INTERACTION BETWEEN LEAF SURFACE AND NITROGEN SUPPLY IN GRAPEVINE PLANTS : OBSERVATIONS ON CHASSELAS AND PINOT NOIR VINES

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Abstract

Experimental trials on Chasselas and Pinot noir vines were set up on the estate of the Agroscope Changins-Wädenswil Research Station at Pully, Vaud (Switzerland), in order to study the interaction between plant outgrowths and nitrogen supply in grapevines. Significant differences in leaf surface were obtained either by eliminating lateral buds or by varying the height of hedgerows. It became evident that nitrogen content in leaves at the time of veraison and in musts at harvesting, as well as leaf chlorophyll content, were negatively correlated with an increase in vine plant outgrowth (total leaf surface). By exceptional climatic conditions or in situations where nitrogen supply may be restrictive, excessive leaf surface can increase nitrogen competition problems with possible repercussions on wine quality.
Key words: leaf surface, grapevine, nitrogen competition, canopy management, wine quality

Introduction

An insufficient supply of nitrogen to grapevines may have a negative impact on wine quality and in particular on white wines (Maigre *et al.* 1995; Schwab *et al.*, 1996; Löhnertz, 1998). During experimental studies carried out in western Switzerland (Spring, 2001; 2003; 2006), cases of poor nitrogen content in grapes of vigorous vine plants, which had not suffered any significant water stress, were also present. In view of this fact, the theory was put forward that an excessive leaf surface could lead to a decrease in plant nitrogen content by the effect of dilution. Two trials were set up to study this question on the experimental estate of the Agroscope Changins-Wädenswil (ACW) Research Station at Pully in Switzerland.

The objective of the first trial, carried out on Chasselas vines, was to modify the leaf surface by removing all lateral buds of every cane. By comparison, in the control plants, lateral buds were removed according to traditional practice along a third of the cane in the fruit cluster zone. In the second trial, a variation in hedgerow height of Chasselas and Pinot noir vines, planted at the same density, was studied.

Material and methods

The experimental plots, located at Pully in the canton of Vaud, have a mean temperature of 15°C during the growth period (from 15 April to 15 October) and a mean annual rainfall of 1140mm.

The soil has 16.9% clay, is poor in lime (4% of total calcium) and contains a satisfactory level of organic matter. Chemical analysis shows the soil to be rich in phosphorus and potassium, with normal levels of magnesium and boron. The first trial, to investigate the influence of eliminating all lateral buds, was set up on a plot of Chasselas vines grafted onto 3309C, trained in the single Guyot pruning system and planted in 1988. Vines were planted at a distance of 200 cm between rows and 85 cm on the row. Hedge height was 130 cm. The following variants were made:
A = elimination of lateral buds exclusively in the zone of grape bunches;
B = elimination of lateral buds along the entire cane.
The trial was organized in randomized blocks with four repetitions. Observations concentrated from the years 2001 to 2004.

The second trial focused on the influence of hedgerow height of vines planted in 1999 and trained in single Guyot, spaced at distances of 150 cm between rows and 80 cm between plants on the row. Two cultivars were looked at: Chasselas (clone ENTAV 31) and Pinot noir (clone RAC 12) planted on adjacent plots with a similar experimental layout. This trial was organized in split-splot formation with four repetitions. Two parameters were monitored: the influence of the rootstock (3309C, 5C and Riparia Gloire) and the hedgerow height. In the present article, only the influence of the latter parameter is discussed and the results reflect an average of the three rootstocks. The variations in hedge height were as follows: A = 60 cm, B = 100 cm, C = 140 cm.

Experimentation were conducted between the years 2001 and 2006. The following procedures were carried out:

- Nitrogen levels were determined at the time of veraison in leaves situated in the cluster zone;
- The chlorophyll index was monitored (using the N-Tester method) in principal leaves from level 7 to 10, according to the method put forward by Spring (1999) and Spring and Zufferey (2000) in trials on the elimination of lateral buds;
- The chlorophyll index was monitored in 2005 in the principal leaves found in the grape bunch zones of Pinot noir vines, in the trials on hedgerow height;
- Plant growth was measured by determining the leaf area surface, according to the method devised by Carbonneau (1976), between 2001 and 2004 for the lateral bud studies and in 2005 for the hedgerow height experiments;
- Weight of pruned wood;
- Yield components were measured: bud fertility, berry weight, grape bunch weight and yield; production was limited to one cluster per branch in the lateral bud elimination trials, and to one cluster per branch in the Pinot noir vines and four clusters per vine plant in the Chasselas vines in the hedgerow height studies;
- In musts, the levels of sugar, pH, total acidity expressed by tartaric acid, and tartaric and malic acids were measured. In addition, nitrogen levels were measured according to Aerny's 1996 method.

Between 2001 and 2004, the grapes derived from the vines involved in the lateral bud elimination trials were made into wine with a standardized vinification protocol. A recognized group of wine tasters from the ACW tasted the wines a few weeks after bottling. The various organoleptic criteria were evaluated on a scale of 1 (poor, bad) to 7 (high, excellent).

Results and discussion

Plant growth and leaf-fruit ratios

Tables 1 and 2 bring together the observations made concerning readings of total leaf surface per m^2 of soil, as well as the weight of pruned wood per vine plant. Surface leaf areas were measured throughout the four years of experimentation in the lateral bud elimination trials, whereas these readings were made only in 2005 in the hedgerow height studies.

The experimental variants showed major differences in plant outgrowths among the vine plants. For example, in the lateral bud elimination trial (Table 1), the control variant (A) was conspicuous by an increase in pruned wood weight of 29% and the total foliage surface area of 76%, in comparison with the variant where all side buds were removed.

In trials on hedgerow height, an increase in height from 60 cm to 100 and 140 cm led to a rise in pruned wood weights of approximately 50% and 90 to 100%, respectively. This was true for both the Chasselas and the Pinot noir vines. In addition, higher hedges led to increased total foliage surface areas of 85 to 90% for the 100 cm high rows and of 164% in the 140 cm variant. The relationship between total leaf surface area and grape production, expressed in kg/m^2, shows that the variant with total removal of lateral buds (B) presented a leaf-fruit ratio below that considered optimal by Murisier (1996) in terms of sugar content in grapes and of reconstitution of hydrocarbon reserves in the vine plant. Equally, this was true of the 60 cm high hedges in the hedgerow height experiment. A balanced leaf-fruit ratio was obtained from the control variant (A) plants in the lateral bud elimination study and from the 100 cm high hedges in the hedgerow height trials, and was found to be excessive in the 140 cm hedges from the same trials.

Nitrogen in leaves and musts

Nitrogen values shown in Figure 1 were determined in leaves at the time of the veraison and in musts at harvesting in the lateral bud elimination study. The total elimination of lateral buds always led to an increase in nitrogen content in leaves and in musts. Differences between the experimental plots were less obvious in 2003, a year characterized by a greater water stress. In general, it can be stated that the greater the water stress during the main growing period (early May to the end of August), the lower the observed nitrogen content in musts (Fig. 2). The nitrogen supply levels thus fluctuated greatly in relation to the growing conditions of each vintage. As far as foliage nitrogen was concerned, average supply values were mediocre, according to Spring *et al.*'s (2003) proposed thresholds. The formol index in musts provides a good indication of the nitrogen supply levels in the vineyard. Formol index threshold values were determined by Lorenzini (1996) in Chasselas vines as follows: < 10: distinct lack; 10-14: moderate lack; > 14: unrestricted nitrogen supply.

Differences between the two variants were more noticeable during years when the water stress levels were low (2001 and 2002). In the control variant (A) low values of nitrogen, situated in the zone of distinct lack of nitrogen, were always found in musts. The variant in which lateral buds were removed totally (B), gave values considered to be normal in 2001 and 2002, whereas in 2003 and 2004 these values were much lower.

Throughout each of the four vintage years taken into consideration, a good correlation between plant growth, expressed by the total leaf surface area, and the nitrogen levels in musts (Fig. 3) was found to exist. The larger the total leaf surface area, the lower the nitrogen levels. The amplitude of the observed variations in particular varied greatly with changing climatic conditions between the vintages.

Nitrogen values from leaves in the hedgerow height variation studies are displayed in Figure 4, taken from Chasselas and Pinot noir vines. The nitrogen content in Chasselas leaves is strictly inversely proportional to the height of foliage. On the other hand, in Pinot noir vines, nitrogen levels were significantly lower mostly in the variant with hedges measuring up to 140 cm high. Figure 5 gives nitrogen values in musts from the same trial. The nitrogen content in musts is inversely proportional to hedgerow height. In Chasselas vineyards, musts from the 140 cm high hedges were frequently to be found in the area of very low nitrogen supply. As in the lateral bud elimination experiments, the variation in total leaf surface area, obtained through modifying hedgerow height, was well correlated with nitrogen content in musts (Fig. 6).

Leaf chlorophyll index (N-Tester)

The evolution of the leaf chlorophyll index, measured using the N-Tester, was monitored between 2002 and 2004 in the lateral bud elimination trials (results not showed here). The resulting observations confirm readings of nitrogen content in leaves and musts. Leaves from the variant B (total removal of lateral buds) were found to be greener then those from the control experiment (A). Differences were, however, less noticeable during the year 2003 when plants had greater difficulty in assimilating nitrogen. In the hedgerow height trial, the evolution of leaf chlorophyll index was monitored in the Pinot noir vines in 2005 (results not showed here). Monitoring in Chasselas vines was not possible due to visible signs on leaves of a lack in magnesium. Observations from the Pinot noir plants also confirmed the results of nitrogen content obtained in leaves and musts. Foliage from maximum height hedges (140 cm) was distinguished by a less green color and a more rapid regression in chlorophyll at the end of the growing season.

In both of the trials undertaken, all indicators of nitrogen supply to the plant (leaf diagnostics, nitrogen in musts and leaf chlorophyll index) clearly show that increasing the leaf surface area, either by developing more secondary foliage (lateral spurs) or by raising hedge height, results in reduced nitrogen content in leaves and musts. This may well lead to confirmation of the theory that assimilated nitrogen is diluted when plant outgrowths become excessive.

Yield components and must composition

Table 3 assembles the principle elements concerning yield components and must quality for the trial on lateral bud suppression. The reduction in vine plant outgrowths from the variant B (total removal of lateral buds) resulted in a lower weight of berries, clusters and yield. Sugar content in musts was also lower. These observations may be explained by the variation in the leaf-fruit ratio, as Bertamini *et al.* (1991) have already demonstrated, and who also observed an upper limit on the evolution of sugar content in musts for a ratio of total leaf surface area per kilogram of grapes above 1.5 m^2/kg. No other noticeable differences were observed for the other criteria.

In the hedgerow height trials (Table 4), few differences were noted, with the exception of higher sugar levels in variants where foliage in hedges was more abundant and which can be explained by the variation in the leaf-fruit ratio.

Wine quality

The results of wine tasting from the lateral bud elimination trial, undertaken several weeks after bottling, are illustrated in Figure 7. The “stress” note is indicative of all the characteristics linked to extreme nitrogen competition (masked aroma, astringency, a hint of atypical reduction).

Wines from the years 2001 and 2002 were distinguished by their sensorial profiles whereas those from 2003 and 2004 not at all. These effects can easily be accounted for by the nitrogen levels in musts recorded for each of the variants for nitrogen stress criteria and the overall impression of the wines. This relationship has already, and on several occasions, been demonstrated for the Chasselas grape. (Maigre, 1995; Spring, 2002).

Conclusions

The trials undertaken on Chasselas and Pinot noir vines, involving the modification of plant outgrowth by either eliminating lateral buds wholly or partially or by opting for different hedgerow heights (60 cm, 100 cm and 140 cm), have enabled the following observations to be made:

- Nitrogen content in leaves at the time of fruit-ripening and in musts at harvesting, together with the leaf chlorophyll index (N-tester), are negatively correlated with an increase in vine plant outgrowth (total leaf surface area);

- During certain years of wine-growing, and in situations where nitrogen supply may be restricted, excess plant growth, largely above the ideal leaf-fruit ratio of 1.0 to 1.2 m^2 exposed leaf surface area/kg of grape defined by Murisier (1996), could worsen problems linked to nitrogen competition with possible negative consequences on wine quality.

Literature

Aerny J., 1996. Composés azotés des moûts et des vins. *Revue suisse Vitic., Arboric., Hortic.* **28** (3), 161-165.
Bertamini M., Iacono F. & Scienza A., 1991. Manipulazione dei rapporti sink-source mediante il diradamento dei grappoli e riflessi sulla qualità (cv. Cabernet Sauvignon). *VigneVini* **10**, 41-47.
Carbonneau A., 1976. Principe et méthodes de mesure de la surface foliaire. Essai de caractérisation des types de feuilles dans le genre Vitis. *Ann. Amél. Plantes* **26** (2), 327-343.
Löhnertz O., 1998. Begrünung und Weinqualität in "Gesunder Boden durch Begrünung". Compte rendu 5e Symposium international "Technik im Weinbau", Stuttgart, Allemagne, 12-13 mai 1998, 101-112.
Lorenzini F., 1996. Teneur en azote et fermentescibilité des moûts. *Revue suisse Vitic., Arboric., Hortic.* **27**, 237-251.
Maigre D., Aerny J. & Murisier F., 1995. Entretien des sols viticoles et qualité des vins de Chasselas : influence de l'enherbement permanent et de la fumure azotée. *Revue suisse Vitic., Arboric., Hortic*. **27**, 237-251.
Murisier F., 1996. Optimalisation du rapport feuille-fruit de la vigne pour favoriser la qualité du raisin et l'accumulation des glucides de réserves. Relation entre le rendement et la chlorose. Thèse N° 11729, EPFZ Zurich, 134 p.
Schwab A. L., Peternel M., Köhler J. & Hergel K.-P., 1996. Die untypische Alterungsnote im Wein. *Rebe und Wein* **6**, 181-187.
Spring J.-L., 1999. Indice chlorophyllien du feuillage et nutrition azotée du cépage Chasselas. Premières expériences en Suisse romande. *Revue suisse Vitic., Arboric., Hortic*. **31** (3), 141-145.

Spring J.-L. & Zufferey V., 2000. Intérêt de la détermination de l'indice chlorophyllien du feuillage en viticulture. *Revue suisse Vitic., Arboric., Hortic*. **32** (6), 323-328.
Spring J.-L., 2001. Influence du type d'enherbement sur le comportement de la vigne et la qualité des vins. Résultats d'un essai sur Chasselas dans le bassin lémanique. 1. Résultats agronomiques. *Revue suisse Vitic., Arboric., Hortic.* **33** (5), 253-260.
Spring J.-L., 2002. Influence du type d'enherbement sur le comportement de la vigne et la qualité des vins. Résultats d'un essai sur Chasselas dans le bassin lémanique. 1. Résultats oenologiques. *Revue suisse Vitic., Arboric., Hortic*. **34** (2), 111-116.
Spring J.-L., 2003. Localisation de la fumure azotée sur l'intercep dans les vignes enherbées. Résultats d'un essai sur Chasselas dans le bassin lémanique. *Revue suisse Vitic., Arboric., Hortic*. **35** (2), 113-119.
Spring J.-L., Ryser J.-P., Schwarz J.-J., Basler P., Bertschinger L. & Häseli A., 2003. Données de base pour la fumure en viticulture. *Revue suisse Vitic., Arboric., Hortic*. **35** (4).
Spring J.-L. & Lorenzini F., 2006. Effet de la pulvérisation d'urée sur l'alimentation azotée et la qualité du Chasselas en vigne enherbée. *Revue suisse Vitic., Arboric., Hortic*. **38** (2), 105-113.

Table 1. Trial with removal of lateral buds on Chasselas vines. Plant outgrowth and leaf/fruit ratio. Pully (Switzerland), averages 2001-2004.

	Total leaf surface (m^2/m^2 soil)		Pruning weight (g/vine)		Total leaf surface/yield (m^2/kg)
Partial removal of lateral buds	1,65	(176%)	564	(129%)	1,35
Total removal of lateral buds	0,94	(100%)	437	(100%)	0,98
lsd (p=0,05)	0,48		63		0,33

Table 2. Trial with the variation of the height of the hedgerow on Chasselas and Pinot noir. Plant outgrowth and leaf/fruit ratio. Pully, 2005.

	Hedgerow height (cm)	Total leaf surface (m^2/m^2 sol)		Pruning weight (g/vine)		Total leaf surface/yield (m^2/kg)
Chasselas	60	0,70	(100%)	265	(100%)	0,62
	100	1,32	(189%)	407	(154%)	1,26
	140	1,85	(264%)	524	(198%)	1,67
ssd (s=0,05)		0,25		99		0,12
Pinot noir	60	0,85	(100%)	275	(100%)	0,89
	100	1,57	(185%)	408	(148%)	1,55
	140	2,24	(264%)	523	(190%)	2,37
lsd (p=0,05)		0,20		101		0,12

Table 3. Trial with removal of lateral buds on Chasselas vines. Yield components and must composition. Pully (Switzerland), averages 2001-2004.

	Yield components				Must composition				
	Bud fertility (number of cluster/cane)	Weight(g)		Yield (kg/m^2)	Sugar (° Oe)	Total acidity (g/l)	Tartaric acid (g/l)	Malic acid (g/l)	pH
		Berries	Clusters						
Partial removal of lateral buds	1,94	3,14	348	1,22	75,0	6,1	5,7	2,7	3,39
Total removal of lateral buds	1,83	2,84	293	0,96	72,1	6,3	5,8	3,0	3,41
lsd (p=0,05)	n.s.	0,03	50	0,21	2,0	n.s.	n.s.	n.s.	n.s.

Table 4. Trial with the variation of the height of the hedgerow on Chasselas and Pinot noir vines. Yield components and must composition. Pully (Switzerland), averages 2001-2006.

	Hedgerow height (cm)	Yield components				Must composition				
		Bud fertility (number of cluster/cane)	Weight(g)		Yield (kg/m^2)	Sugar (° Oe)	Total acidity (g/l)	Tartaric acid (g/l)	Malic acid (g/l)	pH
			Berries	Clusters						
Chasselas	60	1,76	2,84	322	1,13	73,6	5,2	5,3	2,5	3,46
	100	1,51	2,83	366	1,05	73,9	4,2	5,1	2,0	3,47
	140	1,82	2,98	324	1,10	75,8	4,7	5,0	2,2	3,48
lsd (p=0,05)		n.s.	n.s.	n.s.	n.s.	1,6	n.s.	0,2	n.s.	n.s.
Pinot noir	60	1,76	1,51	225	0,96	89,6	9,3	6,4	4,8	3,13
	100	1,81	1,56	237	1,01	90,9	9,5	6,3	5,1	3,13
	140	1,83	1,61	221	0,94	91,6	9,6	6,3	5,2	3,12
lsd (p=0,05)		n.s.	n.s.	n.s.	0,05	1,5	n.s.	n.s.	0,2	n.s.

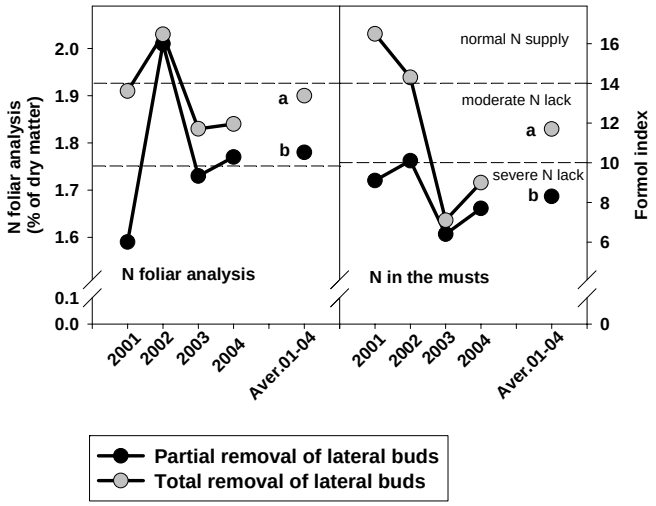

Fig. 1. Trial with removal of lateral buds on Chasselas vines. Foliar and must nitrogen content. Pully (Switzerland), 2001-2004.

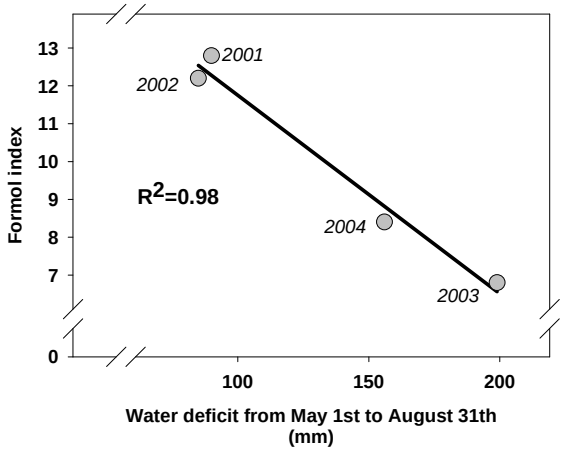

Fig. 2. Trial with removal of lateral buds on Chasselas vines. Relationship between the water deficit (from 1st May to 31th August) and the nitrogen content of the musts (averages of the two variants). Pully, Switzerland, 2001-2004.

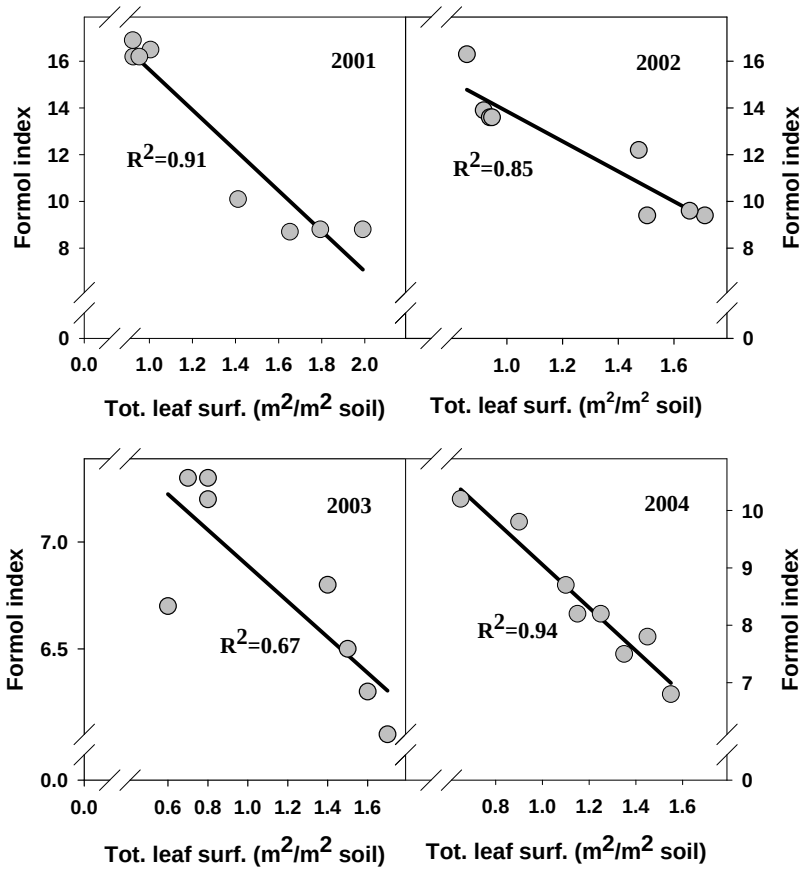

Fig. 3. Trial with removal of lateral buds. Relationship between the total leaf surface of the vines and the nitrogen content of the musts. Pully (Switzerland), 2001-2004.

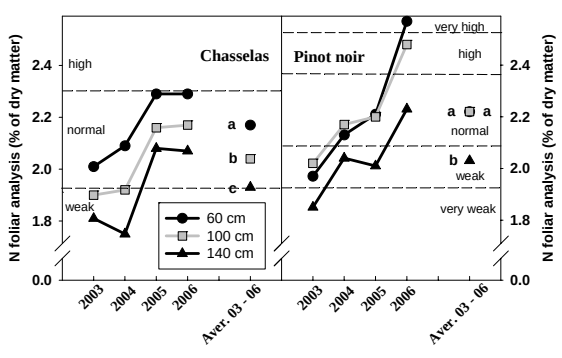

Fig. 4. Trial with the variation of the height of the hedgerow. Influence of the height of the hedgerow on the foliar nitrogen content at the veraison. Pully (Switzerland), 2003-2006.

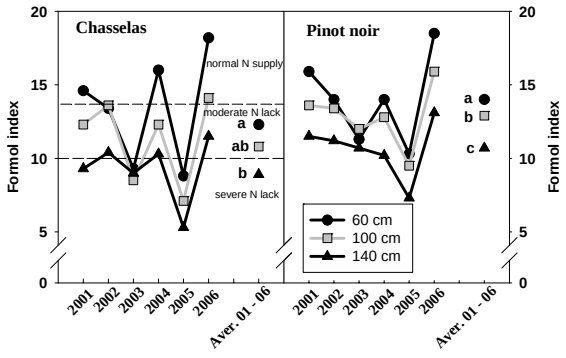

Fig. 5. Trial with the variation of the height of the hedgerow. Influence of the height of the hedgerow on the foliar nitrogen content of the musts. Pully (Switzerland), 2001-2006.

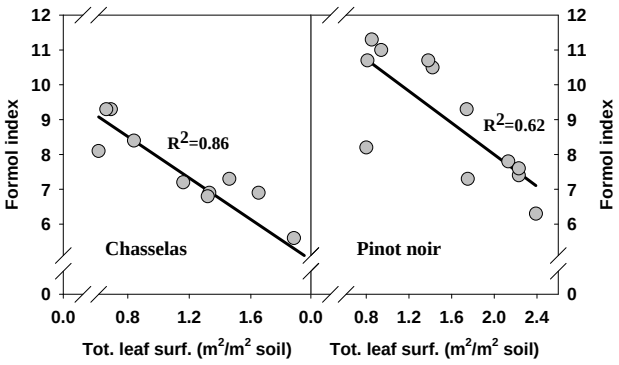

Fig. 6. Trial with the variation of the height of the hedgerow. Relationship between the total leaf surface of the vines and the nitrogen content of the musts. Pully (Switzerland), 2001-2004.

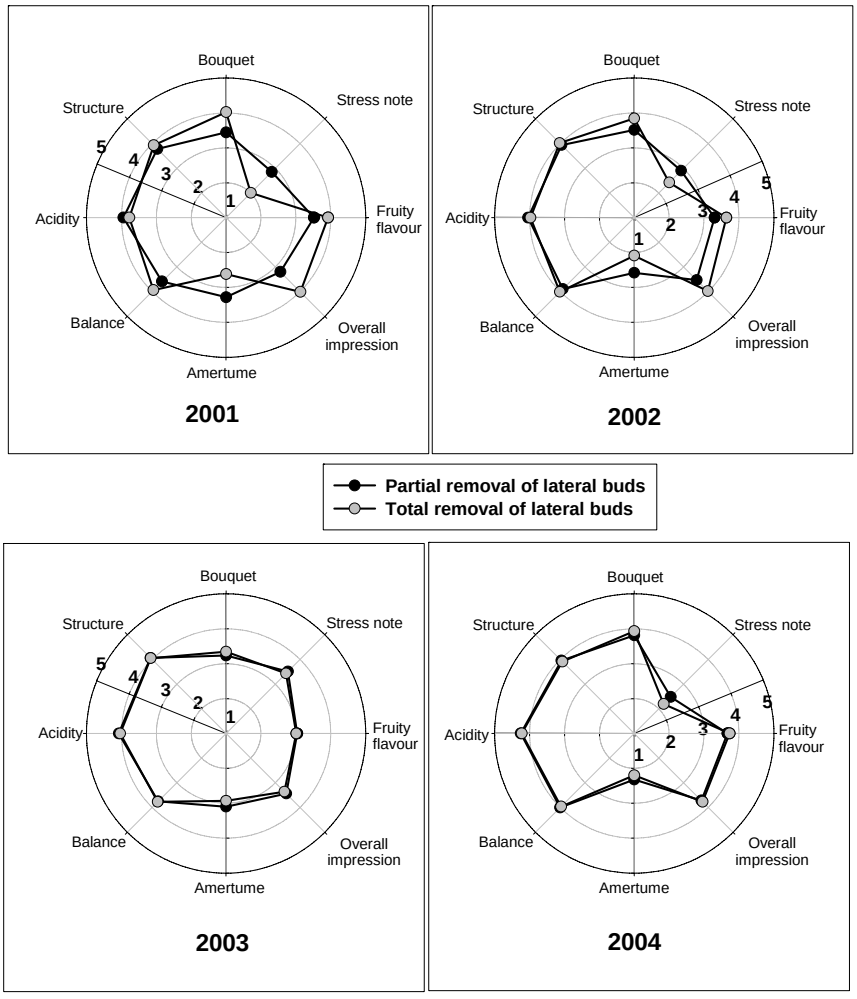

Fig. 7. Trial with removal of lateral buds on Chasselas vines. Sensoric analysis of the wines. Notation from 1 (= weak, bad) to 7 (= high, excellent). Pully (Switzerland), 2001-2004.