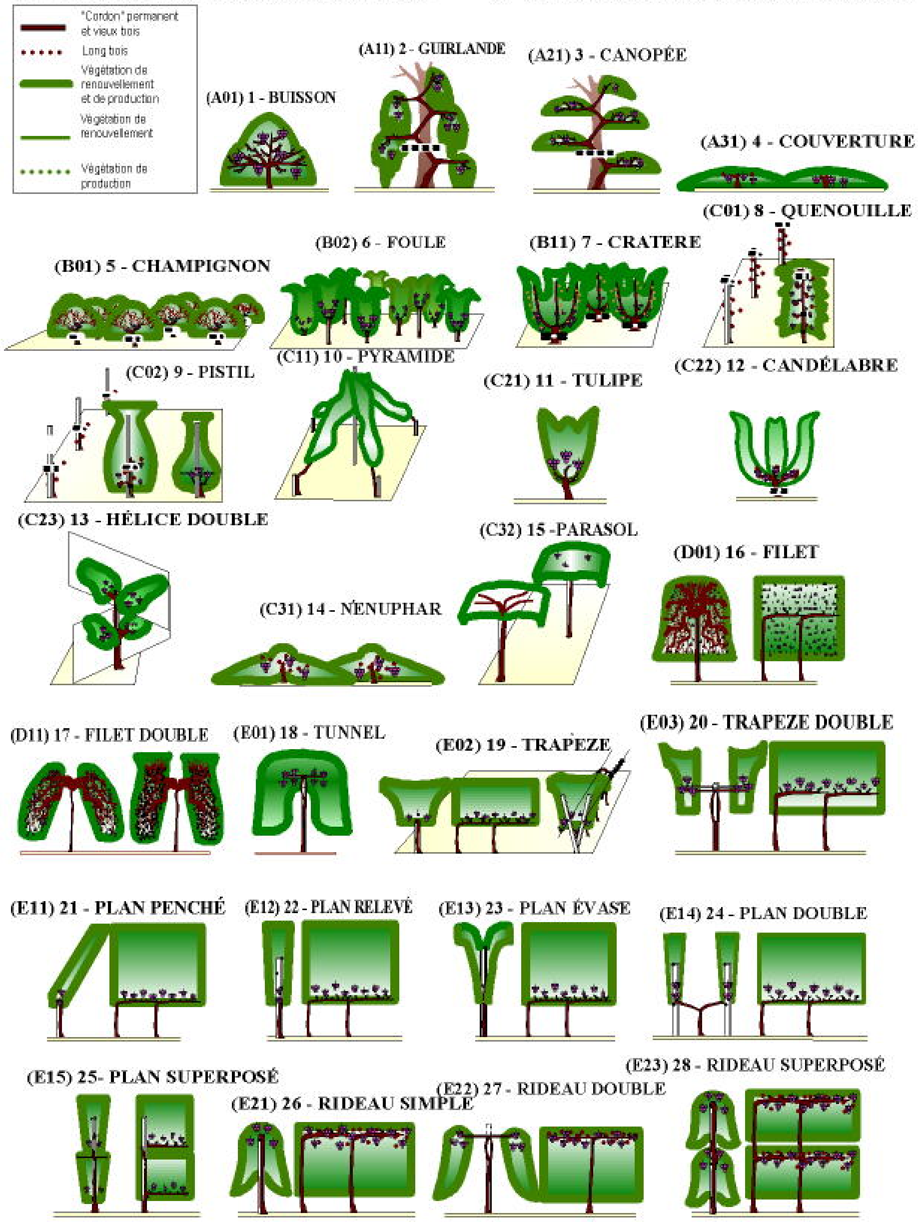
ANALYSE DES "ARCHITECTURES" DE VIGNES

DICTIONNAIRE DES SYSTEMES DE CONDUITE (1)

FIGURES DES FORMES DE BASE

A. CARBONNEAU **1997-1998-1999-2001-2002** **G. CARGNELLO**

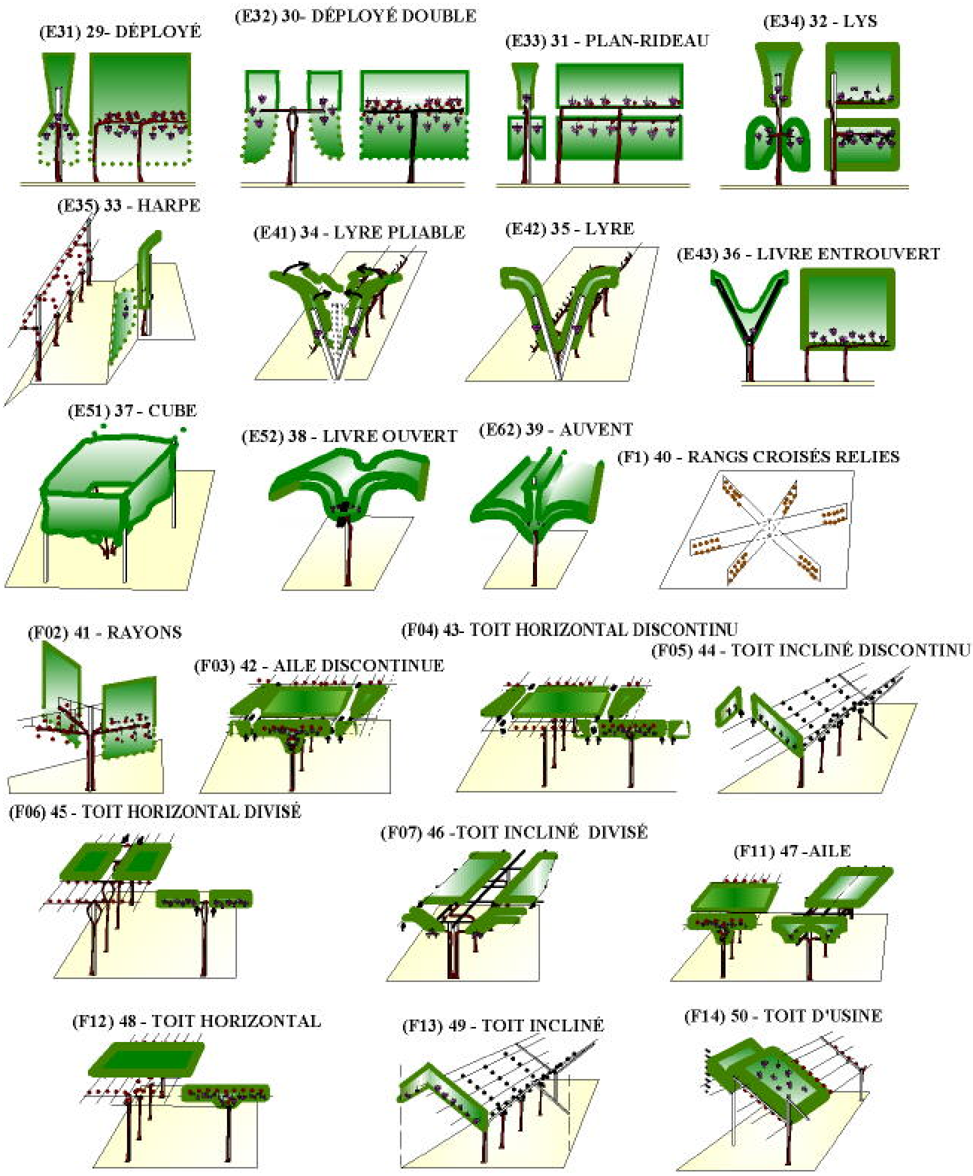
ISVV-Agro;Place P.Viala-34060 Montpellier Cedex1-France ISV-TC;Viale 28 Aprile,26-31015 Conegliano(Treviso)-Italie

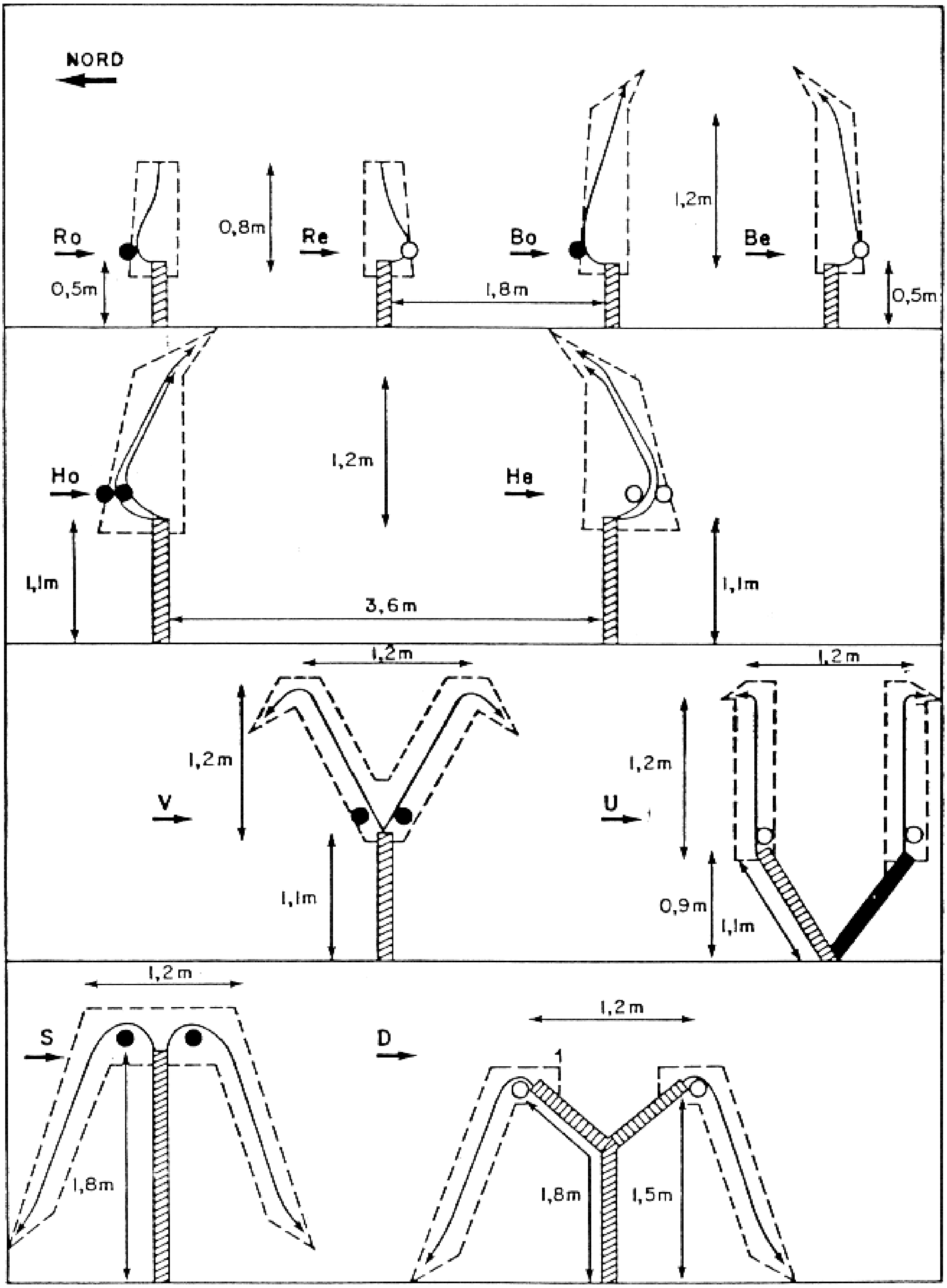


(1) Avec le concours du GESCO (Groupe d'Etude des Systèmes de COnduite de la vigne) et notamment du Giuliana GAY-EYNARD

ANALYSE DES "ARCHITECTURES" DE VIGNES
DICTIONNAIRE DES SYSTEMES DE CONDUITE ①
FIGURES DES FORMES DE BASE

A. CARBONNEAU 1997-1998-1999-2001-2002 G. CARGNELLO
ISVV-Agro;Place P.Viala-34060 Montpellier Cedex1-France ISV-TC;Viale 28 Aprile,26-31015 Conegliano(Treviso)-Italie




NORD
Ro
0,5m
0,8m
Re
1,8m
Bo
1,2m
Be
0,5m
Ho
1,1m
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3,6m
He
1,1m
1,2m
1,2m
V
1,1m
1,2m
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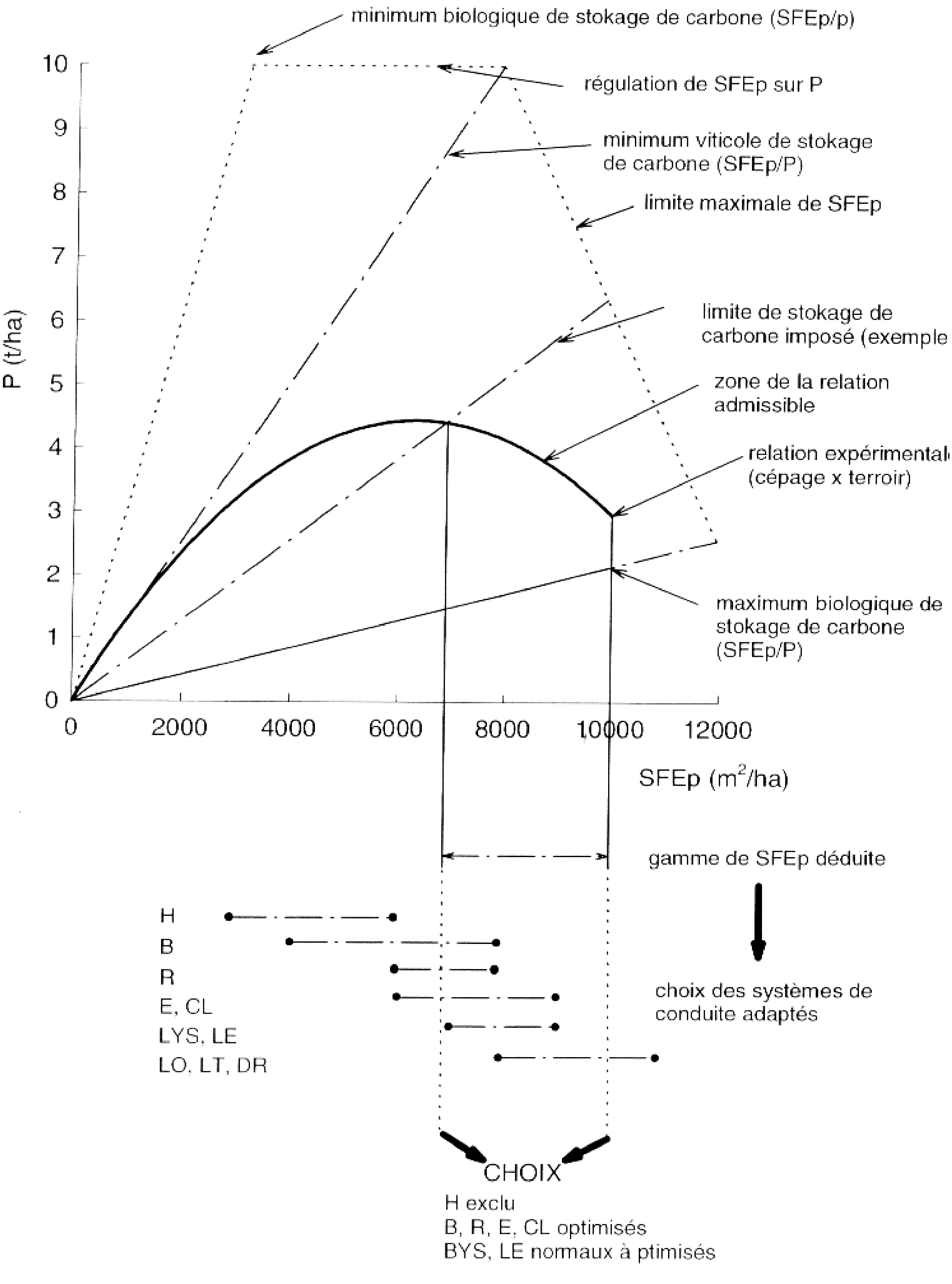
1
1,8m
1,5m


minimum biologique de stokage de carbone (SFEp/p)
régulation de SFEp sur P
minimum viticole de stokage de carbone (SFEp/P)
limite maximale de SFEp
limite de stokage de carbone imposé (exemple
zone de la relation admissible
relation expérimental
(cépage x terroir)
maximum biologique de stokage de carbone (SFEp/P)
P (t/ha)
SFEp (m²/ha)
0
2000
4000
6000
8000
10000
12000
1
2
3
4
5
6
7
8
9
10
gamme de SFEp déduite
H
B
R
E, CL
LYS, LE
LO, LT, DR
choix des systèmes de conduite adaptés
CHOIX
H exclu
B, R, E, CL optimisés
BYS, LE normaux à ptimisés

BASIS OF BIOLOGICAL FUNCTIONNING

BASIC TRIPTYCH :

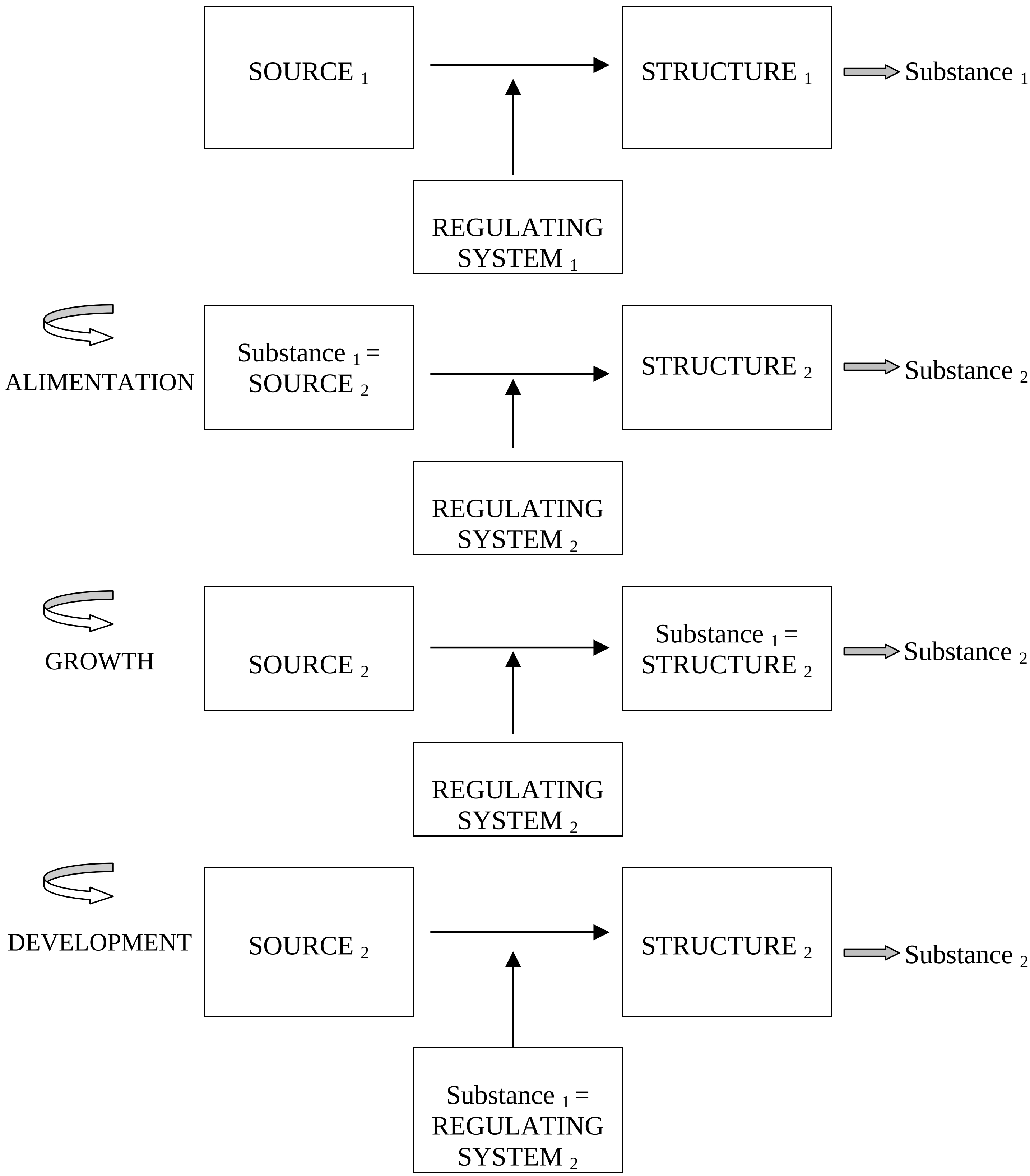
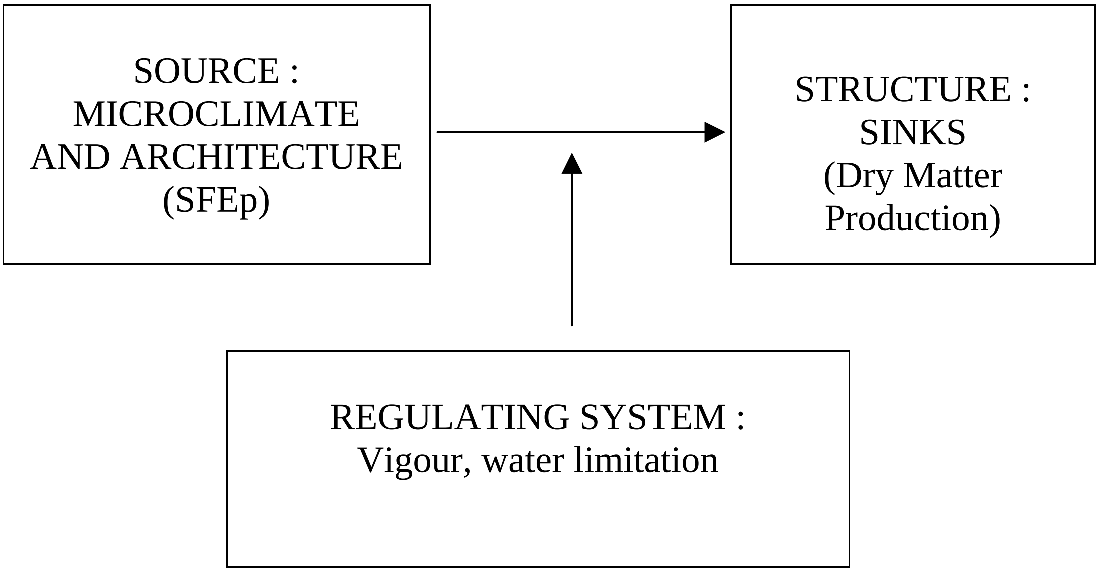


Figure 4 – Basic biological triptychs and theoretical types.

BASIS OF BIOLOGICAL FUNCTIONNING

PLANT TRIPTYCH :

Example 1 :



Example 2 :

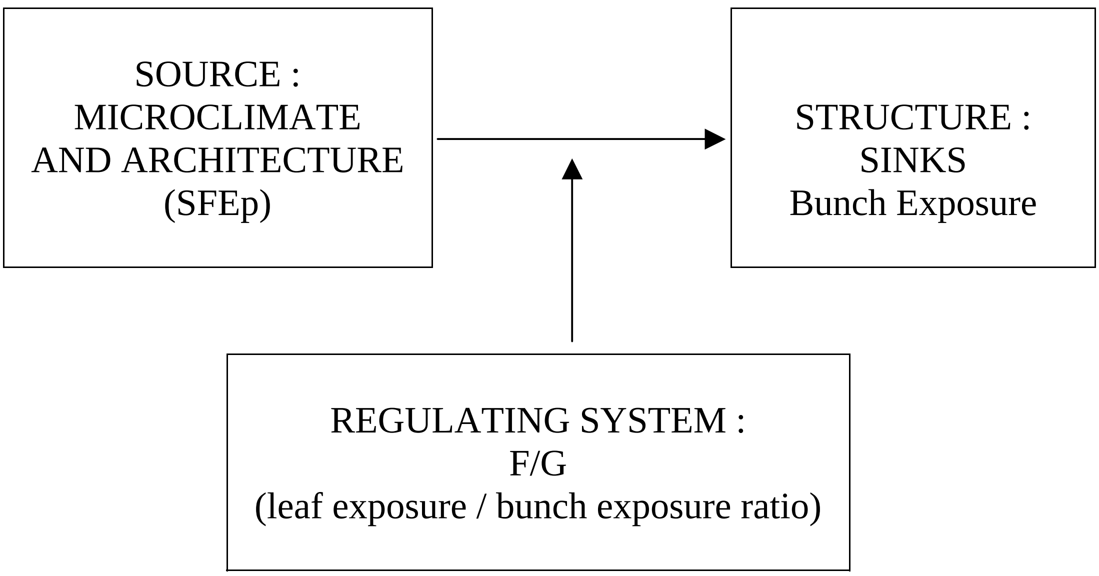
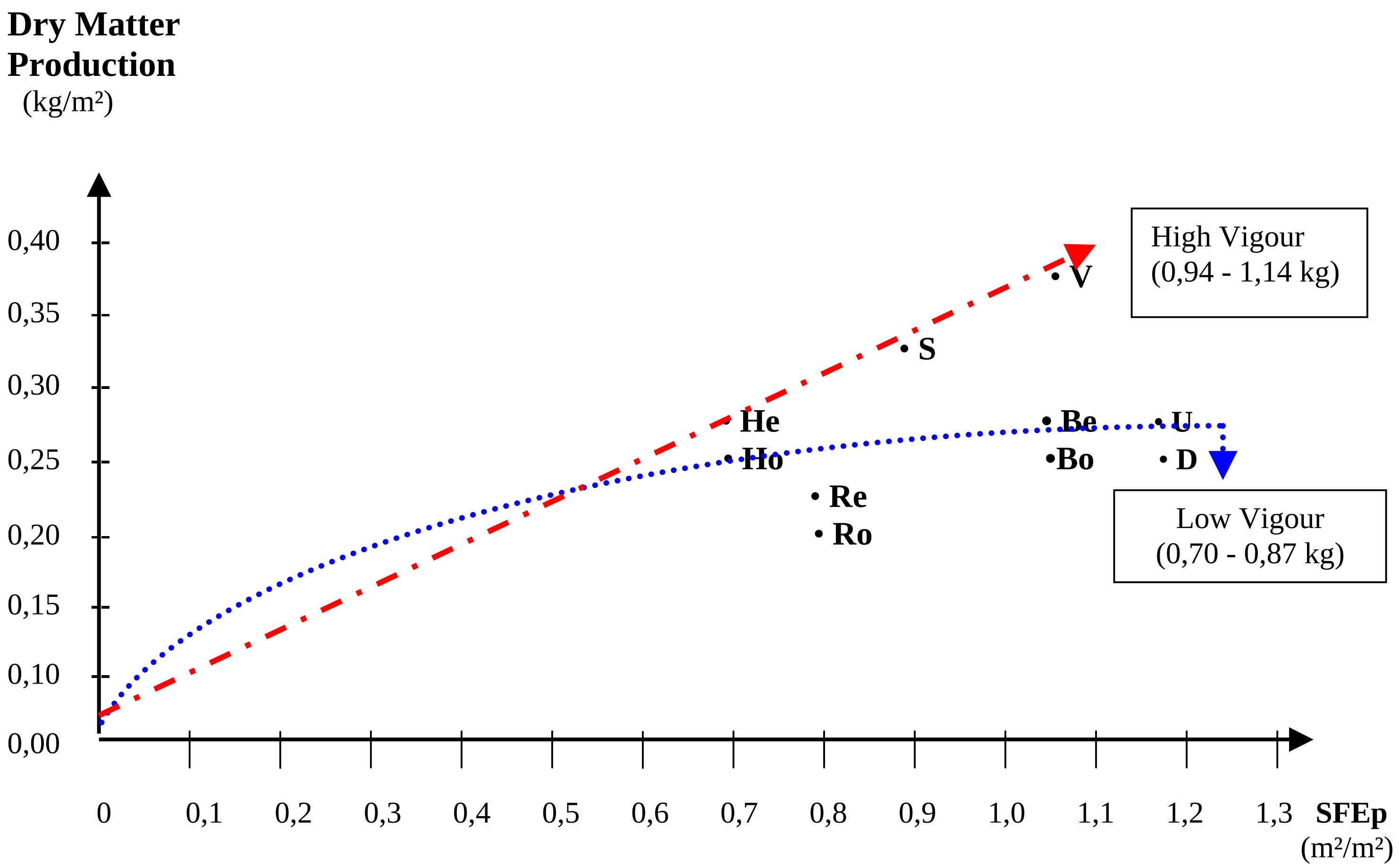


Figure 5 – Vine triptychs in relation to architecture and microclimate: « SFEp – DMP – V », « SFEp – EG – F/G ».



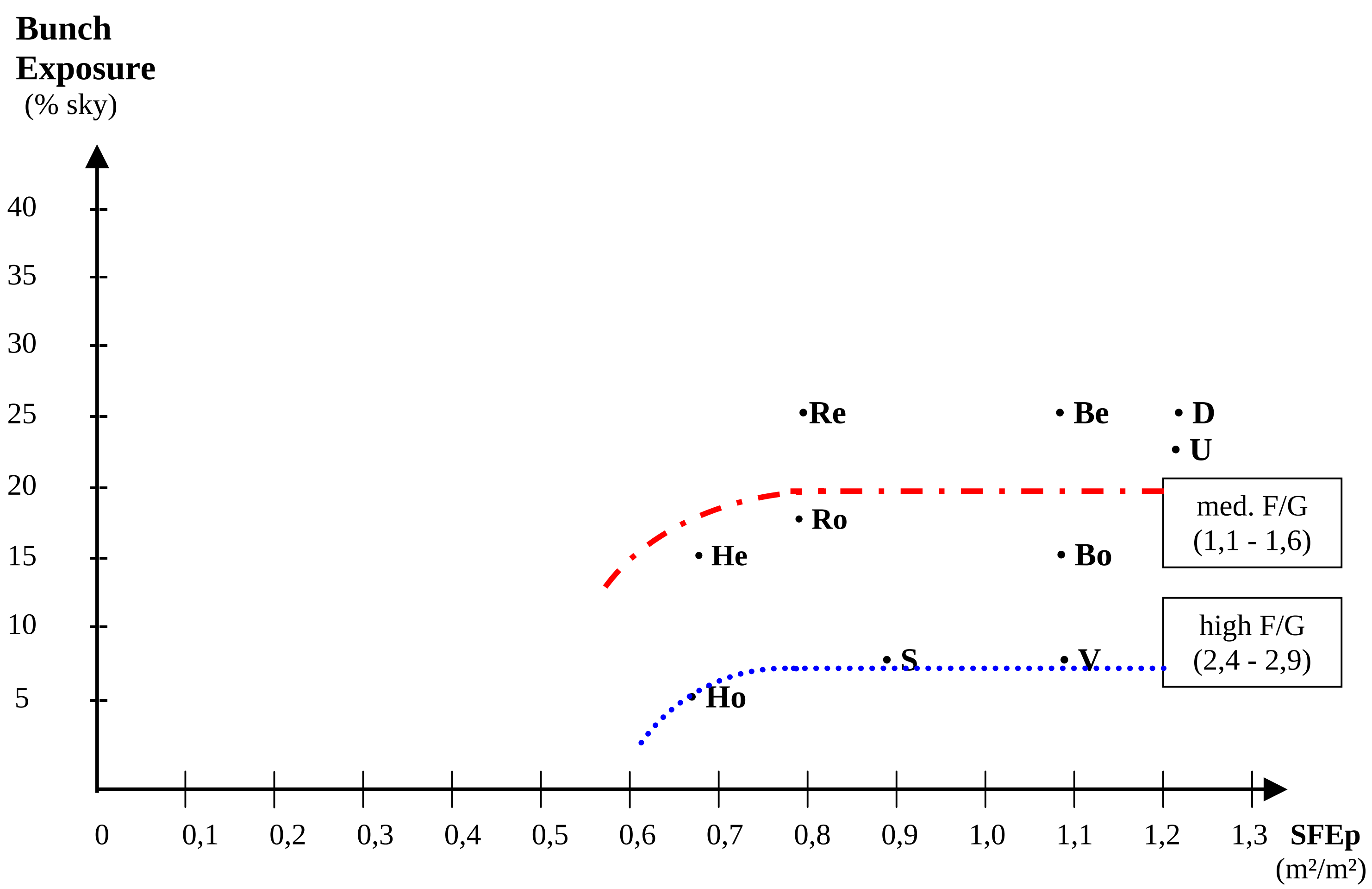
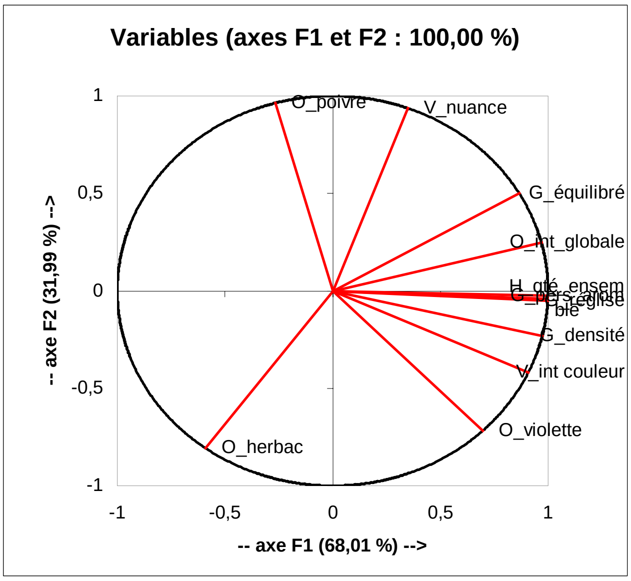
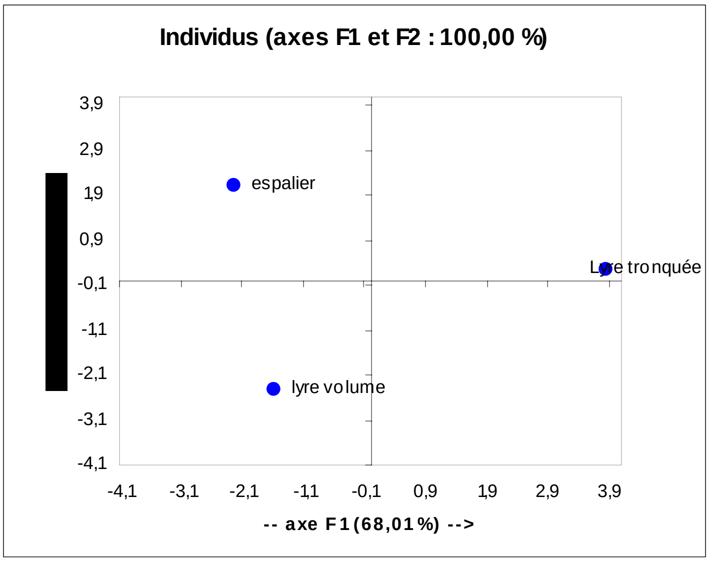


Figure 6 – Experimental application of the plant biological triptych theory, based on SFEp with : Dry Matter Production and Vigour, Bunch Exposure and F/G (Leaf exposure/Bunch exposure ratio).



Correlation circle - axis 1 and 2 – projection of significant variables



projection of wines from : Vertical trellis (Espalier), truncated Lyre, Lyre-volume

Figure 7 – Graphic result of a Principal Component Analysis on sensorial analysis data of 2001 Syrah wines. Experiment on « architecture x planting density » at INRA Pech Rouge Experimental Unit.

TABLEAU 1 – Ecophysiology results of the trial on architectures. Cabernet-Sauvignon, INRA Bordeaux (Carbonneau et al., 1978).

FORM	S.E.C.V. Exterior Surface of Végetal Canopy (m^2/m^2)	S.F.E.p. potential Exposed Leaf Area (m^2/m^2)	P.A.R. mean per leaf (% incident)	E G Bunch Exposure (% sky)	F / G Leaf exposure / Bunch exposure ratio	V Vigour : mean shoot weight (kg)	MS Dry Matter : 0,5 B + 0,2 P (kg/m^2)
Ro	1,3	0,8	27,8	18,2	1,5	0,52 (rognage)	0,23
Re	1,4	0,8	31,7	25,4	1,3	0,49 (rognage)	0,24
Bo	1,7	1,1	23,4	16,9	1,4	0,71	0,26
Be	1,8	1,1	24,9	23,8	1,1	0,87	0,28
Ho	0,9	0,7	15,7	6,3	2,5	0,71	0,26
He	1,0	0,7	19,1	16,8	1,1	1,06	0,27
S	1,2	0,9	19,0	8,0	2,4	0,94	0,30
D	1,8	1,2	31,6	25,2 (*)	1,3	0,81	0,27
V	1,2	1,1	21,8	7,6	2,9	1,14	0,34
U	1,7	1,2	34,5	21,8	1,6	0,80	0,27

* (bunch overexposure at the top of the canopy)