EFFECTS OF WATER AND NITROGEN UPTAKE, AND SOIL TEMPERATURE, ON VINE DEVELOPMENT, BERRY RIPENING AND WINE QUALITY OF CABERNET-SAUVIGNON, CABERNET FRANC AND MERLOT (SAINT-EMILION, 1997)

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INTRODUCTION

Wine quality depends largely on berry ripening conditions in relation to soil and climat. The influence of the soil has been studied in Bordeaux since the early Seventies (SEGUIN, 1970; DUTEAU et al., 1981; VAN LEEUWEN, 1991; VAN LEEUWEN et SEGUIN, 1994) and, more recently, in the Val de Loire (MORLAT, 1989), the Alsace (LEBON, 1993) and the Costières de Nîmes regions (MARTIN, 1995). Its influence is complexe, because both physical (soil temperature, water uptake) and chemical (nitrogen uptake) soil parameters interfere on vine development and berry ripening.

Vine development, berry ripening and wine quality were studied in Saint-Emilion (Bordeaux area, France), in 1997, in relation to three different soil types:

- G: Gravelly soil
- S: Sandy soil, with a water table in reach of the roots
- C: Heavy clay soil

Three cultivars were compared, Vitis vinifera Cabernet-Sauvignon, Cabernet franc and Merlot. Water uptake, nitrogen uptake and soil temperature were measured to explain the different vine expressions on the nine plots (3 soils x 3 cultivars).

MATERIALS AND METHODS

Experimental plots

The three different plots are located less than 1 km apart in a flat area. Climat can be considered homogeneous. On each soil, 300 established vines (over 25 years old) have been grafted in 1995 with Cabernet-Sauvignon cl. 191 (100 vines), Cabernet franc cl. 327 (100 vines) and Merlot cl. 181 (100 vines). Rootstock is Riparia x Rupestris (3309 on "G" and "C", 101-14 on "S"). Vine density is 6000 vines per hectare. Yield, in 1997, was close to 1 kg of grapes per vine on each plot. No chemical fertilisation has been used on the plots since 1992; weed control is done by ploughing. Pesticide sprayings are carried out on the same dates and the same products were used.

Soils

The gravelly soil ("G") contains over 50% of gravel and stones. A very compact layer at 110 cm limits root depth.

The clayey soil ("C") is composed of a shallow sandy-clay layer on a very heavy clay sub-soil (over 60% of parts < 2 microns). Roots use cracks, which appear in the dry season, to colonise the clay.

The sandy soil ("S") has a very sandy top soil. At 100 cm, a clayey-sandy sub soil appears. This soil contains a water table in reach of the roots, which was located at 85 cm depth around budbreak (March) and at 155 cm depth in September.

Soil temperature, water uptake and nitrogen uptake

In each soil thermocouples were placed at 30, 60 and 120 depth. Soil temperature was measured once every week with a portable data logger (SAM 70, AOIP mesures).

Vine water status was evaluated by mesuring pre-dawn leaf water potential (SCHOLANDER et al., 1965), from July through September.

Must total nitrogen content, analysed by KJELDAHL method, was used as an indicator for vine nitrogen uptake (SOYER et al., 1996).

Vine development, berry ripening and wine quality

Shoot growth (average of 30, horizontally trained, shoots per plot) and leaf area development were followed through the season (CARBONNEAU, 1976). Major juice and skin compounds of the grapes were analysed, as well as Isobutylmethoxypyrazine (IBMP), which is responsable for green pepper taste in wine. High IBMP content can be considered as an indication of a lack of physiological ripeness of grapes. Wines, obtained from microvinifications of 50 kg of grapes, were analysed and tasted.

RESULTS

I - VINE DEVELOPMENT, BERRY RIPENING AND WINE QUALITY IN 1997

1 - Climatic conditions in 1997

1997 was a warm year in the Bordeaux area. Temperatures were largely above average from January until early June and from late July through September (fig. 1). The weather was cool from mid June until mid July.

The beginning of the season (January through April), as well as the end of the season (September through October) was very dry (fig. 2). May, June and August were very rainy.

2 - Vine development, leaf area development and shoot growth

Phenological stages

1997 was a vintage of great precociousness in Bordeaux because of the warm and dry weather in the late winter and the early spring (table 1). Flowering and veraison dates were close for the three cultivars on the three soil types. For each cultivar, ripeness was achieved at the same date on the three soils, though important differences have been noticed between varieties: 4th September for Merlot, 16th September for Cabernet franc and 29th September for Cabernet-Sauvignon.

Leaf area development

Primary, secondary and total leaf area were measured at the end of April, May, June and July (fig. 3).

Primary leaf area increased until June and then remained unchanged at the nine plots because of the trellissing system (vertical shoot positioning with shoot tipping at 105 cm of shoot length).

Secondary leaf area was similar at the three soils for Cabernet franc.

For Merlot and Cabernet-Sauvignon, secondary leaf area was high at S and continued its development after July. Secondary leaf area was low on C, where it either had finished its development (Cabernet-Sauvignon) or had very much slowed it down (Merlot) at the end of June. On the gravelly soil (G), secondary leaf area was high for Merlot and low for Cabernet-Sauvignon.

Shoot growth

Shoot growth, measured on horizontally trained shoots which were not tipped, was above average in 1997 and growth slackening happened very late in the season. For Merlot, total shoot length was particularly high on S (445 cm) and shoot growth stopped only 22nd September (fig.4). On G, total shoot length was slightly shorter (431 cm) and shootgrowth stopped earlier (10th September). Shoot growth was lower on C (326 cm).

For Cabernet-Sauvignon and Cabernet franc, shooth growth was also high on S, low on C and intermediate on G.

3 - Berry ripening

We will comment on analytical results at ripeness. Values given for a cultivar are averages on the three soils; values for a soil are averages of the three cultivars. Ripening speed was calculated according to DUTEAU (1990).

Some of the parameters measured were more influenced by the soil than by the cultivar (fig. 5). Berry sugar and anthocyan content were similar for Cabernet-Sauvignon, Cabernet franc and Merlot. They were high on C, low on S and intermediate on G.

Other parameters measured were influenced both by the cultivar and the soil type. Merlot produced big berries, which ripened quickly and which were low in total acidity. Cabernet-Sauvignon berries were small; ripening speed was low, resulting in relatively high total acidity. Cabernet franc produced small berries, which ripened quickly, and which were not very acid at ripeness. On the sandy soil, berries were big, ripened slowly and were high in total acidity. On the clayey soil, the inverse was observed. On the gravelly soil, berry weight, ripening speed and total acidity were intermediate.

Isobutylmethoxypyrazine (IBMP) content depended more on the cultivar than on the soil type. IBMP was low for Merlot and intermediate for Cabernet-Sauvignon. In our study, Cabernet franc was the only variety with IBMP levels above detection treshold (15 ng/l).

4 - Constitution and quality of wines obtained by micro vinification.

Wines were chaptalised in order to obtain habitual alcohol levels for red Bordeaux wine. Their constitution is a logical result of berry composition. On C, the wines are rich in color and phenolic compounds (table 2); they were much appreciated by the tasting panel (average ratings fot the three cultivars: 14.8/20). On S, wines are poorly coloured and contain little phenolic compounds. The panel judged the wines diluted and short (average rating: 9.3/20). On G, wine composition was intermediate as was the average rating (12.7/20). For each of the three soil types, Merlot was preferred over Cabernet franc and Cabernet-Sauvignon. This might be a consequence of the climatic conditions of the vintage: in most estates in Bordeaux, in 1997, the best lots were generally produced from Merlot grapes.

II - SOIL PARAMETERS

Three soil parameters have been taken in account in this study: soil temperature, nitrogen uptake and water uptake

1 - Soil temperature

Soil temperature, which was measured from March through November at three depths (-30, -60 and -120 cm) was significantly higher on G (average of the three depths for each soil type: fig. 6). The differences between G, on the one hand, and C and S, on the other hand, were small in March and in November, and big in July and August. The average difference was +0.9°C compared to C and +1.4°C compared to S. In the Val the Loire Region (France), where Cabernet franc is grown at the limit of its ripening possibilities, soil temperature is an important factor for precociousness and wine quality (MORLAT, 1989). This does not seem to be the case in our plots, in Saint-Emilion, in 1997: despite higher soil temperature, G is not producing the best wines and grapes do not, in comparison to the other soils, attain ripeness in an earlier stage.

2 - Vine nitrogen uptake

Total nitrogen content of grape juice is a valuable indicator for vine nitrogen uptake (SOYER et al., 1996). We measured big differences among the soils, though neither of them had received mineral nitrogen fertilization since 1991.

On S and C, must total nitrogen is low, which shows that vines are close to nitrogen deficiency (fig 7: example of Merlot).

On G, must total nitrogen is about twice as high. Although soil humus content is similar to that on S and C, mineralisation speed might be higher due to higher soil temperatures and better soil aeration.

On our plots, vine nitrogen uptake does not seem to explain vine development and wine quality: on S and C, vine vigor and wine quality were very different despite similar nitrogen uptake. On G though, higher nitrogen uptake might have contributed to a relatively big secondary leaf area.

3 - Vine water status

In 1997, due to regular rainfal in summer, vines never suffered big water stress in Bordeaux. Though, differences in water uptake we noticed on the three soils (fig. 8: example of Merlot) and seems to explain vine development, berry ripening and wine composition.

Unlimited water uptake on S resulted in high shoot growth and a large secondary leaf area. High berry weight was associated with low sugar and anthocyan content and high total acidity. The wines obtained low ratings for all the cultivars.

On C, a moderate but early water shortage appeared late July, around veraison. Shoot growth was low and secondary leaf area was not very developped. Berries were small, rich in sugar and anthocyans, and low in acidity. Wine quality was high.

On G, water shortage was similar to that on C, but it occured later in the season (end of August). Shootgrowth and secondary leaf area were intermediate. Berry composition and wine quality were better than those observed on S, but less compared to C.

CONCLUSION

In 1997, on our plots in Saint-Emilion, vine development and berry ripening depended on the soil type, resulting in high differences in wine composition and quality, for each of the three cultivars. Among three soil parameters studied, our results seem to be best explained by vine water status.

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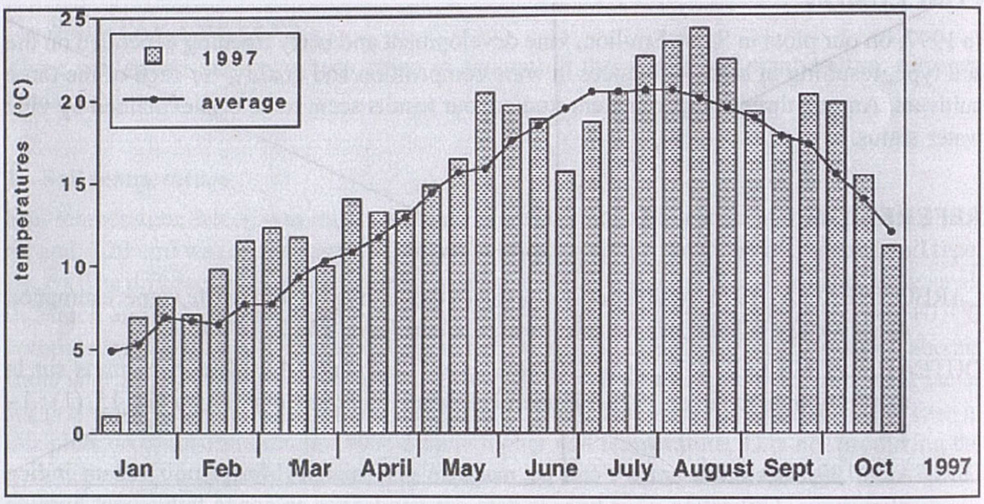

Fig. 1 - *Temperatures per period of ten days in Saint-Emilion in 1997; comparison with average values over a 25 year period*

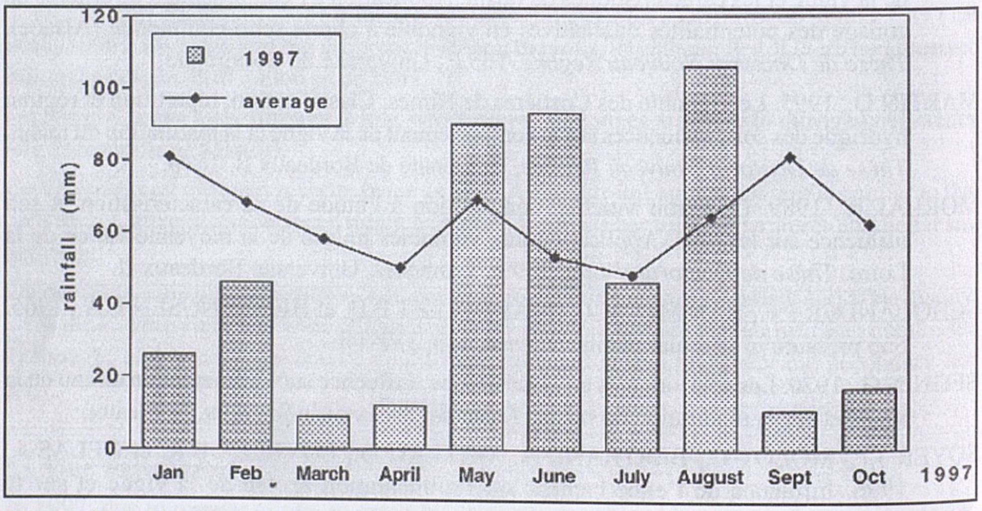

Fig. 2 - *Monthly rainfall in Saint-Emilion in 1997; comparison with average values over a 25 year period*

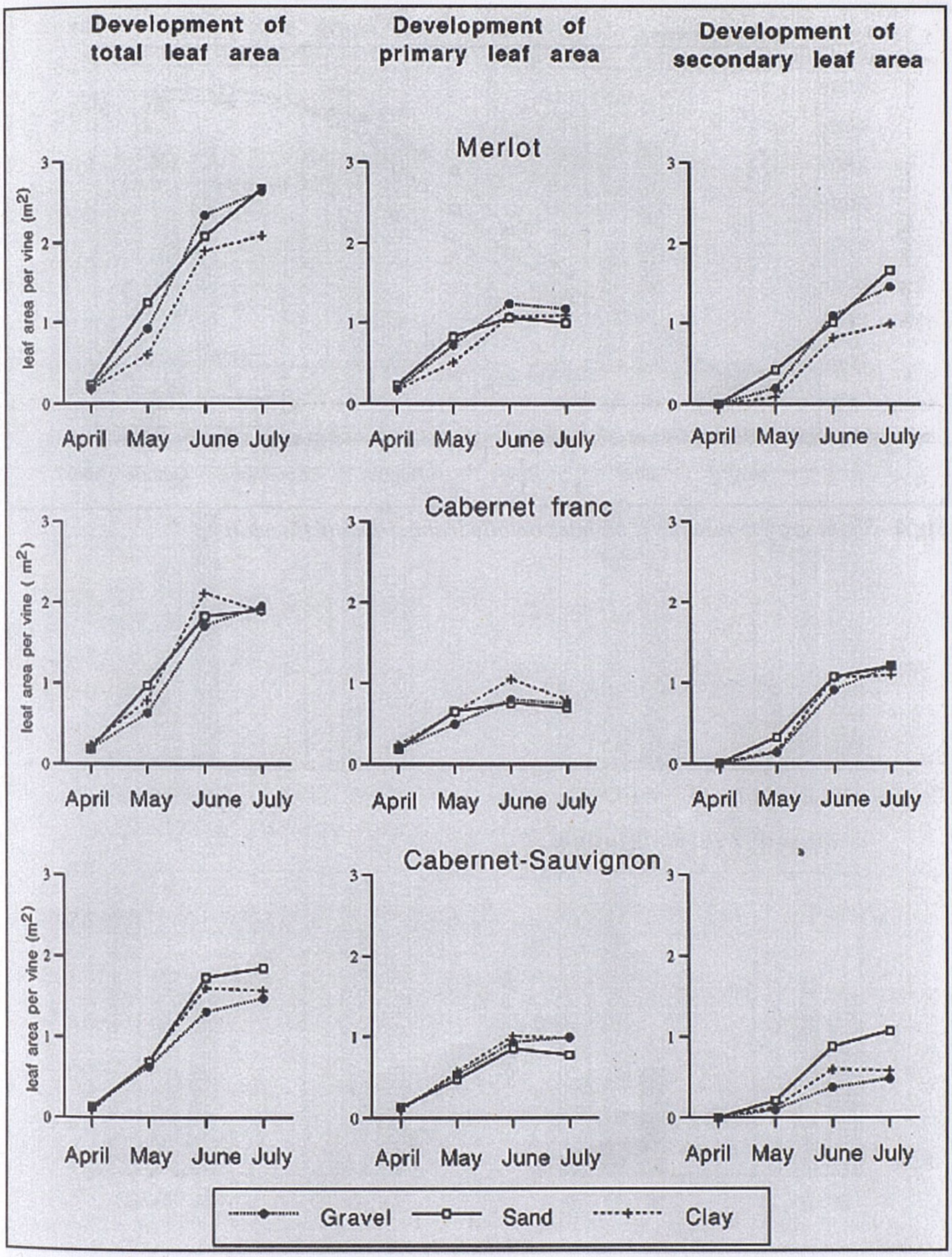

Fig 3 - *Development of primary, secondary and total leaf area from April through July*

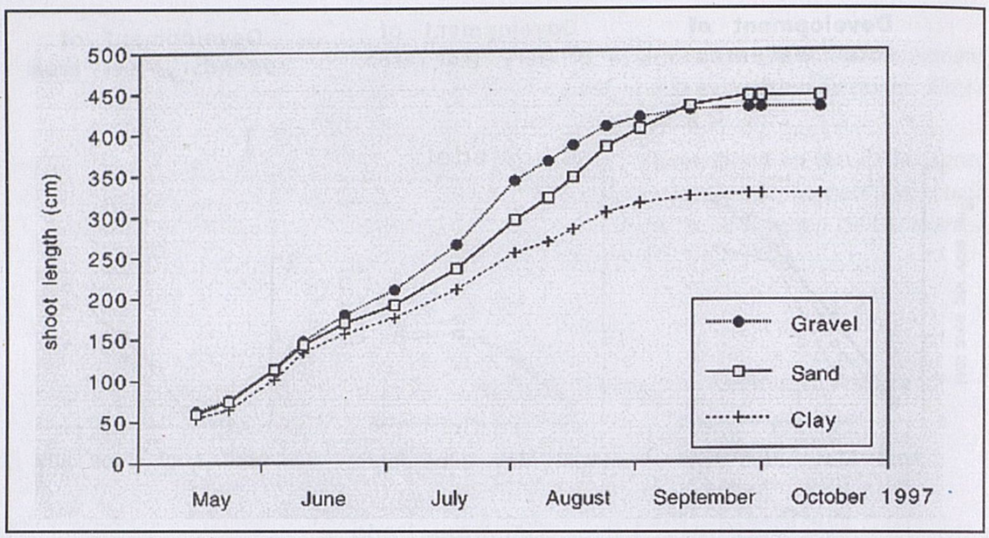

Fig 4 - *Shoot growth measured on horizontally trained shoots (Merlot)*

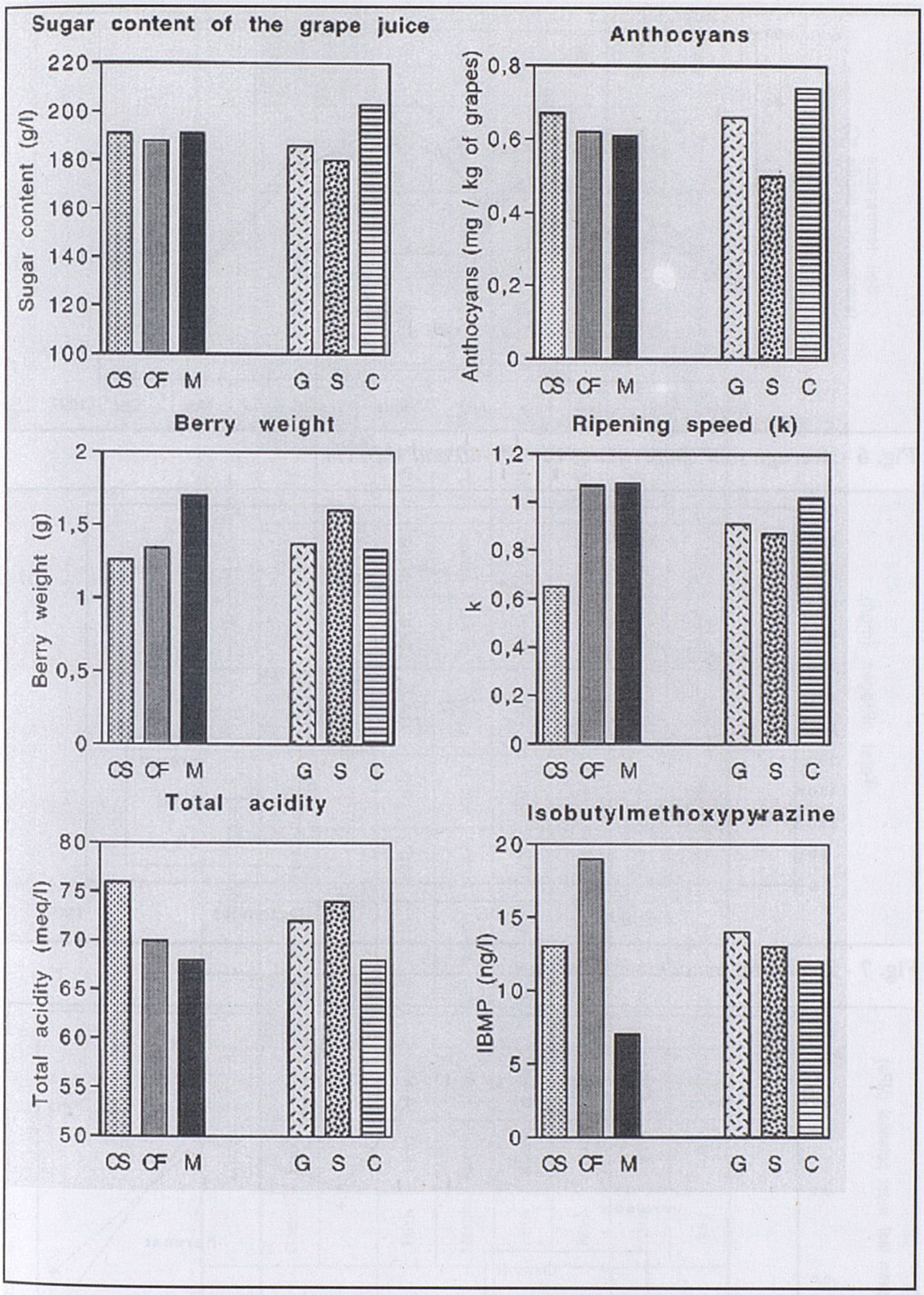

Fig 5 - *Berry composition at ripeness*

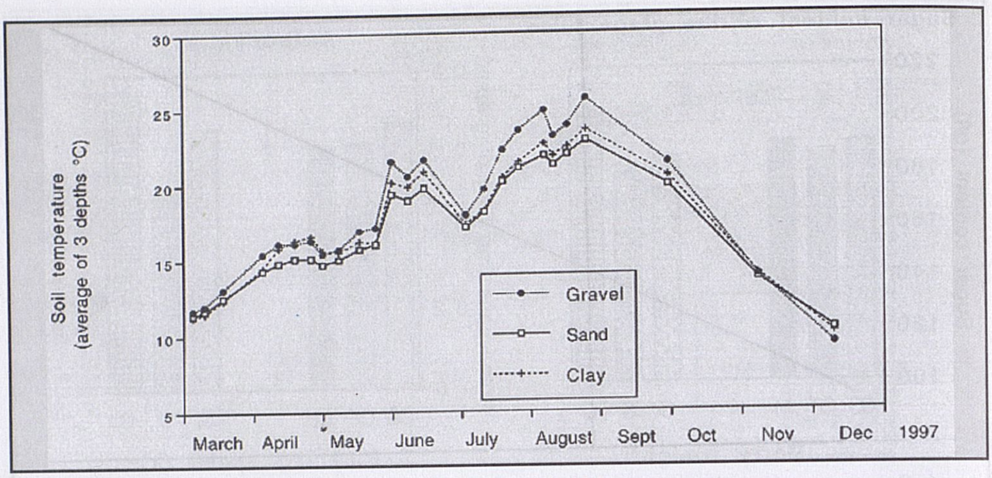

Fig. 6 - *Average soul temperatures at -30, -60 and -120 cm.*

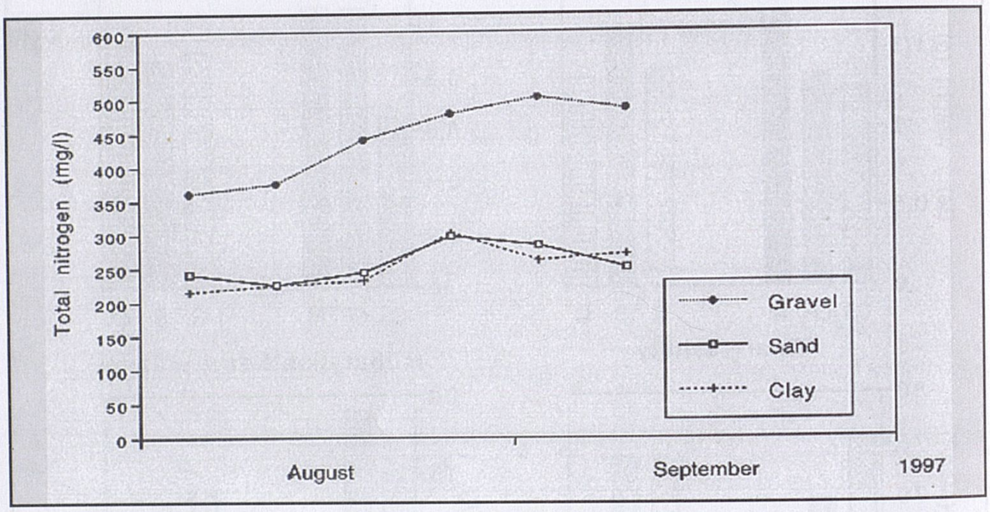

Fig. 7 - *Total nitrogen content in berries*

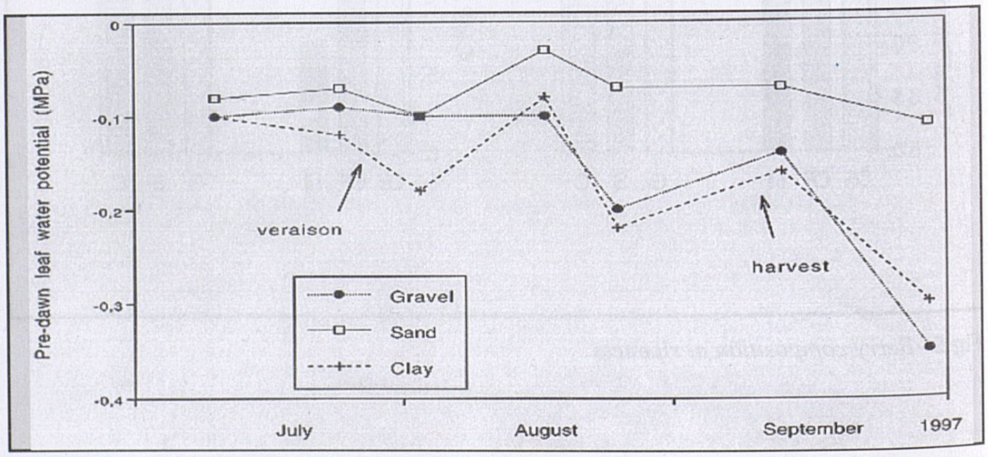

Fig 8 - *Vine water status of Merlot vines from July through September*

	Merlot				Cabernet franc				Cabernet-Sauvignon				soils			
	Gravel	Sand	Clay	average merlot	Gravel	Sand	Clay	average CF	Gravel	Sand	Clay	average CS	average Gravel	average Sand	average Clay	general average
Bud break	15th	17th	13th	15th	17th	18th	16th	17th	25th	29th	23th	26th	19th	21th	17th	19th
	March	March	March	March	March	March	March	March	March	March	March	March	March	March	March	March
Flowering	19th	20th	18th	19th	22th	22th	22th	22th	24th	26th	24th	25th	22th	23th	21th	22th
	May	May	May	May	May	May	May	May	May	May	May	May	May	May	May	May
Veraison	23th	23th	21th	23th	27th	29th	29th	28th	23th	24th	20th	23th	24th	25th	23th	24th
	July	July	July	July	July	July	July	July	July	July	July	July	July	July	July	July

	Gravel	Sand	Dlay
Total acidity (meq/l)	58	62	64
pH	3,87	3,74	3,80
Alchol content (%)	12,3	12,4	12,8
Volatile acidity (meq/l)	0,67	0,69	0,64
Anthocyans (mg/l)	510	350	510
Color intensity (DO 420+DO 520 + DO 620)	0,57	0,42	0,78
Total Phenolic compounds (D280)	41	35	49
Total tannin content (g/l)	2,0	1,7	2,4