Comparative Studies on Wine Grapes on Different Trellising Systems:
II. Micro-climatic Studies, Grape Composition and Wine Quality

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ABSTRACT

In a field experiment the micro-climate and grape composition of four trellising systems viz., *(a)* Bush vines, *(b)* Perold system, *(c)* Lengthened Perold, and *(d)* Slanting trellis were investigated and compared. Significantly more air movement, higher bunch and ambient air temperature as well as higher soil temperatures at 200 mm depth were recorded in the bush vines compared to the lengthened Perold and slanting trellis. Bunch temperature differences among trellising systems became most pronounced at 12h00 to 14h00.

The sugar concentration in grapes from the bush vines increased at a slower rate compared to the other trellising systems and retarded the harvesting date of the former by a week. Fluctuations in soil moisture content affected both sugar concentration and berry volume positively or negatively, depending on the stage of berry development and quantity of water applied to the soil. Malic acid concentration of the bush vines juice was 1,78 g/ℓ lower compared to the slanting trellis at harvesting time, while tartaric acid contents were the same for all trellising systems.

Although a distinct relationship between micro-climate and grape composition was found, apparently no relationship existed amongst these two aspects and the organoleptically evaluated wine quality. A re-appraisal of the results of a former trial obtained in the same experimental vineyard led to the conclusion that wine quality from these different trellising systems is directly related to the incidence of *Botrytis cinerea*.

INTRODUCTION

Experimental data on the relationship between grape composition and climatic elements, especially temperature, light intensity, rainfall and hours sunshine were reported in many publications (Kliewer & Lider, 1968; Kliewer & Lider, 1970; Buttrose, Hale & Kliewer, 1971; Kliewer, 1971; Kliewer & Schulz, 1973; Winkler, Cook, Kliewer & Lider, 1974; Hofäcker, Alleweldt & Khader, 1976). However, these results were seldom evaluated under different micro-climatic conditions as induced by viticultural practices, such as different trellising systems. Kliewer & Lider (1968) reported a lower total acidity, higher pH and a change in the tartrate/malate ratio when comparing grapes in a sunny position on the vine to shaded grapes. Similar differences can be expected to exist among different trellising systems. Draganov & Dragonov (1976) found a decrease in sugar concentration but an increase in grape yield and total acidity of grapes from higher trellised vines compared to vines trained on lower systems. In a field trial Van der Westhuizen (1974) found that higher bunch, leaf and soil temperatures, higher wind speeds, Class A-pan evaporation and nett radiation existed in bush vines compared to a slanting trellis. Research done by Draganov, Pondeliev & Antanov (1975) showed that the biggest differences between green plant parts and the ambient air temperature existed in a Guyot trained vineyard, and that the smallest differences occurred in umbrella-shaped trellised vines. Smart, Dry & Bruer (1978) stressed the important influence of cultural practices on the micro-climate. According to them the traditional European viticultural practices associated with high wine quality may well be the result of a specific micro-climate.

In South Africa large slanting type trellising systems have been shown to be advisable on fertile soils where moisture is not a limiting factor. However, due to the inadequate knowledge as to how and to what extent the micro-climate is modified by trellising systems, a comprehensive study was undertaken in an existing trellising experiment at Robertson (Zeeman, 1975) to quantify the most prominent micro-meteorological elements and to determine its effects on grape composition and eventually also on wine quality.

MATERIALS AND METHODS

In the first paper of this series the experimental conditions viz., locality, soil type and cultural practices regarding the experimental vineyard are described (Van Zyl & Van Huyssteen, 1980). The four trellising systems used in this investigation were:

(a) Bush vines.
(b) 3-Wire Perold system.
(c) 5-Wire lengthened Perold system.
(d) 1,7 m Slanting trellis.

Bush vines were pruned to 12 buds per vine (35 400 buds/ha), but the other three trellising systems were each divided into 6-vine plots which were either pruned to 20 buds per vine (59 000 buds/ha) or 26 buds per vine (77 700 buds/ha).

The micro-climatic elements were measured in three of the trellising systems on the "20 bud plots". The 3-wire Perold system was omitted in this case, and it was further assumed that the two cropping levels would not affect the micro-climate differently. Air movement was measured at average bunch height in the middle of the rows by means of a standard three cup recording anemometer. Piché evaporimeters were installed to give an indication of evaporation just above the soil surface, while bunch temperatures, air temperatures among the foliage of the vines and relative humidity were measured by means of copper/constantan thermocouples. The latter two measurements took place in small aluminium shields placed inside the canopy of the vines. Relative humidity was calculated from temperature differences between an uncovered thermocouple and one housed in a cloth which was wetted prior to each measurement. These thermocouple measurements were carried out at certain fixed times of the day, namely at 06h00, 12h00, 14h00 and 16h00. For a 5 day period in January the latter measurements were done more intensively on a 24 hour basis in order to get an indication of diurnal fluctuations. Soil temperatures were measured at two depths, i.e. 200 mm and 500 mm, in each system under the vine row by means of standard continuous recording soil thermographs. The thermograph probes were installed in an undisturbed profile wall.

All aforementioned measurements commenced at flowering (beginning November) and continued till harvesting (end February). Soil moisture was measured on a weekly basis (Van Zyl & Van Huyssteen, 1980) by means of the neutron backscattering method. A nearby weather station supplied all other relevant meteorological data.

Parallel to the weekly soil moisture determinations and micro-meteorological measurements, berries were sampled weekly from the bush vines as well as the 20 bud plots of the other three trellising systems, starting three weeks after flowering and continuing until harvest. Berry sampling took place on a statistical basis suggested by Du Plessis & Van Schalkwyk (1974). The mass and volume of berries in each sample of ±200 berries were then determined in the laboratory, the berries macerated in a mortar, squeezed through cheesecloth and the juice centrifuged at 5 000 r.p.m. for 10 minutes. Thereafter the juice was immediately analyzed for: total soluble solids, using an Abbé refractometer; pH; total acidity by titration with 0,1 N sodium hydroxide up to pH 7,0; tartaric acid (Rebelein, 1973) and malic acid using the method described in a Boehringer—Mannheim GmbH publication (Anonymous, 1976). Part of the non-centrifuged juice was frozen for the determination of arginine by the method of Gilboe & Williams (1956) and of total nitrogen by the micro-Kjeldhal method at a later date. Just prior to harvest the incidence of Botrytis rot was statistically evaluated in the grapes of each trellising system. Harvesting took place at a degree Balling/Total titratable acidity ratio of approximately 2,5. Grape yield was determined at that stage. Experimental wines were made in duplicate (20 ℓ containers) from selected healthy grapes that showed little or no signs of *Botrytis cinerea*, and subjected to organoleptic evaluation. Shoot mass was determined at pruning in order to get an indication of vegetative growth.

RESULTS AND DISCUSSION

The micro climate

Air movement: By far the lowest air movement (49% less than in the bush vines) was measured in the lengthened Perold system, while most air movement occurred among the bush vines (Table 1). This finding confirmed the expectation that bush vines generally offer low resistance to air flow. Vines trellised on a lengthened Perold grow into hedges not easily penetrated by wind, especially when the wind direction is at right angles to the rows as mostly happened in this case. Table 1 also shows somewhat less wind in the slanting trellis (11,5% less over a three month period) than among the bush vines. This seems to be due to the fact that air movement can take place underneath the foliage of vines trellised on high stems.

TABLE 1
Average air movement at bunch height (km/day) measured in different trellising systems compared to wind speed at a nearby weather station at Robertson

Month	Bush vines	Lengthened Perold	Slanting trellis	Weather station
November ..	34,4	19,2	28,2	92,0
December ..	31,7	16,1	26,6	130,0
January	28,2	12,3	28,1	93,0
Average	31,43	15,87	27,63	105,0

Ambient and bunch temperatures: A comparison between the bunch temperatures of the different trellising systems and the air temperature in the immediate vicinity of the bunches, revealed a rather complex pattern. No temperature differences were found in either of the positions at 06h00, but at 12h00 differences among the trellising systems became most pronounced (Fig. 1 & 2). Although the curves are intermingled, Fig. 1 distinctly shows a higher air temperature in the bush vines, especially during the important ripening stage (4th January–17th February). The biggest temperature differences were found in the bunches (Fig. 2). From véraison to ripening these temperatures at 12h00 were on an average 6,73 °C higher in the bush vines than in the lengthened Perold and 5,71 °C higher than that of the slanting trellis (Table 2). On individual days these differences were even greater. High temperatures in the bush vines are the result of bunches being more exposed to the sun than in other trellising systems, where shoots and leaves provide more shade. Bush vines also receive much more reflected heat from the soil surface than vines on higher stems. The relative temperatures in the lengthened Perold are unexpected and probably due to the growth pattern of the vegetative parts which is concentrated in a vertical plane above the bunches. Measurements of the shading patterns of the trellising systems (Van Zyl & Van Huyssteen, 1980) further revealed side-shading of bunches by neighbouring rows of the lengthened Perold system, which ran in a more or less north east—southwest direction.

soil surface. This could have an effect on evapotranspiration.

(b) According to research done by Hofäcker, Alleweldt & Khader (1976) grape acidity is negatively correlated to soil temperature. In view of the desirability of higher acidity levels in South African white wines, the influence of trellising systems on soil temperature should not be neglected.

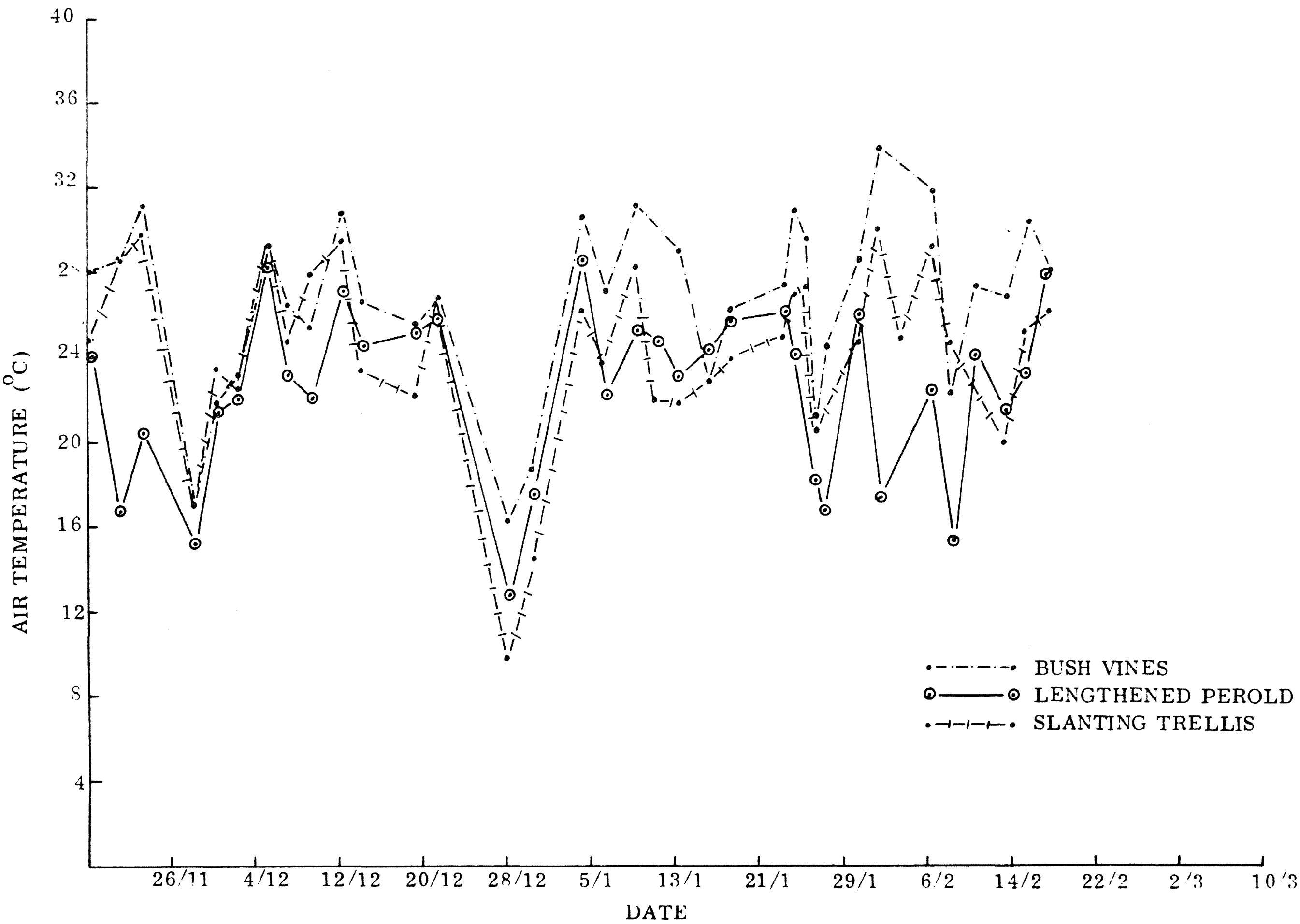

FIG. 1
Air temperature in the vine canopies of different trellising systems at 12h00.

Bunch temperature measurements intensively carried out over a five day period (Fig. 3) in order to follow diurnal fluctuations, showed bunch temperature maxima at 12h00 to 14h00. Noticeable differences among bunch temperatures of the three trellising systems occurred mostly between 10h00 and 15h00 to 16h00. Although temperature differences were sometimes small and valid for short periods only, it should be borne in mind that its effect e.g. on grape composition is cumulative. Small but regular temperature differences should thus not be ignored as far as it may effect the composition of grapes.

Soil temperatures: Soil temperature was considered to be an important parameter, and much attention was given to its measurement for two reasons:

(a) Lower soil temperatures were expected in the trellising systems which provide more shading of the

Mean weekly maximum soil temperatures at two depths in the different trellising systems are illustrated in Fig. 4. A marked lowering in soil temperature occurred in the first week after irrigating the vineyards in November as well as in December and also to a lesser extent in January. Seasonal averages at the 200 mm depth were 24,6; 23,7 and 23,3 °C for the bush vines, lengthened Perold and slanting trellis, respectively. At the 500 mm depth, soil temperature in the lengthened Perold system was the highest viz. 23,3 °C in comparison with 22,7 °C in the bush vines and 21,7 °C in the slanting trellis. Present knowledge concerning the effect of temperature on plant roots is still too limited to relate these small temperature differences to plant reaction. It should, however, be kept in mind that irrigation water might have masked the effect of the trellising system on soil temperature. Soil temperatures nearer to the surface (not measured in this experiment) might also have shown more pronounced differences.

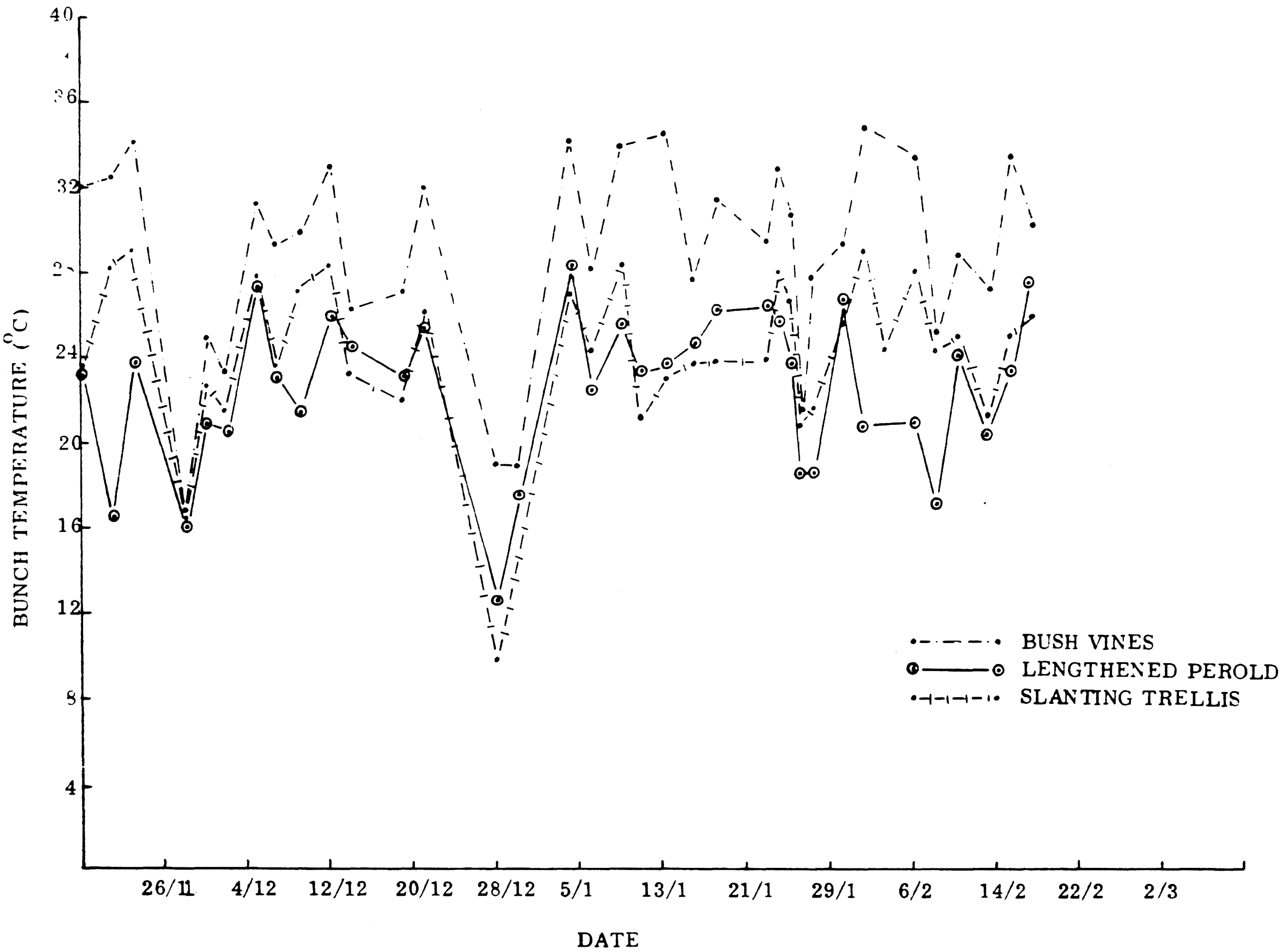

FIG. 2

Bunch temperatures of different trellising systems at 12h00 for the period fruit set to harvesting.

Attempts to quantify atmospheric conditions immediately above the soil surface in the different trellising systems by means of the Piché-evaporimeter did not succeed because of instrumental failure. Problems were mainly encountered with the filter paper discs which either leaked, became clogged with dust or did not make good contact with the water column. Field conditions were apparently too harsh for this apparatus to function reliably.

Botrytis and humidity: It is a well-known fact that the incidence of certain fungus diseases e.g. Botrytis rot is increased by conditions of high humidity, hence the importance of this climatic element (Matthee, 1970; Winkler *et al.*, 1974). Results from humidity measurements were far more inconsistent than in the case of temperature, probably due to complicating factors such as wind. Table 2 shows a slightly higher average humidity in the bush vines than in the other two systems at 06h00, 14h00 and 16h00 during the ripening stage. When data for the whole season are compared, it becomes evident that the relative humidity dropped much lower in the slanting trellis and, to a lesser extent, in the lengthened Perold than in the bush vines. The biggest differences among trellising systems occurred at night, as demonstrated by the 06h00 measurement (Fig. 5). This could be expected since the measurements in the bush vines were much nearer to the soil surface, where cooling takes place most rapidly and the moisture saturation of the air should be highest. It is, however, highly improbable that the small differences in humidity encountered in this study, could have much effect on Botrytis rot. However, according to Van Zyl & Van Huyssteen (1980) more statistically significant Botrytis rot occurred in the bush vines (46,2% rot) than in the lengthened Perold (34,4% rot) and the Perold system (32,0%). The percentage bunch rot in the slanting trellis was 40,1, which does not differ statistically from the other systems.

Grape characteristics and composition

Berry growth: The seasonal changes in both berry mass (not shown here) as well as berry volume (Fig. 6), followed the well-known double sigmoid growth curve (Winkler, *et al.*, 1974). This is due to rapid berry enlargement during the cell division period, followed by a lag phase and eventually the swelling of the grapes at véraison. The slanting trellis system produced slightly larger berries than the other three trellising systems (Fig. 6) among which berry size did not differ. This finding is explained by Table 3, which shows a relative low grape yield on the slanting trellis in 1977/78, while the other three systems yielded more in accordance with Zeeman's (1975) findings. It is assumed that smaller berries are favourable to better wine quality (Amerine, Berg & Cruess. 1972).

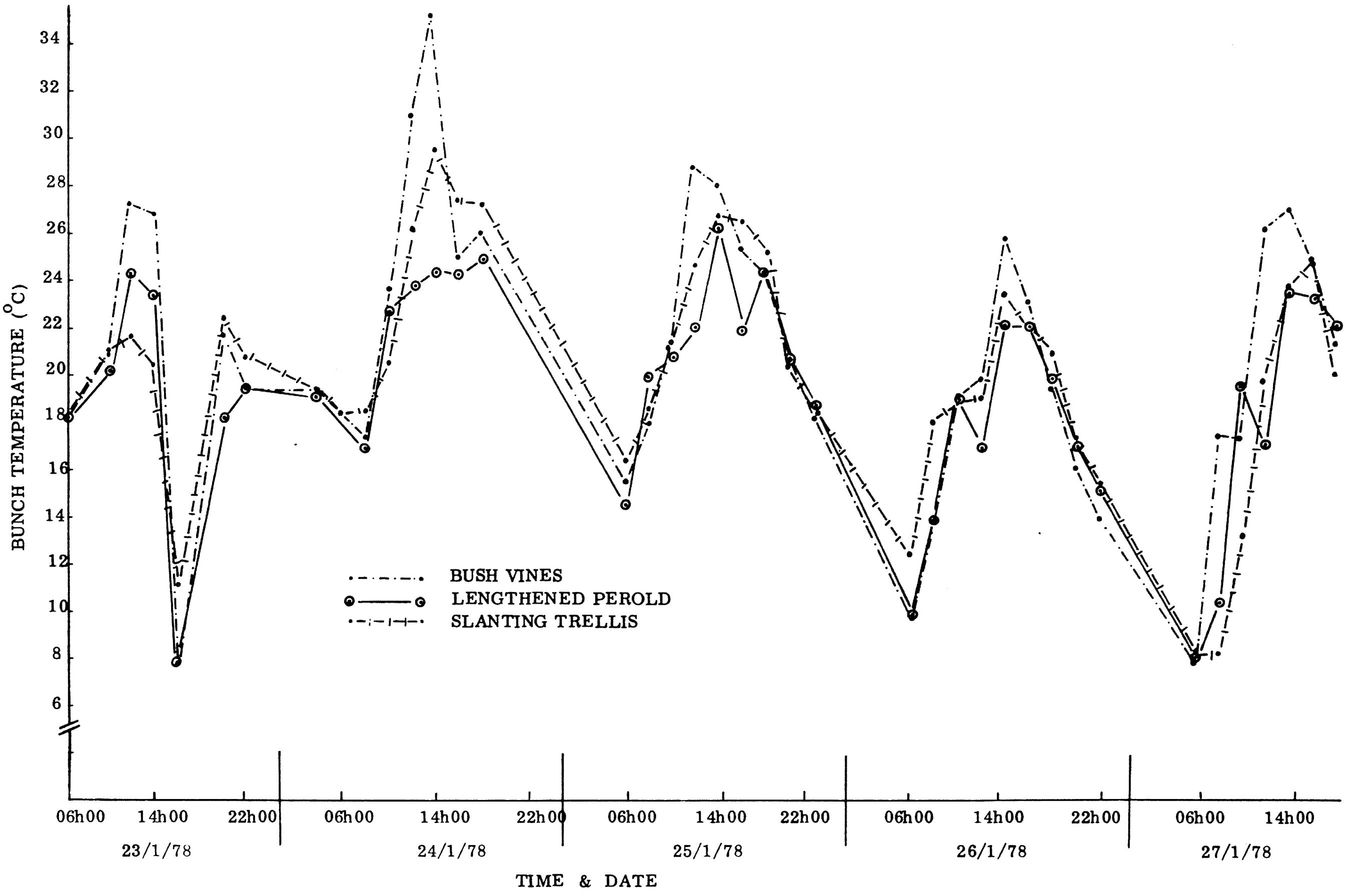

FIG. 3
Diurnal fluctuations in Bunch Temperatures of three different trellising systems.

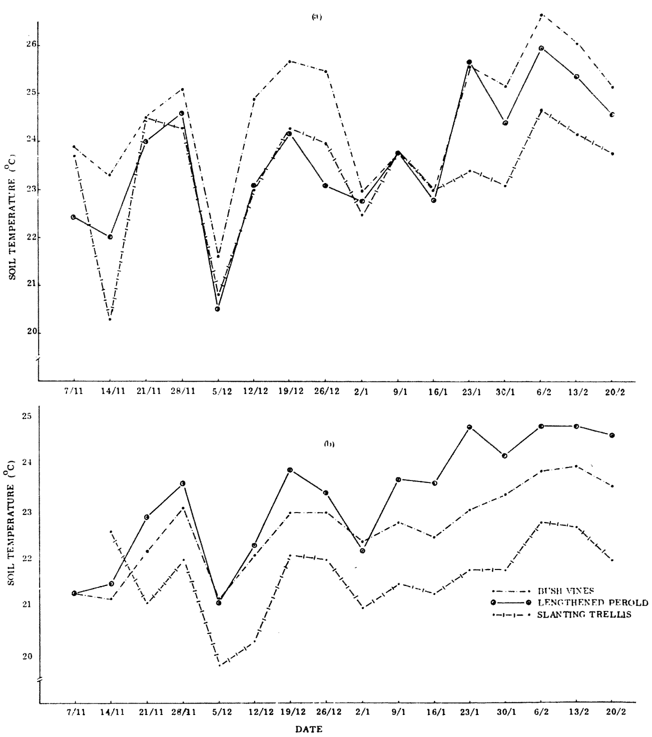

FIG. 4
Mean weekly maximum soil temperatures at (a) 200 mm and (b) 500 mm depth in different trellising systems.

Total soluble solids (TSS): The change in TSS concentration during the season is illustrated by Fig. 7. TSS increases for the Perold, lengthened Perold and slanting trellis followed a similar pattern. TSS concentrations in bush vine grapes were, however, much lower than those of the other systems. This deviation started at véraison and continued till harvesting, even though grapes from the bush vines were allowed to ripen 8 days longer. This finding was rather unexpected in view of the higher tempatures measured in the latter vines. A similar lower sugar content in the bush vines in comparison with the other trellising systems was also found by Zeeman (1975) in some years. Active vegetative growth observed on the bush vines during ripening and probably due to a lighter crop in comparison with the other more heavily cropped vines, may offer an explanation for this phenomenon.

Fig. 8 shows the rates of both berry volume increase and TSS concentration increase in different trellising systems. From Fig. 8 it is clear that the rate of berry growth was positively influenced by irrigation as well as rainfall. At véraison the rate of both sugar and berry volume increase showed a peak, which is natural for that specific growth stage. The irrigation on the 20th of January, however, increased the rate of change in berry volume and decreased the rate of sugar formation. Soon afterwards when this effect was cancelled, the rate of sugar synthesis again exhibited a peak, but berry enlargement slowed down. A few days before harvesting a mere 7,0 mm rainfall increased both the rate of sugar formation as well as berry

TABLE 2
Average temperature and relative humidity at various times during the day in different trellising systems

Growth stage	Time	Bunch temperature (°C)			Ambient air temperature (°C)			Relative humidity (%)		
		Bush vines	Lengthened Perold	Slanting trellis	Bush vines	Lengthened Perold	Slanting trellis	Bush vines	Lengthened Perold	Slanting trellis
Fruitset—Véraison	06h00	15,06	14,64	15,54	15,32	14,81	15,98	91,1	89,7	88,9
	12h00	27,22	21,61	22,90	24,90	21,61	23,43	68,9	61,2	66,1
	14h00	25,30	20,86	22,61	24,23	21,12	23,00	63,0	53,5	62,4
	16h00	22,62	21,08	22,37	22,42	20,91	22,37	64,2	60,2	61,2
Véraison—Harvesting	06h00	15,06	14,94	14,79	14,98	14,59	14,60	93,4	89,8	88,9
	12h00	30,06	23,33	24,65	27,71	22,78	24,55	66,4	64,7	67,8
	14h00	30,28	25,36	27,35	28,18	24,77	26,29	61,4	57,6	58,5
	16h00	23,23	21,17	23,07	22,60	20,88	21,82	59,4	50,9	53,9

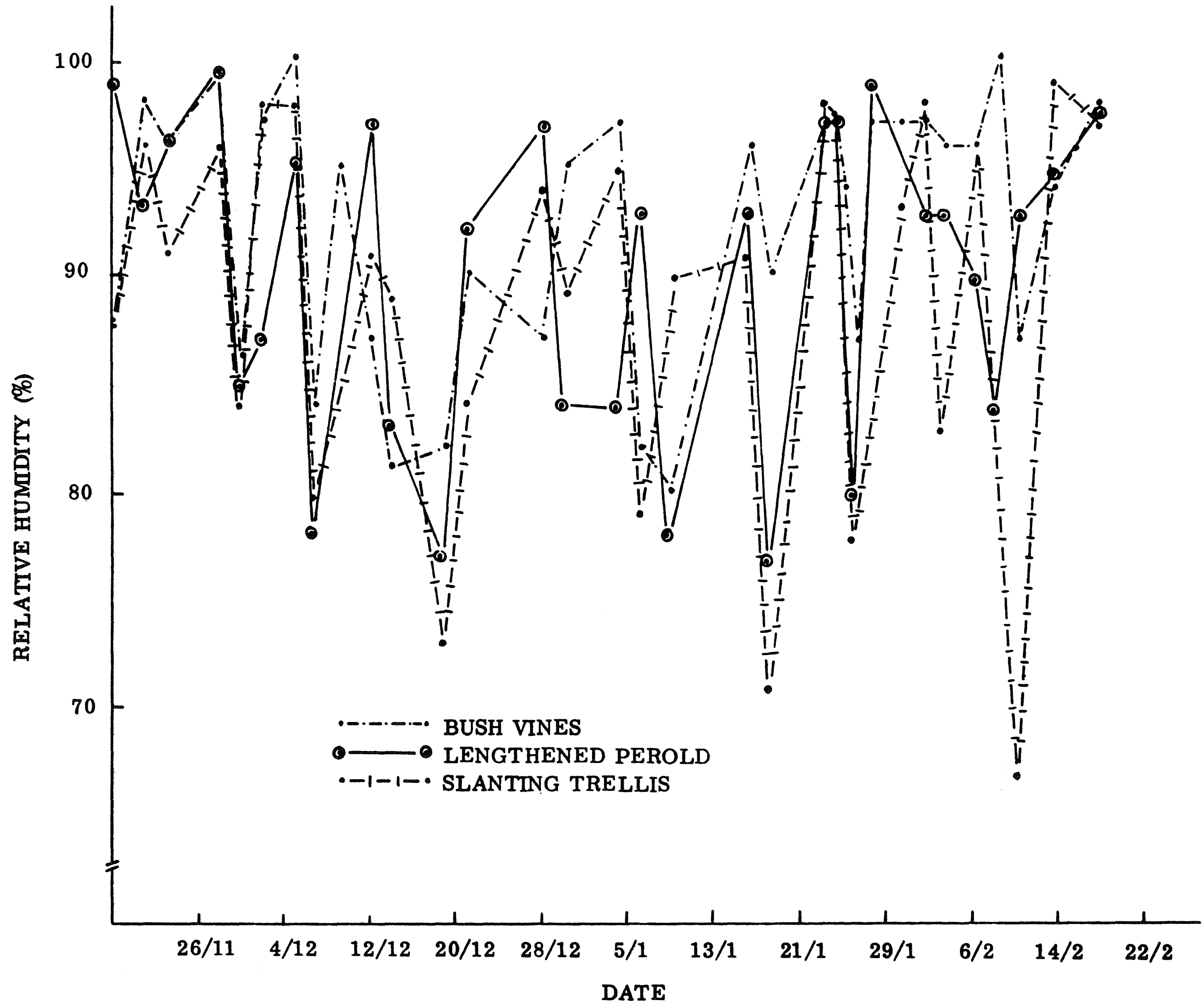

FIG. 5
Relative humidity in three trellising systems at 06h00.

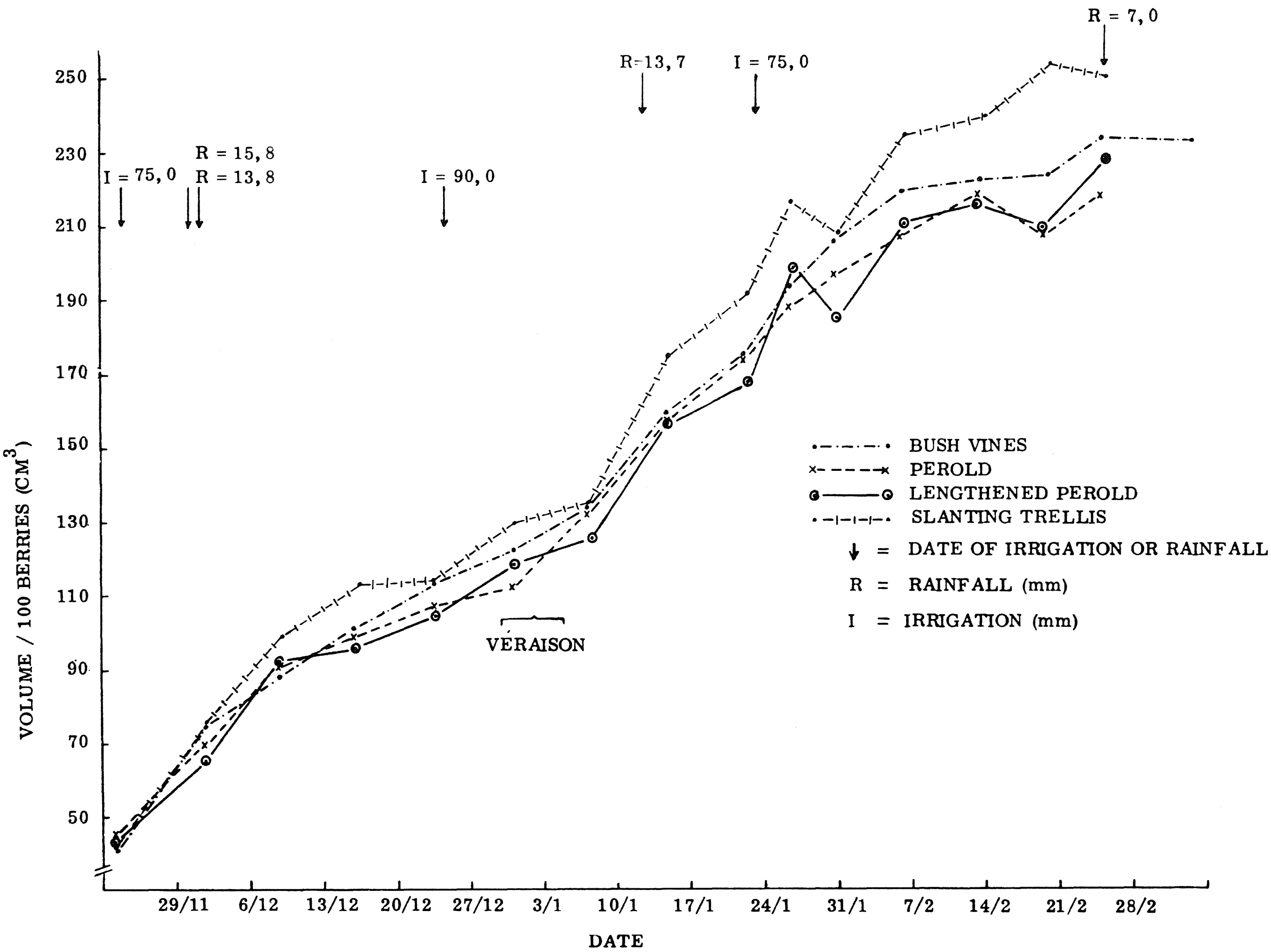

FIG. 6
Incrase in berry volume with time in different trellising systems.

enlargement, except in the case of the slanting trellis, which did not show an increased berry enlargement. This varying effect of rainfall and irrigation demonstrates that the effect of soil moisture on quality phenomena can never be evaluated in absolute terms, but will depend, as was the case in this experiment, on other factors, such as growth stage of the vine and soil moisture conditions.

pH and acidity: Although differences in pH of the must among trellising systems were small, values for the bush vines were consistently higher than those of the three larger systems. Final pH values were:

Bush vines	3,70
Perold	3,42
Lengthened Perold	3,50
Slanting trellis	3,62

It should be borne in mind, however, that grapes from the bush vines were harvested one week later than the other systems. The pH of the musts was therefore directly correlated to temperatures of the bunches (Table 2), as both parameters followed the same sequence, viz., bush vines > slanting trellis > lengthened Perold. The total titratable acid (TTA) reached a maximum just prior to véraison at the end of December. At that stage the TTA in grapes from the slanting trellis was 1,2 g/ℓ higher than those of the other three systems, which were almost the same. The decomposition rate of the TTA followed the same pattern in all the systems. The lower TTA value in the bush vines may be attributed solely to its later harvesting date. The tartaric acid content in grapes from the different systems did not differ significantly from each other (Fig. 9). However, it is noteworthy that these curves did not show the expected peak at the same period, as was the case with the TTA and the malic acid (Fig. 10). This was probably due to the irrigation on the 26th of November, followed shortly afterwards by 30 mm rainfall at the end of November which might have had a large "dilution" and/or a metabolic effect on the tartaric acid. Later water applications also led to a similar decrease in tartaric acid concentration, as can be seen in Fig. 9.

The malic acid content of the grapes, just before véraison increased to reach maxima of 26,5; 26,5; 25,0 and 25,5 g/ℓ in the slanting trellis, lengthened Perold, Perold and bush vines, respectively. During the ripening phase decomposition of malic acid took place at a very fast rate, ending up with 5,91; 5,14; 5,31 and 4,84 g/ℓ in the slanting trellis, lengthened Perold, Perold and bush vines, respectively. Due to slower ripening, the bush vines were harvested one week later than the other three systems and its final malate concentration was thus 1,78 g/ℓ lower than that of the slanting trellis.

According to literature (Kliewer & Schulz, 1964; Kliewer, 1968; Kliewer & Antcliff, 1970; Kliewer & Lider,

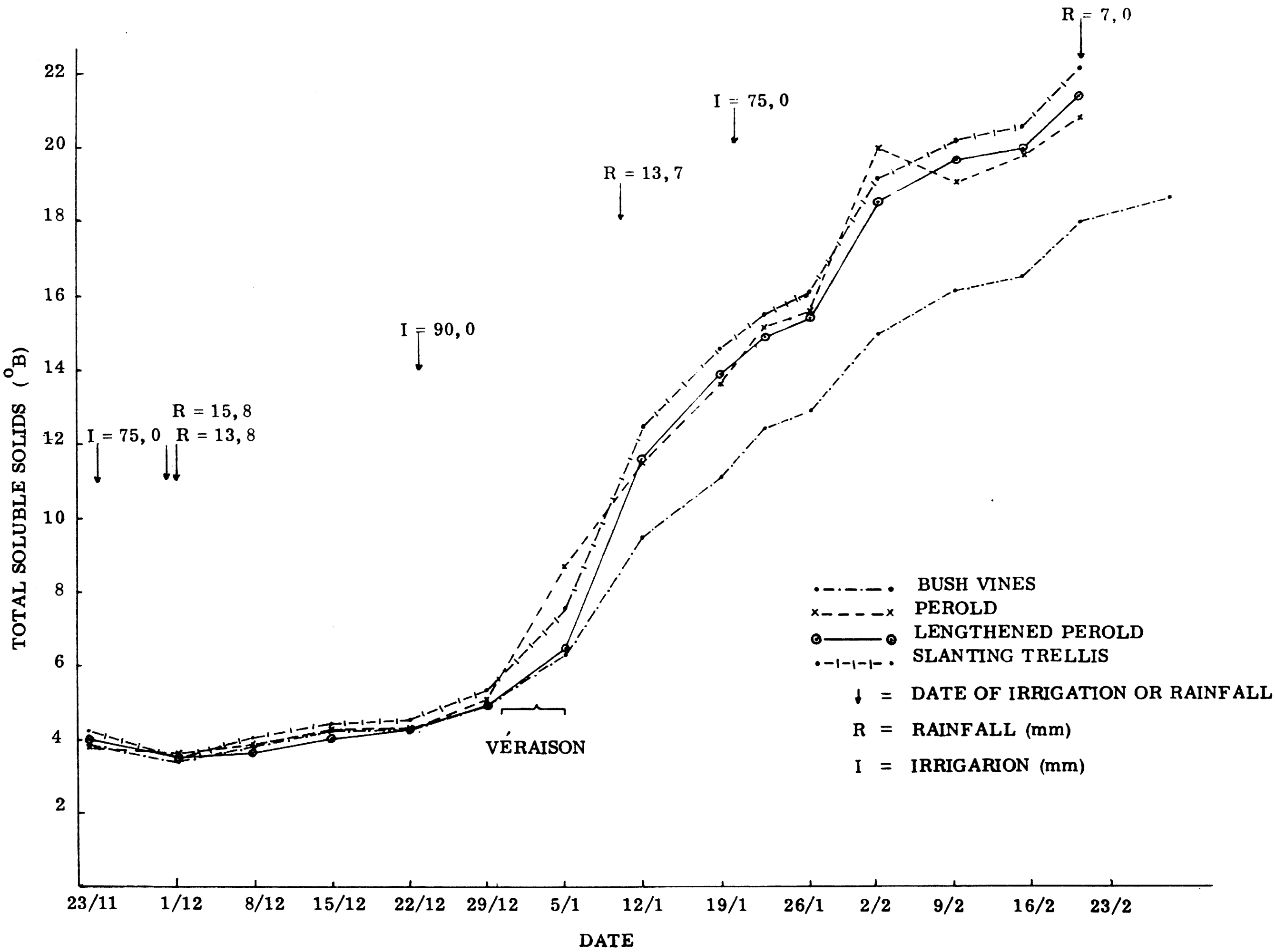

FIG. 7
Changes in sugar concentration with time in Chenin blanc grapes from different trellising systems.

1970; Kliewer, 1971; Kliewer, 1973; Kliewer & Schulz, 1973; Winkler, *et al.*, 1974) the formation and degradation of TTA, and especially malic acid, in contrast with tartaric acid, are very sensitive to temperature regimes. Thus temperatures induced by various growth patterns on the different trellising systems (Table 2) affected TTA and malic acid according to expectation. High temperatures led to low TTA and malic acid in this experiment, and *vice versa.*

The relatively insignificant effect of significant micro-climatic differences on grape composition is rather unexpected. However, Robertson falls in Region IV according to the heat-summation techniques of Winkler *et. al.* (1974). There probably does exist a temperature border value, which once exceeded, may lead to the cancellation of small temperature differences caused by viticultural practices. This may have the implication that in very hot regions like Robertson, small micro-climatic differences induced by trellising systems are overruled by the overwhelming effect of the macro-climate. It can thus be expected that the effect of micro-climate will probably be much more pronounced in cooler climatic areas.

Wine quality: Results of final must analyses and organoleptic rating of the experimental wines are presented in Table 3. The organoleptic wine quality from the bush vines was significantly better than that made from the slanting trellis. A closer inspection of the judges' score cards revealed no single property of the experimental wines other than colour to explain the above-mentioned result. Apparent differences in grape composition of the different trellising systems were not reflected in wine quality. The Perold system is not taken into account since must from these vines yielded incomplete fermentation, and the wine still contained unfermented sugar. This was most probably due to the relatively low nitrogen content of the must, which is reflected in an arginine content of only 115 ppm (total nitrogen content 233 ppm). Stuck fermentation due to a low total nitrogen content (lower than 163 ppm) is described by Agenbach (1977).

No simple explanation can be suggested for the low nitrogen content in this case, since a grape yield/pruning mass ratio of 8,8 (Table 4) is not uncommonly high, and the vines were therefore not too heavily cropped in relation to their growth vigor.

It should be kept in mind that only Botrytis free grapes were selected to make the experimental wines. A comparison between this study and Zeeman's (1975) data on the incidence of bunch rot and wine quality (Table 5) gave interesting results. Not only was a higher percentage of bunch rot found in the bush vines, than in the other three

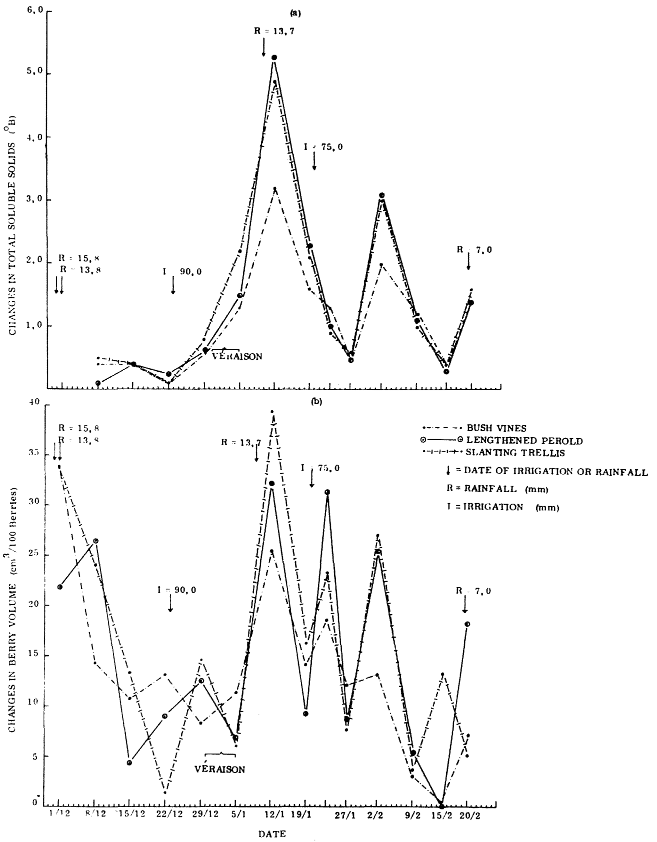

FIG. 8

Changes in (a) total soluble solids and (b) berry volume of Chenin blanc grapes from three trellising systems.

systems, (the slanting trellis was an exception to the rule in 1972) but wine quality within one season showed a close inverse relationship with the incidence of Botrytis rot. In 1970 (Table 5) the trellising system with the highest incidence of bunch rot yielded the lowest wine quality and vice versa. In 1971 bunch rot was low in all trellising systems, viz. lower than the borderline of 15% at which wine quality has been shown to become affected (Wagener, 1978). In this year an equally good wine quality was found in all four systems. Results of 1972 again followed the same pattern as that recorded in 1970.

CONCLUSION

It is evident that different trellising systems create their own effective micro-climatic environments, as reflected in particular by air movement, bunch temperatures and air temperature in the vine canopies. These micro-climatic differences were usually restricted to certain periods during the day, but were of such a magnitude that it affected evapotranspiration as well as grape composition. Although not the only grape properties which differed among trellising systems, it was mainly the sugar concentration, total titratable acidity and malic acid content which were affected. Grape composition was also found to be highly dependant on harvesting date.

However, differences found in the composition of the grapes were not reflected in the eventual wine quality under the conditions of this experiment. From the results of previous investigations on the same vineyard, it is quite

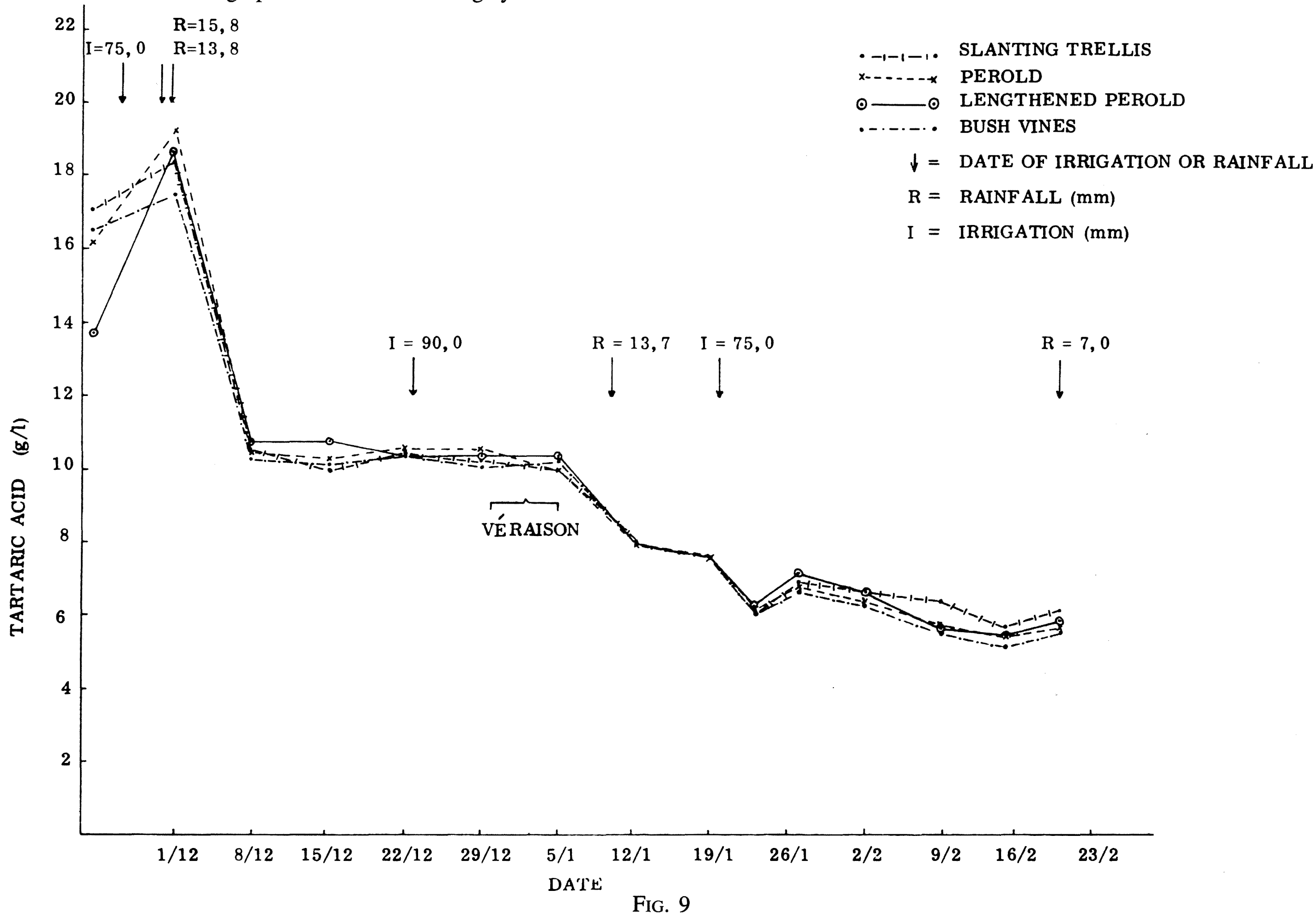

FIG. 9

Changes in tartaric acid content of grapes from different trellising systems.

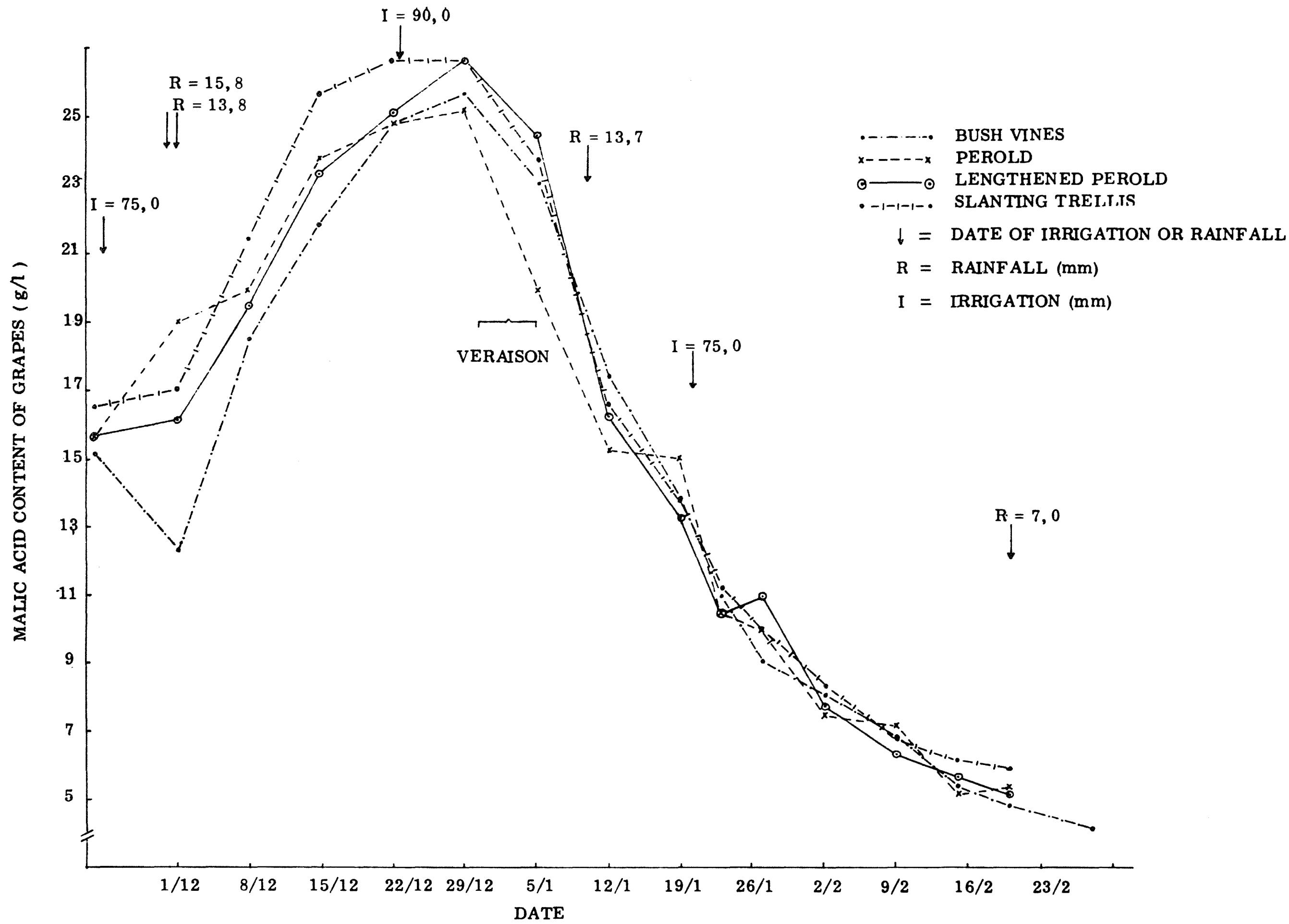

FIG. 10

Changes in malic acid content of grapes from different trellising systems.

TABLE 3

Must analyses at harvesting and wine quality of Chenin blanc grapes grown on four trellising systems

Trellising system	Malic[1] acid (g/ℓ)	Tartaric[1] acid (g/ℓ)	Total titratable acidity (g/ℓ)	pH	Total soluble solids (°B)	TSS/TTA ratio	Arginine (ppm)	Organoleptic[3] wine quality (%)
Bush vines	4,13	5,50	8,22	3,50	17,9	2,18	290	61,3
Perold	5,31	5,80	8,91	3,20	18,6	2,09	115	50,0[2]
Lengthened Perold	5,14	5,90	8,87	3,45	19,6	2,21	185	57,7
Slanting trellis	5,91	6,20	7,80	3,39	20,8	2,67	205	52,2

1 Determined on berry samples picked on the day of harvesting. All other determinations in Table 3 was done on must used for making the experimental wines.
2 Incomplete fermentation—residual sugar.
3 LSD ($P \leqslant 0,05$) = 6,05.

TABLE 4

Grape yield and vegetative growth data of a Chenin blanc vineyard before the commencement of the trial (averages for 1969–1973)* and for the 1977/78 season

Trellising system	Grape yield at 20 °B (t/ha)		Pruning mass Kg/vine		Grape/Shoot ratio	
	1969–73	1977/78	1969–73	1977/78	1969–73	1977/78
Bush vines	12,32	14,72a	1,09	1,21 a	3,84	4,74
Perold	28,36	26,05 b	1,35	1,09 a	7,19	8,77
Lengthened Perold	31,27	26,30 b	1,64	1,82 ab	6,56	4,97
Slanting trellis	42,05	23,59 b	2,26	2,47 b	6,58	3,54

Numbers not followed by the same letters, differ significantly from each other at the 5% level.
*Zeeman, 1975.

TABLE 5
Data on the incidence of bunch rot and the organoleptic evaluation of wine quality of Chenin blanc*

Season	Bush vines		Perold		Lengthened Perold		Slanting trellis	
	Bunch rot (%)	Wine quality(%)	Bunch rot (%)	Wine quality(%)	Bunch rot (%)	Wine quality(%)	Bunch rot (%)	Wine quality(%)
1970	45	<35	25	59	10	76	5	77
1971	13	55	5	54	3	54	7	54
1972	25	38	7	63	13	48	26	42

*Zeeman, 1975.

clear that the incidence of *Botrytis cinerea* played a major role in determining differences in wine quality among trellising systems. It may therefore, be concluded that under these specific viticultural and climatic conditions, the trellising systems apparently affect wine quality mainly via its influence on Botrytis rot and not via grape composition and micro-climate. However, the fact that the rather pronounced differences found in must composition were not reflected in the organoleptic ratings of the wines as would have been expected, emphasises the need for further investigations.

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