THE EFFECT OF PEDOCLIMATIC CONDITIONS ON THE YEAST ASSIMILABLE NITROGEN CONCENTRATION ON WHITE CV. DORAL IN SWITZERLAND

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Abstract
Aims: Agroscope investigated the efficiency of nitrogen fertilization via foliar urea application at veraison with the aim of raising the YAN (yeast assimilable nitrogen) content in the musts. The observations were conducted on the white grapevine cultivar Doral (Chasselas x Chardonnay) in several pedoclimatic conditions of the Leman wine region, Switzerland, in the years 2012 and 2013. Knowing that the YAN in must plays a key role in wine quality, the aim was finding the main parameters affecting the final YAN level in order to better control them.
Methods and results: Five plots of Doral were chosen over 80 km of vineyards. Pedologic profiles were realised. Vegetal materials, date of plantation and cultivation practices were kept constant for comparison purposes. Each plot was divided in two treatments of 60 vines each: a control treatment and a nitrogen fertilized treatment (20 kg/ha as foliar urea applied at veraison). Phenological development, nitrogen status and grape maturation of vines were monitored. 50 kg of grapes were harvested in each treatment. Musts were analysed after crushing and then vinified separately using a standard protocol. Wines were then analysed and tasted by an expert panel. Strong vintage and site effects were pointed out. YAN levels in musts were significantly affected by nitrogen fertilization. YAN gain in must was 56 ± 31 mg/L average. YAN gain between control and fertilised treatments was globally higher in 2013. Some sites consistently presented higher gains. The soil seemed to mainly affect vine nitrogen status by its water holding capacity and its effective root zone depth. No correlation could be established between initial leaf N content and the variation of YAN gain. YAN in must was the parameter that best explained the positive variations in wine sensory characteristics, although not always significant.
Significance and impact of the study: This work has so far confirmed that YAN level in must, in relation to climate and soil characteristics, contributes to the terroir effect on the wine quality. YAN concentration is clearly influenced by pedoclimatic conditions (i.e. vintage and site). The study is ongoing in 2014 in order to better understand which parameters in the vineyard we could optimize with the aim of raising up the YAN level in musts.

Keywords: terroir, yeast assimilable nitrogen YAN, leaf urea fertilisation, wine quality, terroir

1 INTRODUCTION

It is general knowledge in winemaking that a minimum of 140 mg/L of yeast assimilable nitrogen (YAN) – amino acids and ammonium – in the must is required for the proper completion of alcoholic fermentation (Agenbach 1977, Hannam et al. 2013). But a non-restrictive concentration of 200 mg/L of YAN would also guarantee optimal organoleptic results in terms of wine quality (Spring and Lorenzini 2006). In case of YAN deficiency, a common practice is the direct addition of diammonium phosphate (DAP) in the must in order to improve the fermentation kinetics, although its positive effect on the wine aromas has not yet been established (Lorenzini and Vuichard 2012). Indeed, only the amino acids, as the main part of YAN, act as precursors in the synthesis of wine aromas (Rapp and Versini 1991). Knowing this, the natural YAN concentration from the grapes is preferable to must DAP addition. YAN concentration can be significantly increased in the must through the addition of nitrogen in the form of urea directly on the vine canopy (Lacroux et al. 2008, Dufourcq et al. 2009). Urea application is usually recommended at veraison for increasing the must YAN concentration without increasing the vigour of the vine (Lasa et al. 2012). The present study follows on the project of Reynard et al. (2011) which highlighted the large role of the soil parameters (i.e. structure, depth, water holding capacity) in the grape N content and their impact on the final wine characteristics and quality. The relatively wide variation of N use reported for grapevines suggest that nutrient management recommendations should be developed on a regional basis (Conradie 2005). Agroscope set an experiment throughout the vineyard of the Leman region, Switzerland, to observe the YAN fluctuation in function of vintage and soil type and to evaluate the impact that urea fertilisation can have in the different situations on the YAN concentration in the must and further on the wine quality.

2 MATERIALS AND METHODS

Vineyard sites and experimental setup

Five plots of white cultivar *Vitis vinifera* Doral (Chasselas x Chardonnay) were chosen in the Leman wine region. The vines were all grafted on rootstocks 3309 C, planted in 2003 and trellised in a single Guyot pruning system. Plant density varied from 5000 vines/ha in Pully up to 7800 in Villeneuve and Cully. The **Table 1** describes the soils profiles of each site. Villeneuve was the only site without moraine soil but fallen stones (hyperskeletic leptols) instead, with a very small water holding capacity (50 mm). Cully and Pully soils were composed of gravely moraine (eutric cambisol). Pully soil had particularly big water holding capacity of 226 mm. Whereas Vufflens and Changins soils were made of moraine over molasses and basal compact moraine respectively (both calcaric cambisol with endostagnic conditions). Each plot was divided in two treatments of 60 vines each: a treatment which received foliar urea at veraison (20 kg/ha N applied in four times) and a control treatment with no fertilisation.

Table 1: Soil description of the five sites of the study. The soils profiles were realised in February 2013. The soil water holding capacity corresponds to the water accessible for vine root uptake.

	Altitude (m)	Soil class	Rock type	Hydromorphy	Depth	Water holding capacity (mm)	Stones (%)
Villeneuve	462	Hyperskeletic leptols	Fallen stones	-	140	50	75
Cully	490	Eutric cambisol	Gravely moraine	-	150	150	20
Pully	469	Eutric cambisol	Gravely moraine	-	180	225	15
Vufflens	487	Calcaric cambisol	Moraine over molasse	Endostagnic	150	200	5
Changins	442	Calcaric cambisol	Basal moraine	Endostagnic	150	185	5

Field measurements, sampling and analysis

The phenological stage flowering was dated. The fertility was estimated on 20 vines and was expressed as the average number of clusters per shoot. The total leaf area was estimated in August on 10 vines twice per treatment. The chlorophyll index (N-tester®, Yara, France) which permitted the monitoring of the chlorophyll concentration in the leaves throughout the season, was measured every 3 weeks for each treatment on 30 primary leaves of the medial part of the canopy. The light-exposed leaf area (m^2/m^2 of soil) was determined using the Carbonneau's method (1995). The vigour of the vines was assessed during winter by weighing 50 one-meter long pruned canes per plot and was expressed in grams per meter (g/m). The carbon isotope discrimination ($\delta^{13}C$), showing the global water constraint from veraison to harvest, was determined at the Stable Isotopes Laboratory of the University of Lausanne. Water restriction is considered high when $\delta^{13}C$ is above -23 ‰, moderate between -23 and -24.5 ‰ and weak to null under -24.5 ‰ (van Leeuwen et al. 2009). A leaf diagnosis was carried out after the four urea applications on 25 leaves (limb + petiole) per treatment from the medial part of the canopy and analysed at the registered laboratory Soil-Conseil in order to assess the N, P, K, Ca and Mg contents. The grape maturation was controlled weekly (200 berry sample) at the Agroscope laboratory using the following parameters: berry weight (g), total acidity (TA, g/L as tartaric acid), tartaric (g/L) and malic acids (g/L), soluble solids (°Brix), pH and yeast available nitrogen (YAN, mg/L). Finally, 50 kgs of grapes from each treatment were harvested and vinified separately at the Agroscope winery. Wine sensory analysis was realised by the Agroscope tasting panel.

Statistics

The data description and the significance of the differences between treatments, sites and vintages were statistically evaluated using analysis of variance (ANOVA, p values < 0.05), multiple comparison Newman-Keuls test and principle component analysis (PCA) realised with ©XLSTAT 2011.2.04. Results are presented as average ± 1 SD.

3 RESULTS AND DISCUSSION

Climate and phenology

Total precipitations from April to October (vegetative period) were 645 mm in 2012 and 820 mm in 2013. Average temperatures over the same period were 17.2 °C in 2012 and 16.7 °C in 2013 (Pully weather station). 2012 was a relatively early vintage with Doral flowering occurring on the 15th of June. On the other hand, 2013 was a late vintage with flowering on the 1st of July. Changins vineyard production was lost in 2013 due to hailstorm. Leaf diagnosis did not show any deficiency in terms of mineral nutrients N, P, K, Mg and Ca (results not shown). Average N concentration in the leaves was 2.1 ± 0.2 % of dry weight.

Physiology, yield and grape maturity

The **Table 2** shows the main results of physiology and must composition. Fertility was slightly higher in 2013. Yield was maintained at approximately 1.2 kg/m^2. Only Villeneuve had a lower yield because of important symptoms of millerandage for both vintages. As a consequence, leaf-fruit ratio varied from 0.9 to 2.6 m^2/kg. Differences between sites in terms of grape maturity were negligible. Only a strong vintage effect could be observed, with 22.0 ± 0.7 °Brix and 8.4 ± 0.6 g/L of TA in average in 2012 in comparison to 19.2 ± 0.7 °Brix and 11.1 ± 0.5 g/L in 2013. No differences could be observed between treatments within a site, except for YAN as described further.

Table 2: Variability of vine parameters, yield and must composition at harvest in function of site. There was no difference between control and fertilised treatments, thus only averages per site are presented. (cv. Doral, 2012 and 2013)

2012	Bud fertility (Clusters/shoot)	Yield (kg/m^2)	Leaf-fruit ratio (m^2/kg)	Pruning weight (g/m)	°Brix	pH	TA (mg/L)
Villeneuve	1.8	0.5	2.6	55	22.0	3.1	7.8
Cully	1.4	1.1	1.2	59	21.4	3.1	8.1
Pully	1.8	1.3	0.9	74	21.4	3.2	9.4
Vufflens	1.6	1.3	0.9	64	21.6	3.0	8.8
Changins	1.7	0.8	1.7	50	23.8	3.1	8.2
2013	Bud fertility (Clusters/shoot)	Yield (kg/m^2)	Leaf-fruit ratio (m^2/kg)	Pruning weight (g/m)	°Brix	pH	TA (mg/L)
Villeneuve	1.9	0.4	2.6	57	19.1	2.8	11.6
Cully	1.7	1.2	1.1	63	18.4	2.9	11.0
Pully	2.2	1.0	1.2	81	20.0	3.1	10.4
Vufflens	1.7	0.9	1.2	61	19.1	2.9	11.3
Changins	-	-	-	-	-	-	-

Principle component analysis

To better understand the links between the different parameters measured in this study, a global PCA was realised and is presented in **Figure 1**. The Figure 1A presents the parameters measured in the soils, upon the vines and in the musts. The Figure 1B shows the sites and treatments for each vintage. With this information, we can observe the vertical differentiation due to the differences in grape maturity between both the vintages, mainly due to the variation in soluble sugars and TA concentrations in the musts. Despite the vintage effect, we can see the site effect with identical site differentiation within both vintages. On the extreme right hand side, Pully presented more vigour (higher berry, cluster and pruning weights). Water holding capacity and soil depth seemed to be discriminant between sites and correlated with vigour and YAN level. On the other side, Villeneuve had the lowest vigour, the highest leaf-fruit ratio, which seemed to be correlated with its high soil stone percentage and its low water holding capacity. The plant density seemed to play a key role in the final YAN concentration since it directly affects the leaf area per vine and the quantity of urea applied per vine. Site altitude and water constraint were not discriminating parameters (short vectors), since altitude variation between sites was negligible (470 ± 20 m) and water supply from rain was not restrictive ($\delta^{13}C$ = -26.7 ± 0.7 ‰). N leaf content and chlorophyll index were not discriminant neither since N level in the vines were high and non-restrictive everywhere.

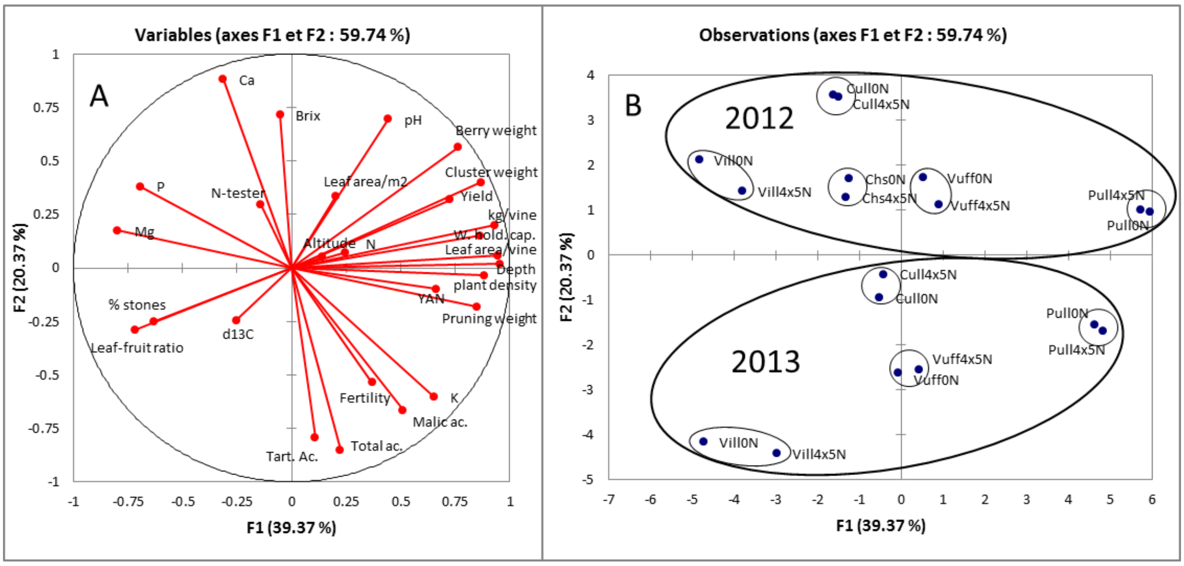

Figure 1: Principle component analysis on the data from both vintages 2012 and 2013. Figure A shows the correlations between the vine parameters; the vectors pointing in the same direction are correlated together. Figure B shows the similarities in terms of physiological behaviour between vintages, between sites (Cull=Cully, Pull=Pully, Vill=Villeneuve, Chs=Changins, Vuff=Vufflens) and between treatments (0N=control treatment, 4x5N=treatment with urea). Closer are the points, higher are the similarities. The vines in Changins were hit by hail in 2013. The vintage effect (2012 vs 2013) represents the main explanation of the plot differentiation, followed by the site effect, and then by the treatment effect (4x5N, 0N) (cv. Doral, 2012 and 2013).

YAN concentration in the must

Figure 2 shows the YAN concentrations per site and per treatment for both vintages. The average YAN concentrations in musts from control treatments were 124 ± 67 mg/L in 2012 and 124 ± 54 mg/L in 2013. The average gain in YAN due to urea application was larger in 2013 with 69 ± 34 mg/L in comparison with 46 ± 29 mg/L in 2012. For both vintages, Pully had the highest YAN concentration and Villeneuve had the largest YAN gain (+ 100 mg/L in average). On the other hand, the smallest YAN gain (+ 17 mg/L) was in Changins in 2012.

YAN concentration in the must from control treatments was positively correlated with the vine vigour represented by pruning weight (r^2 = 0.60) and by berry weight (r^2 = 0.53). Vigour was itself positively correlated with soil depth (r^2 = 0.82) and water holding capacity (r^2 = 0.56). YAN concentration was also negatively correlated with Phosphor (r^2 = 0.58) and Magnesium (r^2 = 0.72). No correlation could be pointed out neither between YAN concentration and leaf N content nor between initial YAN in control treatment and YAN gain after treatment. The YAN gain between control and fertilised treatments seemed to be correlated with leaf-fruit ratio (r^2 = 0.57), but this last result needs to be confirmed because of important chick and peas symptoms in Villeneuve site.

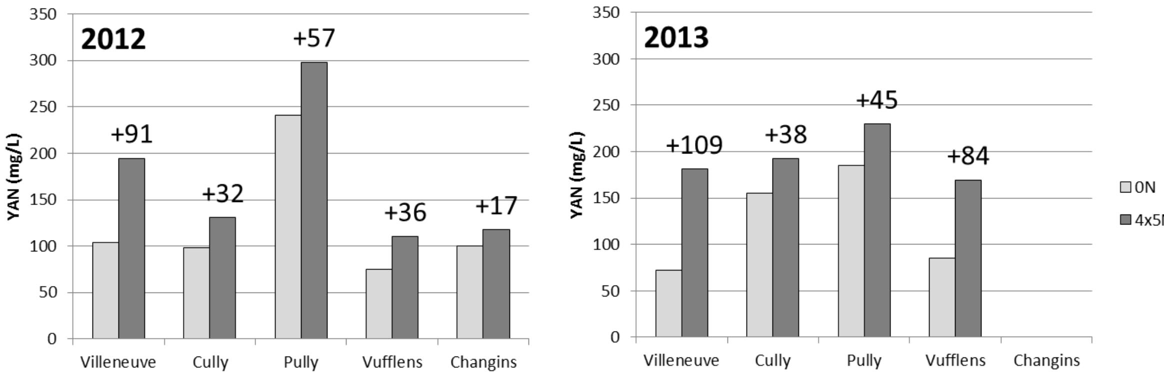

Figure 2: YAN content in the musts at harvest (mg/L) per site and per treatment. The vines in Changins were hit by hail in 2013. (cv. Doral, 2012 and 2013)

Wine quality

Because of vinification issues in 2012, only the wines from Villeneuve, Cully and Pully could be tasted by the Agroscope panel, and in 2013, no grape could be harvested from Changins due to hail. The wines from Pully were significantly preferred for both vintages in comparison with the other sites. At Villeneuve, the wine from the treatment with urea was preferred for both vintages: it was quoted significantly better balanced for both vintages and had a better bouquet in 2013. 2012 wines from Villeneuve were presented to 67 winemakers on the occasion of a hedonistic blind tasting: they significantly preferred the wine from the treatment with urea. On the other hand, no difference was noticed between both treatments from Cully for 2012, and from Cully and Vufflens en 2013. The treatment with urea from Pully was quoted visually more intense than the control treatment en 2012. The impact of urea treatment on the wine quality was not regular and affected various criteria, but it was globally either positive or non-significant. Indeed, the gain in wine quality becomes obvious when the YAN in the must rises from a restrictive to a non-restrictive concentration, above 200 mg/L (Spring and Lorenzini 2006).

4 CONCLUSION

The effect of foliar urea application at veraison significantly enhances the YAN concentration in the must in all the sites of the study without influencing the vine vigour and maturity parameters such as soluble sugars and acids concentrations in the must. This result confirms earlier publications (Lasa et al. 2012, Hannam et al. 2013). The sites Villeveuve and Pully beneficiated of a gain in terms of wine quality (colour, bouquet) whereas Cully and Vufflens did not present any difference for both vintages. The YAN concentration in the must was the parameter that best explained the enhancement in wine quality since it was the only parameter which significantly changed between control and fertilised treatments. The absence of wine quality enhancement in some sites can be justified by the YAN concentration which remained under the threshold of non-restrictive YAN concentration (200 mg/L) despite the urea application, as mentioned by Spring and Lorenzini for the cultivar Chasselas (2006). The effect of urea fertilisation was clearly negligible in comparison with the vintage effect which was particularly strong between 2012 and 2013. Despite the vintage effect and the relatively constant leaf N content between site, some sites regularly presented low YAN concentration in grape must (Villeneuve, Cully, Vufflens), whereas other sites beneficiated of high YAN concentration (Pully). This site effect was stronger than the urea treatment effect and could be correlated with the soil – more precisely the root zone size and structure – and the plant density which affects the leaf area per vine, the yield per plant and the quantity of urea applied per vine. Further investigation should be realised on the influence of root activity (growth, uptake, reserves) on the YAN concentration in the must.

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