RELATIONSHIP BETWEEN TERROIR AND ACIDITY FOR THE RED WINE GRAPE CULTIVAR MALBEC N OR COT N (*Vitis vinifera* L.) IN AOC "CAHORS" AND "COTES DU FRONTONNAIS "

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Key words : terroir, cot n, must and wine acidity, potassium, tartaric and malic acids.

Abstract

A preliminary study on the main red wine grape cultivars of the Midi-Pyrénées area showed that The Cot N presents higher tartaric acid contents in musts and wines than the Négrette, Tannat, Duras and Fer Servadou grape cultivars.

The Cot N grape cultivar is widely planted in the most qualitive terroirs of the "Cahors" and "Côtes du Frontonnais" appellations. Our study focuses on the behaviour of Cot N and therefore, on the possible terroir effect on Cot N must and wine acidity.

The results show the important role played by the physical and chemical nature of soils in plant nutrient uptake and translocation (particularly potassium). Whatever the terroir, Cot N synthesizes similar quantities of malic and tartaric acids; yet differences are significant $\alpha = 5$ %. Even if titrable acidity and must pH do not vary much from one terroir to another, pH variation in wines is high depending on the nature of soils. On acidic soils, differences are insignificant whereas they are very important on calcareous soils. These observations confirm the main role of potassium during vinification. Indeed, it accounts for considerable precipitations of tartaric acid in bitartrate of potassium form and for a correlative increase in wine pH levels. The quality of wines depends on a good understanding of mineral nutrition and a reasoned fertilization practice.

Resume

L'étude préliminaire, réalisée sur les principaux cépages de la région Midi-Pyrénées, a montré que le Cot N possédait des teneurs en acide tartrique dans les moûts et les vins plus élevées que celles des cépages Négrette N, Tannat N, Duras N et Fer Servadou N.

Ce travail a porté sur l'étude du comportement du cépage Cot N sur les terroirs les plus qualitatifs des deux appellations Cahors et Côtes du Frontonnais, ainsi que sur la mise en évidence de l'effet éventuel du terroir sur l'acidité des moûts et des vins.

Les résultats montrent le rôle important joué par la nature physico-chimique des sols sur l'absorption et la translocation des éléments minéraux, et en particulier du potassium par la vigne. Quelque soit le terroir, le Cot N synthétise des quantités similaires d'acides malique et tartrique, mais, celles-ci diffèrent significativement au seuil $\alpha = 5$ %. Alors que l'acidité titrable et le pH des moûts varient très peu selon le terroir, les pH des vins varient beaucoup en fonction de la nature des sols. Sur les terroirs acides, ces différences sont faibles, alors qu'elles sont très importantes sur le terroir calcaire. Ceci confirme le rôle capital joué par le potassium, qui, au cours de la vinification, entraîne des précipitations importantes d'acide tartrique sous forme de bitartrate de potassium, et corrélativement, l'augmentation du pH des vins. La qualité des vins est donc très dépendante de la prise en compte de la nutrition minérale du cépage et de la pratique d'une fertilisation raisonnée.

INTRODUCTION

Throughout the world, there are vineyards which present a lack of wine acidity (Somers, 1977 and Gallego, 1999). This is the case of the "Côtes du Frontonnais" appellation where the Cot N or Malbec N is the second most planted variety. Cot N originates from the "Cahors" appellation ; it is the most planted grape variety there and it is appreciated for the colour, the aromas, the tannins and the acidity of the wines it gives. (Garcia *et al.,* 2002).

Previous studies on these two appellations permitted to determine different terroir zones (Rouvellac, 1998; Gallego, 1999 and Garcia *et al.,* 2002). In controlled and hydroponic culture, Cot N presents higher calcium contents and lower potassium contents in leaves and berries than the Négrette, Duras, Tannat and Fer Servadou grape varieties (Attia *et al.,* 2004). However, the Cot N presents the highest tartaric acid contents in musts and wines. In hydroponic conditions, Daverede, (1996); Daverede and Garcia (1997) and Garcia *et al.,* (2001a) reported the key role of potassium in cationic nutrition and must and wine acidities.

Accordingly, the objective of this study is to apprehend the specific behaviour of the Cot N grape cultivar when grown on three different terroirs:

- the first is a calcareous kimméridgien soil (rendzines) in the Cahors AOC;
- the second is an ancient alluvial acid terrace in the Cahors AOC;
- the third is an ancient alluvial decalcified terrace in the "Côtes du Frontonnais"AOC.

Furthermore, the study aims at showing the possible effect of the soil composition on cationic nutrition, on tartaric and malic acids in leaves and berries during the ripening period and finally on must and wine acidities.

MATERIALS AND METHODS

These investigations were carried out over two successive seasons, on (*Vitis vinifera* L.) Malbec N or Cot N grafted onto 3309 Couderc (*Riparia tomenteux* X *Rupestris martin*), in the "Cahors" and "Côtes du Frontonnais" AOCs in the Midi-Pyrénées region in south-western France. Three terroir units were selected; on each terroir, one experimental referenced field was chosen for the experiments. Two terroirs of the "Cahors" appellation were chosen: a calcareous kimméridgien soil (rendzines) (T Calc) and an ancient alluvial acid terrace (T Ac) (Garcia, 2002). In the "Côtes du Frontonnais" appellation where the vineyard is only planted on ancient alluvial acid decalcified terraces, one sandy boulbènes plot was chosen (T SB). Results of the soil section of each terroir showed that the roots were localized in the first 50 cm under the soil surface. 0:30 cm soil and 30:60 cm sub-soil samples were taken and analysed, both chemically and physically. Soil texture, cationic exchange capacity (CEC) and soil pH were tested in accordance with AFNOR norms (1999). For foliar diagnoses, leaves were sampled at blooming and veraison stages and the cations (K, Ca and Mg) were determined in accordance with the IAOPN protocols (Martin-Prével *et al.,* 1984). Tartaric acid and malic acid contents in young and mature leaves during the ripening period were determined from fruit setting to harvest in accordance with Ibrahim, (2001).

Microvinifications were performed in accordance with Garcia *et al.,* (2001b). Analyses of musts and wines were carried out in order to determine pH, titrable acidity and cations contents in accordance with O.I.V. norms (1999). Organic acids (tartaric and malic acids) in berries and wines were determined by Spectra Physics Capillary Electrophoresis 500 (C-E) with ultraviolet detection (Arellano *et al.,* 1997).

The experimental layout was monofactorial, with three terroir zones combinations with the Cot N grape cultivar and three replications. Data were subjected to analysis of variance and means using Sigmastat® 2.03 statistical software. The probability of all tests was assumed as $P<0.05$.

RESULTS AND DISCUSSION

Soil analysis : The physical and chemical soil analyses (Tables 1 and 2) show a certain homogeneity between the two acidic terroirs in Cahors and Côtes du Frontonnais. However, there is a great difference between these two acidic terroirs and the calcareous terroir in Cahors:

- the acidic Terroir in Cahors (T Ac): an ancient alluvial acid terrace, the soil and sub-soil horizons are sandy with respectively 66 % and 65 % of sand. The pH are 6.2 and 6.4 for soil and sub-soil respectively. The Cation Exchange Capacity (CEC) is high 29 $cmol^+/kg$ for the two horizons. Indeed,

the soil and sub-soil are low in calcium and magnesium contents. This terroir presents an intermediate K/Ca ratio, ranging between 20 and 22 %.
- the acidic Terroir in the Côtes du Frontonnais appellation (T SB): an ancient alluvial decalcified terrace, the soil and sub-soil are sandy redoxi-luvi (Boulbènes) with 100 % fine soil for the two horizons. The sub-soil is more acidic (pH = 5.7) than the surface horizon (pH = 6.2). The CEC is lower (21 $cmol^+/kg$) than in the Cahors terroirs. However, the K/Mg ratio is well-balanced (0.56 and 0.43 for soil and sub-soil horizons respectively). This terroir presents a K/Ca ratio between 14 and 18 %, compared to the other terroirs under study.
- the calcareous Terroir in Cahors (T Calc): calcareous kimméridgien soil. The surface horizon is gravely-stony with 66 % gravel. The soil is sandy-clay, alkaline (pH = 8.1) with a high CEC level (47 $cmol^+/kg$) with a well-balanced K/Mg ratio. The sub-soil horizon is sandy clay with only 20 % gravel and stones (less than the surface horizon). The pH is alkaline (8.3) and the CEC is very high, saturated with calcium and showing a high K level (6.5 % of the CEC). This terroir presents a K/Ca ratio between 4 and 8 % which is the lowest among the three terroirs.
The difference of K/Ca ratio between terroirs plays a key role in the cationic nutrition of Cot N and consequently in must and wine cations contents, essentially through the antagonism between divalent and monovalent cations.

Cations contents in leaves: from what Table (3) shows, it is obvious that K and Mg contents in leaves varied significantly from one terroir to another during the two successive seasons under study at blooming and veraison stages ; yet, there is no significant difference between terroirs regarding calcium contents at veraison in 2001. The cations contents in leaves at blooming and veraison are in agreement with the optimum terroir standards proposed by Garcia *et al.,* (2002). The evolution of different cations contents in leaves, from blooming to veraison, is in agreement with Martin–Prével *et al.,* (1984) and Fregoni (1985). Indeed, potassium decreased, calcium and magnesium increased, which explains that the divalent cations accumulate preferably in mature leaves, while potassium is mobilized towards young leaves with their more active metabolism. At blooming and veraison stages, Cot N, when grown on acidic soils (T Ac and T SB), presents higher K contents than on calcareous soils. However, at blooming stage and on calcareous soils, Cot N presents higher contents in magnesium and calcium than on acidic soils.
These results show the importance of the antagonisms between mono and divalent cations in accordance with the results obtained by Daverede (1996), Daverede and Garcia (1997) and Garcia *et al.,* (1999). The 'terroir' effect is due to the K-Ca and K-Mg antagonisms, which are very well expressed by the nature of the soils.

Tartaric and malic acids in young leaves, mature leaves and berries during the ripening period: Figures (1 and 2) show that tartaric acid accumulation in young leaves reached a peak just before veraison, 6 weeks post fruit set (FS+6W). Indeed, malic acid reached a peak in the young leaves of the Cot N variety grown on terroir T SB at veraison, 8 weeks post fruit set. Yet, in the Cahors AOC (T Ac and T Calc) it reached its maximum later at FS+10W. For mature leaves, tartaric acid accumulation reached a peak at FS+6W in the Cahors AOC (T Ac and T Calc) and at FS+8W on terroir T SB. At harvest time, tartaric acid content in young leaves for the three terroirs was higher than in 2002.
Tartaric acid content in the leaves of Cot N grown in the Côtes du Frontonnais terroir (T SB) is lower than those of Cot N grown in the Cahors terroirs (T Ac and T Calc) during the two seasons with significant difference at α = 5 %. However, for the three terroirs, malic acid in young leaves at harvest time in 2001 is lower than in 2002. But for mature leaves, malic acid in 2001 is higher than in 2002 for the three terroirs. Moreover, Cot N grown in the Côtes du Frontonnais terroir (T SB) presents the highest content for malic acid in leaves at harvest time for the two seasons.
Figure (3) shows that in Cot N berries, malic acid content in 2002 increased progressively until the end of veraison (FS+8W) and then diminished rapidly until harvest. The difference between the three terroirs is significant at α = 5 % from two weeks post fruit set to harvest time. In 2002, the Cot N grown in the calcareous terroir of Cahors presents the highest malic acid content at FS+8W and at harvest, with respectively 21.6 and 4.03 g/L.
These results indicate that the synthesis of tartaric acid started after fruit set and increased progressively until the start of veraison (FS+6W) where it reached its maximum content. It then

decreased gradually until harvest in agreement with Ibrahim *et al.*, (2001). The evolution of tartaric acid content in berries (Fig 3) shows that Cot N in the Cahors terroirs (T Ac and T Calc) presents higher tartaric acid content in berries than the Cot N in the Côtes du Frontonnais terroir (T SB). The difference is significant at $\alpha = 5$ % between terroirs from two weeks after fruit set to harvest time.
These results reveal a significant correlation between tartaric acid in berries and in leaves depending on the terroir. This correlation is higher in the Côtes du Frontonnais terroir (r = 0.85 in T SB) than in the Cahors terroirs (r = 079 in T Ac and T Calc). For malic acid, this correlation is higher in Cahors (T Ac r = 0.78 and T Calc r = 0.80) than in Côtes du Frontonnais (T SB r = 0.57).
These results support the concept that tartaric acid synthesis is related to cell division. In the three terroirs, Cot N showed a higher capacity to synthesize malic acid than tartaric acid.

***Musts and wines*:**

- *Cation contents*: for the three terroirs, K, Ca and Mg contents in musts and wines were significantly different at $\alpha = 5$ % (Tab 1). The Cot N grown in Côtes du Frontonnais (T SB) has the highest K contents in musts and wines during the two seasons. But, the Cot N grown in T Calc terroir presents the lowest K Contents in musts and wines. The Cot N grown in T Ac terroir presents the lowest Ca and highest Mg contents in musts and wines followed by T SB terroir. The Cot N in the T Calc terroir presents the highest Ca and Mg contents in musts and wines during the two seasons.
- *Organic acids*: The Cot N in Cahors terroirs (T Ac and T Calc) has significantly higher tartaric acid contents in musts and wines than the Cot N in the Côtes du Frontonnais appellation (T SB). The Cot N grown in T Ac has the highest malic acid contents in musts during the two successive seasons (3.67 and 3.76 g/L respectively). The Cot N grown in Côtes du Frontonnais T SB has the lowest contents for 2001 and 2002 (3.03 and 2.89 g/L respectively).
- *Must and wine acidities*: results in Table (4) show that must and wine acidities differ significantly depending on the terroir. The Cot N grown in T Calc give the lowest level of titrable must and wine acidities and an intermediate content of tartaric acid in musts and wines. In 2002, the pH level of musts and wines did not vary significantly from one terroir to another, but in 2001, the pH variation was significant at $\alpha = 5$ %.

The correlation between tartaric acid and pH level is high depending on the terroir, r = - 0.84, r = - 0.82 and r = - 0.81 for T Ac, T Calc and T SB respectively. This correlation is higher than the one between tartaric acid and titrable acidity which is r = 0.51, r = 0.70 and r = 0.87 respectively for the same terroirs. The potassium contents in musts and wines present a greater correlation with pH level than with titrable acidy. Correlation between K and titrable acidity is the highest in terroir T SB (r = 0.85) followed by terroir T Ac (r = 0.65); the lowest is to be found in terroir T Calc (r = 0.62). However, the highest correlation between K and pH level is in T Calc (r = - 0.77) followed by T SB (r = - 0.90) and the lowest is in T Ac (r = - 0.95).
The two main parameters K and tartaric acid are better correlated with terroirs T Ac and T Calc (r = 0.92) than with terroir T SB (r = 0.87).
From these results, it can be assumed that the potassium has a great importance on must and wine acidities. This element presents a high correlation with tartaric acid, pH level and titrable acidity.

CONCLUSION

The most qualitative terroirs in AOCs Cahors and Côtes du Frontonnais were chosen to study the specific nutritional behaviour of Cot N and its must and wine acidity. The terroir is an important factor of grape cationic nutrition and must and wine acidity. Our study clearly demonstrates that the Terroir effect is due mainly to K-Ca and K-Mg antagonisms. The lower K/Ca ratio is, the lower K absorption, storage and therefore contents in musts and wines is. This macro-nutrient is highly correlated with tartaric acid contents, pH level and titrable acidity of musts and wines. The higher the potassium level in musts and wines (is), the higher tartaric acid level and the lower pH level (are). During the ripening period, tartaric and malic acids in berries and in young and mature leaves are highly correlated. Tartaric acid presents higher correlation in Côtes du Frontonnais terroir (T SB). However, malic acid presents higher correlation in Cahors terroirs (Tac and T calc).
In Cahors terroirs (T Ac and T Calc) musts and wines are richer in tartaric acid. Differences between acidic terroirs (T Ac and TSB) and calcareous terroir (T Calc) for pH level and titrable acidity of

musts and wines are significant. These results confirm that tartaric acid is the most important organic acid in grapes, musts and wines because of its high stability and its important effect on must and wine acidity.

LITERATURE CITED

- AFNOR, 1999. Qualité des sols. Vol. 1, 408 pages and vol. 2, 565 pages.
- Arellano, M., Andrianary, J., Dedieu, F., Couderc, F. & Puig, Ph., 1997. Method development and validation for the simultaneous determination of organic acids by capillary zone electrophoresis. J. Chromatography A, 765, 321-328.
- Attia, F., Ibrahim, H., Cadet, A. & Garcia, M., 2004. Evaluation of leaf, must and wine cation contents of must and wines acidity of five red wine grape cultivars (*Vitis vinifera* L.) grafted on to 3309 Couderc and grown hydroponically. Acta Hort (ISHS) 652: 255-263.
- Davered, C. & Garcia, M., 1997. Influence des différents équilibres ioniques (K-Ca) sur la nutrition potassique de la Négrette *Vitis vinifera* L. greffée sur 101-14. Agrochimica, XLI, 1-2, 1-9.
- Daverede, C., 1996. Influence de différents équilibres K-Ca sur la nutrition cationique et le manqué d'acidité des moûts et des vins du cépage négrette (*Vitis vinifera* L.) greffé sur 101-14M.G., cultivé hors-sol (in French). Thesis, Institut National Polytechnique de Toulouse, France.
- Fregoni, M., 1985. Exigences d'éléments nutritifs en viticulture. Bullet. O.I.V. (650-651), 416-434.
- Gallego, P., 1999. Influence des terroirs de l'appellation d'origine contrôlée "Côtes du frontonnais" sur la nutrition cationique et le manqué d'acidité des moûts et des vins de Négrette (*Vitis vinifera* L.) greffée sur 3309 c (in French). Thesis, Institut National Polytechnique de Toulouse, France.
- Garcia, M. 2002. Le vignoble du Sud Ouest.. In : Benoît, F., « Grand Atlas des Vignobles de France » Eds SOLAR, Paris, France, pp. 68-95.
- Garcia, M., Daverede, C., Gallego, P. & Toumi, M., 1999. Effect of various K-Ca ratios on the cation nutrition of *Vitis vinifera* L. cv. Négrette grafted on 101-14 and grown hydroponically. Journal of Plant Nutrition, 22, 3, 417-425.
- Garcia, M., Gallego, P., Daverede, C. & Ibrahim, H., 2001a. Influence of three rootstocks on grapevine (*Vitis vinifera* L.) c.v. Négrette grown hydroponically. 1: Potassium, Calcium and Magnesium nutrition. South African Journal of Enology and Viticulture, 22 (2) 101-103
- Garcia, M., Ibrahim, H., Gallego, P., & Puig, Ph., 2001b. Influence of three rootstocks on grapevine (*Vitis vinifera* L.) c.v. Négrette grown hydroponically. 2: acidity of musts and wines. South African Journal of Enology and Viticulture, 22 (2) 104-106
- Garcia, M., Laffargue, F., Besnard, E., Ibrahim, H. &. Cadet, A., 2002. Influences des terroirs sur la qualité des vins de l'A.O.C Cahors. Zonage Viti-vinocole, IV^{ème} Symposium International, Avignon. France, 17-20 juin 2002.
- Ibrahim, H., 2001. Genèse et evolution des acides organiques dans les feuilles, les baies, les moûts et les vins des cépages Cot et Négrette (*Vitis vinifera* L.) (in French). Thesis, Institut National Polytechnique de Toulouse, France.
- Ibrahim, H., Dedieu, F. & Garcia, M., 2001. Influence of rootstock on malate and tartrate accumulation during grape (*Vitis vinifera* L. CVS Cot and Négrette) berry development. Plant nutrition – Food security and sustainability of agro-ecosystems. 330-331.
- Martin-Prével, P., Gognard, J., & Gautier, P., 1984. Méthodes analytiques de référence. « In L'analyse végétale dans le contrôle de l'alimentation des plantes tempérées & tropicales » Eds Lavoisier TEC & DOC ; pp 161-191.
- OIV, 1999. Recueil des méthodes internationales d'analyses des vins et des moûts. Eds O.I.V.
- Rouvellac, M., 1998. Les terroirs de l'aire AOC Cahors, étude géographique (In French). Thesis Université Toulouse II Mirail, France.
- Somers, T. C., 1977. A connection between potassium levels in the harvest and relative quantity in Australian red wines. Proc. OIV Symp. Qual. Vint. Cape Town, S. Africa.

LIST OF TABLES AND FIGURES

Tables

Table 1. Soil and sub-soil physical analyses of the experimental fields (2001) of the Cot N cultivar in Cahors AOC (T Ac: Alluvial Acidic Terroir and T Calc: Kimméridgien Calcareous Terroir) and in Côtes du Frontonnais AOC (T SB: Alluvial Acidic Terroir).

			Gravel %	Clay %	Silt %	Sand %	Soil texture
Cahors AOC	T Ac	soil	-	15.0	19.0	66.0	Sandy
		sub-soil	-	19.0	16.0	65.0	
	T Calc	soil	66	46.5	22.5	27.5	Sandy Clay
		sub-soil	20	28.0	44.0	28.0	
Côtes du Frontonnais AOC	T SB	soil	-	17.0	17.0	65.0	Sandy Boulbènes
		sub-soil	-	18.0	16.0	64.0	

(Clay, Silt and Sand are in % of fine soil fraction ≤ 2 mm of diameter)

Table 2. Soil and sub-soil chemical analyses of the experimental fields (2001).of the Cot N cultivar in Cahors AOC (T Ac: Alluvial Acidic Terroir and T Calc: Kimméridgien Calcareous Terroir) and Côtes du Frontonnais AOC (T SB: Alluvial Acidic Terroir).

			pH_{H2O}	CEC $cmol^+/kg$	K $cmol^+/kg$	Mg $cmol^+/kg$	Ca $cmol^+/kg$
Cahors AOC	T Ac	soil	6.20	29	1.45	1.22	6.65
		subsoil	6.40	29	1.40	1.65	6.99
	T Calc	soil	8.10	47	1.78	2.71	39.6
		subsoil	8.30	48	3.11	2.59	41.1
Côtes du Frontonnais AOC	T SB	soil	6.20	21	0.93	1.66	5.11
		subsoil	5.70	21	0.73	1.67	5.19

Table 3. Potassium, magnesium and calcium contents in leaves, musts and wines of the Cot N cultivar in Cahors AOC (T Ac : Alluvial Acidic Terroir and T Calc : Kimméridgien Calcareous Terroir) and in Côtes du Frontonnais AOC (T SB: Alluvial Acidic Terroir).

	2001				**2002**			
	Potassium (% of dry matter) and (g/L) in musts and wines							
	Blooming	Veraison	Must	Wine	Blooming	Veraison	Must	Wine
T Ac	1.28 b	1.15 b	1.62 b	0.78 b	1.24 a	1.15 a	1.32 b	0.84 b
T Calc	1.11 c	0.97 c	1.17 c	0.79 b	0.99 b	1.00 b	1.29 b	0.76 c
T SB	1.39 a	1.22 a	1.99 a	1.04 a	1.21 a	1.14 a	2.01 a	1.12 a
	Magnesium (% of dry matter) and (mg/L) in musts and wines							
	Blooming	Veraison	Must	Wine	Blooming	Veraison	Must	Wine
T Ac	0.22 b	0.24 b	86.6 a	84.5 b	0.21 b	0.27 b	81 a	77 a
T Calc	0.27 a	0.37 a	93 b	89.4 a	0.28 a	0.30 a	83 a	74 a
T SB	0.20 c	0.29 a	86.6 a	88.0 a	0.20 b	0.26 b	77 b	66 b
	Calcium (% of dry matter) and (mg/L) in musts and wines							
	Blooming	Veraison	Must	Wine	Blooming	Veraison	Must	Wine
T Ac	2.68 b	3.11 a	87 b	67	2.79 b	3.20 b	73 b	61 b
T Calc	2.99 a	3.22 a	93 a	79 a	3.11 a	3.45 a	83 a	72 a
T SB	2.59 b	3.21 a	90.4 ab	77 a	2.77 b	3.29 ab	75 b	63 b

Means within columns, followed by the same letter, do not differ significantly ($\alpha = 5$ %).

Table 4. Titrable acidity, tartaric acid contents and pH level of musts and wines of the Cot N cultivar in Cahors AOC (T Ac: Alluvial Acidic Terroir and T Calc: Kimméridgien Calcareous Terroir) and in Côtes du Frontonnais AOC (T SB: Alluvial Acidic Terroir).

	2001				2002			
	Titrable acidity (g H_2SO_4/ L)							
	Must	Alc. Fer.	Mal.Fer.	Col. Sta.	Must	Alc. Fer.	Mal.Fer.	Col. Sta.
T Ac	4.66 c	4.71 c	3.62 b	3.21 b	4.34 c	5.55 c	3.71 c	3.21 c
T Calc	3.79 a	4.21 a	3.17 a	2.89 a	3.85 a	4.75 b	3.22 a	2.87 a
T SB	4.2 b	4.31 a	3.73 b	3.12 b	3.93 b	3.92 a	3.29 b	2.95 b
	Tartaric Acid (g/L)							
	Must	Alc. Fer.	Mal.Fer.	Col. Sta.	Must	Alc. Fer.	Mal.Fer.	Col. Sta.
T Ac	4.12 b	3.27 b	3.09 b	2.89 c	4.11 b	3.12 b	2.98 c	2.44 b
T Calc	3.99 b	3.29 b	3.01 b	2.21 b	3.99 b	3.1 b	2.57 b	2.02 b
T SB	3.41 a	2.87 a	2.35 a	2.11 a	3.77 a	2.81 a	2.11 a	1.85 a
	pH level							
	Must	Alc. Fer.	Mal.Fer.	Col. Sta.	Must	Alc. Fer.	Mal.Fer.	Col. Sta.
T Ac	3.41 a	3.47 a	3.64 a	3.87 a	3.51 b	3.62 a	3.69 a	3.87 a
T Calc	3.55 a	3.61 a	3.69 b	3.93 b	3.61 b	3.71 a	3.84 a	3.98 a
T SB	3.45 a	3.64 a	3.99 c	4.17 c	3.38 a	3.62 a	3.81 a	3.92 a

Means within columns, followed by the same letter, do not differ significantly ($\alpha = 5$ %).
Alc. Fer.: Alcoholic Fermentation, Mal. Fer.: Malo-lactic Fermentation and Col. Sta.: Cold Stabilization.

<u>**Figures**</u>

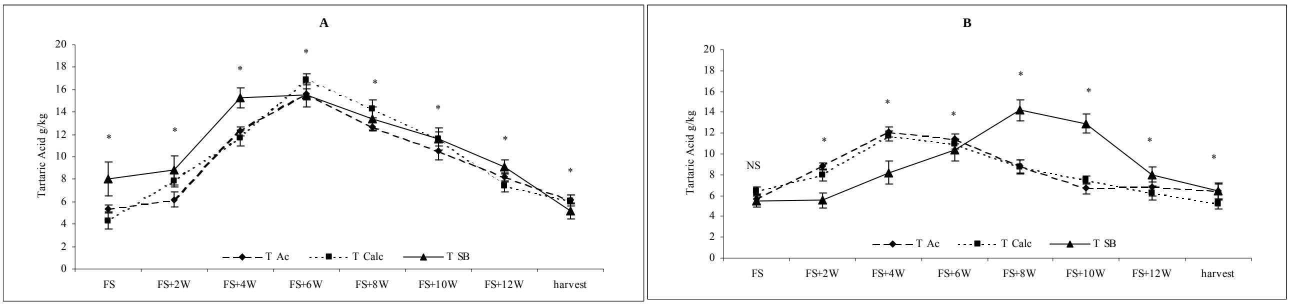

Figure 1. Tataric acid content evolution in young (**A**) and mature (**B**) leaves of the Cot N cultivar from fruit set to harvest time in Cahors AOC (T Ac: Alluvial Acidic Terroir and T Calc: Kimméridgien Calcareous Terroir) and in Côtes du Frontonnais AOC (T SB: Alluvial Acidic Terroir) (season 2002).

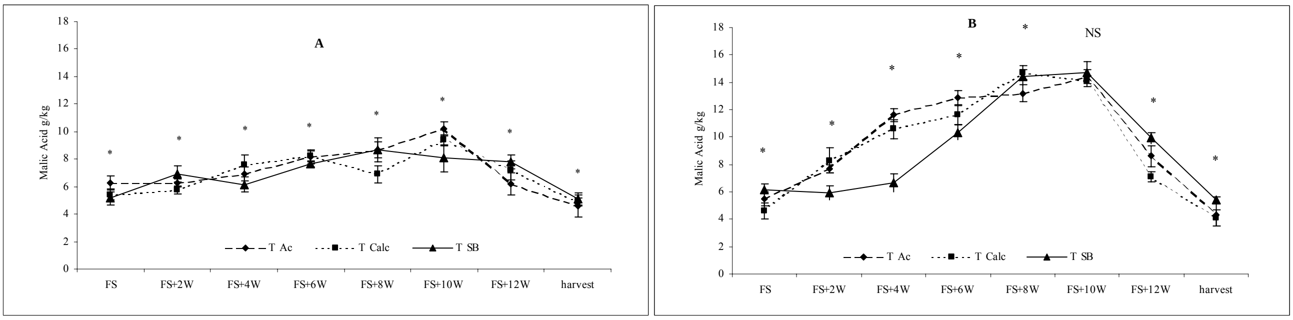

Figure 2. Malic acid content evolution in young (**A**) and mature (**B**) leaves of the Cot N cultivar from fruit set to harvest time in Cahors AOC (T Ac : Alluvial Acidic Terroir; T Calc : Kimméridgien Calcareous Terroir) and in Côtes du Frontonnais AOC (T SB: Alluvial Acidic Terroir) (season 2002).

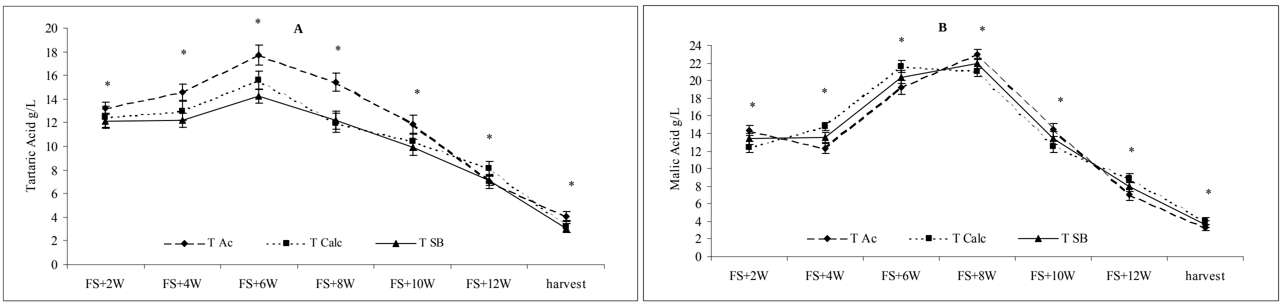

Figure 3. Tataric (**A**) and malic (**B**) acids contents evolution in berries of the Cot N cultivar from two weeks post fruit set to harvest time in Cahors AOC (T Ac: Alluvial Acidic Terroir and T Calc: Kimméridgien Calcareous Terroir) and in Côtes du Frontonnais AOC (T SB: Alluvial Acidic Terroir) (season 2002).