# Comparative Studies on Wine Grapes on Different Trellising Systems:
# I. Consumptive Water Use

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## ABSTRACT

A field trial involving four trellising systems viz.—

(*a*) Bush vines,
(*b*) Perold,
(*c*) Lengthened Perold,
(*d*) 1,7 m Slanting trellis,

showed differences of the utmost importance with regard to rooting densities, consumptive water use and the incidence of Botrytis rot.

Soil physical conditions were dominant in determining root distribution patterns. The slanting trellis had significantly more roots than the other systems. The consumptive water use, however, was not affected by amount of roots but mainly by the micro-climate. Contrary to expectation, the largest trellising system did not show the highest consumptive water use, but under the experimental conditions the bush vines had the fastest evapotranspiration rate. Average crop factors of 0,313; 0,260; 0,241 and 0,205 were found from bud burst to harvesting for bush vines, slanting trellis, lengthened Perold and Perold systems respectively. The high evapotranspiration rate of the bush vines is attributed to higher ambient air temperatures, more air movement as well as less shading of the soil surface than in the case of the slanting trellis.

Crop factors varied according to soil moisture content, indicating the need to determine these parameters for specific irrigation frequencies. The low crop factors determined in this experiment emphasize the high water use efficiency of vineyards and stress the need to adopt existing crop factors to recent findings.

Significant differences which cannot be attributed to micro-climate conditions occurred among trellising systems. Grape juice analyses, carried out throughout the growing season, indicated a relationship between total nitrogen and arginine status and *Botrytis cinerea* determined immediately prior to harvesting. More Botrytis rot was found at lower cropping levels. More investigations as to the relationship among the incidence of Botrytis rot, cropping level and nitrogen status of the plant are needed.

## INTRODUCTION

The most practical method of scheduling irrigation in South Africa is still by means of the Standard American Weather Bureau Class A-pan, together with experimentally determined crop factors (Saayman & Van Zyl, 1976). Crop factors, being a criterium of plant water use, are a function of, amongst others, cultural practices. It was hitherto assumed in South Africa (Saayman & Van Zyl, 1976) that the water requirement of bush vines is 50% less than that of large trellising systems. This assumption is supported by Fregoni (1977) whose calculations indicated a water requirement of 1 750 $m^3$ and 4 150 $m^3$ per ha per year for bush vines and the big Italian Tendone trellising system, respectively. These figures seem to be largely based on calculations only, and are probably applicable only to specific European conditions of climate, shading of the soil and cultural practices.

Vines on large trellising systems are much more productive than those with a smaller leaf surface area (Draganov & Draganov, 1976; May, Clingeleffer, Scholefield & Brien, 1976; Fregoni, 1977; Safran, 1978; Zeeman, 1978), and at first glance a higher moisture demand would be expected in the case of the larger systems. However, contrary to Fregoni's findings, Safran (1978) reported better drought resistance with higher trellising systems on light textured soils in Israel. Van der Westhuizen (1974) reached the same conclusion in a field experiment in which bush vines and a slanting trellis were compared. Lower soil moisture contents were measured in the case of the bush vines than in the case of the larger system. Comparing bush vines to vines on 0,70 m high stems, Negovelov & Akopjan (1968) reported similar results.

Van der Westhuizen (1974) ascribed the lower soil moisture content among bush vines to an unfavourable micro-climate. He found that higher bunch, leaf and soil temperature, higher wind speeds, Class A-pan evaporation and nett radiation existed in bush vines compared to those on a slanting trellis. Research done by Draganov, Pondeliev & Antonov (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.

The results of Zeeman (1978) showed that on highly productive soils, commonly found in the inland irrigation areas, larger trellising systems, such as the 1,7 m slanting trellis, are to be recommended. However, as there seems to be wide controversy in literature concerning the water use of different systems, and due to the preliminary nature of local results (Van der Westhuizen, 1974), further studies were undertaken in an existing trellising experiment at Robertson in order to obtain a better understanding of the water use and economic feasibility of large trellising systems.

## MATERIALS AND METHODS

The investigation was conducted in a 12 year old Chenin blanc vineyard grafted on 101–14 Mgt. rootstock which was part of an earlier trellising system/planting width trial at Robertson of which the performance was recorded from 1969–1973 (Zeeman, 1975). For the purpose of this experiment, four trellising systems (Zeeman, 1978a) at the same planting distance of 2,6 × 1,3 m were selected viz.:

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

The vineyard was clean cultivated, pruned to 20 buds per vine (i.e. 59 000 buds/ha) and received in addition to the 335,6 mm natural rainfall from March 1977 to March 1978 (69,0 mm during the growing season, September to March) a gross amount of 465 mm irrigation water. The irrigation program used was based on averages of long term Class A-pan evaporation data (Saayman & Van Zyl, 1976) and the most up to date crop factors. The same quantity of irrigation water was applied to all trellising systems by means of a portable overhead sprinkler system.

Soil moisture content in the various trellising systems was measured with the aid of a neutron moisture meter. Five replicates per trellising system were used and measurements taken at three depths, namely 200 mm, 350 mm and 500 mm in aluminium access tubes installed in the vine rows. These depths were decided on after carrying out a comprehensive pedological investigation. In the same operation the soil was sampled for chemical analysis, and undisturbed soil cores were sampled for the determination of soil water constants and soil water retention curves with standard pressure plate equipment. Root distribution was investigated on a statistical basis both in and across vine rows, applying the technique of mapping roots on a profile wall.

Moisture measurements commenced at bud burst and continued until leafdrop at weekly intervals, starting three days after an irrigation (Field Capacity was assumed at that stage). Rainfall, Class A-pan evaporation, as well as other standard meteorological measurements were registered at a nearby weather station. Soil moisture changes being the result of evapotranspiration ($E_t$) were calculated and crop factors determined for each trellising system using the following equation:

$$\text{Crop factor} = E_t / E_o \text{ where,}$$

$E_t$ = Evapotranspiration (mm) as calculated from the decrease of soil moisture as measured by means of a neutron moisture meter;

$E_o$ = Class A-pan evaporation (mm).

Shoot mass was measured at pruning, and grape yield determined when a degree Balling/Total titratable acidity ratio of 2,5 was reached. At the same time the degree of Botrytis rot was statistically evaluated in each trellising system. Shading of the soil surface under the different trellising systems was determined according to the meter-stick method described by Adams & Arkin (1977), but using 100 mm instead of 50 mm intervals. Leaf surface area was estimated by sampling the leaves of two representative shoots per vine (6 vines/treatment) and measuring their surface area by means of an electronic area meter.

Berry samples were collected on a weekly basis following the suggestions of Du Plessis & Van Schalkwyk (1974), commencing two weeks after flowering and continuing until harvest. These berries were crushed in a mortar, squeezed through a cheesecloth and analyzed for arginine content according to the method of Gilboe & Williams (1956). Total nitrogen was determined by means of the micro-Kjeldhal method.

Daily ambient temperature measurements were made in aluminium shields placed inside the canopy of the vines, using copper-constantan thermocouples. Air movement was measured between the rows at the average bunch height in each trellising system by means of a standard three cup recording anemometer.

## RESULTS AND DISCUSSION

**Root distribution:** The pedological survey revealed a reddish calcareous Oakleaf soil form: Letaba series (Mac Vicar & Soil survey Staff, DATS/RSA, 1977), which corresponds to Aridosols of the USDA-classification system (soil Survey Staff, 1960), underlain at 700 mm by a hardpan (irreversibly hardened by iron, silica and calcium carbonate), impenetrable to roots. The soil volume from which evaporation and water extraction by roots took place, was thus well defined. Root studies revealed root systems which exploited the total row width as well as the total soil depth but were abruptly halted by the hardpan (Fig. 1 & 2). Roots were very uniformly distributed when depth increments were compared, except in the upper 100 mm which contained the smallest number of roots. This finding corresponds with many previous field observations and is contrary to the classical model of water extraction patterns which closely follows a theoretical root distribution pattern. According to this model the water extraction pattern is triangular in shape, with 40% in the upper 25% of the soil and 10% extraction in the deepest 25% of the soil depth (Israelsen & Hansen, 1967). It thus showed distinctly that this kind of generalisation with regard to root distribution and water extraction pattern is not necessarily

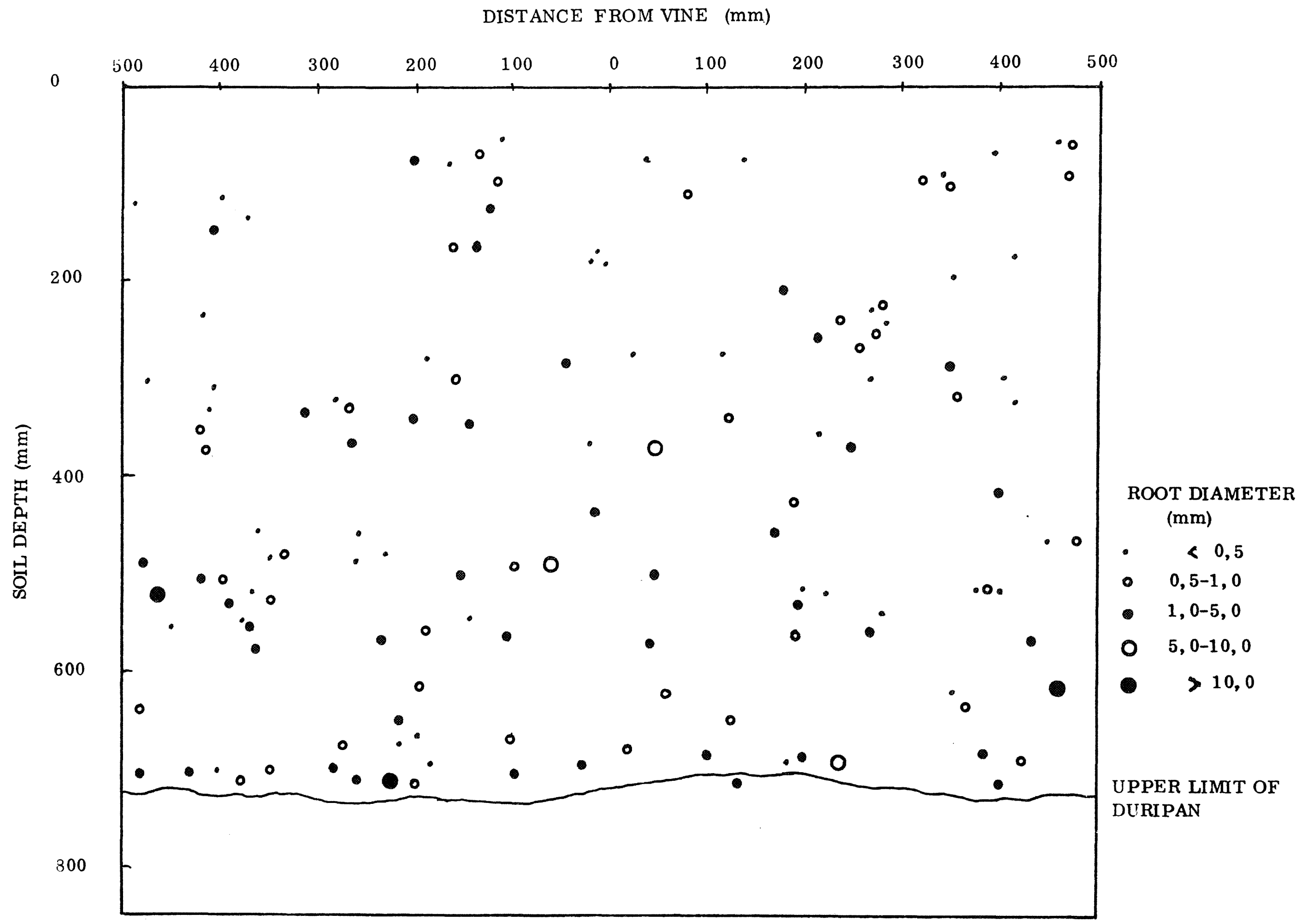


FIG. 1
Root distribution of Chenin blanc / 101–14 Mgt. bush vines—Oakleaf soil, Robertson.

valid for vines. This viewpoint is supported by work of Herkelrath, Miller & Gardner (1977) who clearly showed that no variation exists in root effectiveness with depth in the case of wheat roots.

A statistical analysis of the total number of roots confirmed the belief that a large vegetative growth is balanced by a large root system as shown in Table 1 and Fig. 1 & 2. The slanting trellis had significantly more roots than the other three trellising systems. The tendency for the number of roots in the other three systems was: Lengthened Perold > Perold > bush vines; these differences were not statistically significant. However, as will be shown, there seems to be no relation between root density and the rate of water use by the vines.

TABLE 1
Relationship between shoot mass and root distribution of Chenin blanc/ 101–14 Mgt. in a red Oakleaf soil, Robertson

| Trellising system | Shoot mass (kg/vine) | Number of roots in profile face |
|---|---|---|
| Bush vines | 1,21 | 126,24 |
| Perold | 1,09 | 133,28 |
| Lenthened Perold | 1,82 | 148,24 |
| Slanting trellis | 2,47 | 201,52 |
| D-value (P = 0,05) | 1,31 | 37,68, |

**Crop factors:** The water holding capacity of the soil, amounting to 142,9 mm/m of soil depth, was calculated from soil moisture retention curves (Fig. 3). Crop factors for the different trellising systems are presented in Table 2. The highest values were found in the bush vines viz., an average of 0,313 for the period bud burst to harvesting. For the slanting trellis, lengthened Perold and Perold systems average crop factors of 0,260, 0,241 and 0,205 respectively were obtained. The consumptive water use of the latter systems was therefore in the same sequence as expected from their vegetative growth (Table 3). The crop factors for the bush vines are, however, unexpectedly high, considering the fact that its pruning mass as well as its grape yield were respectively 51,0% and 27,5% lower than those of the slanting trellis. According to theory the lengthened Perold and slanting trellis should have given the highest crop factors because of their large leaf surface area (Table 4) which should favour the transpiration rate. Despite a slightly lower leaf surface area, the slanting trellis yielded a higher average crop factor than the lengthened Perold. These small (probably negligible) differences in both leaf surface area and crop factors may be ascribed to more inactive leaves on the latter system which results in a hedge-shaped and dense foliage. The reason for the higher evapotranspiration rate in the bush vines compared to the slanting trellis should be sought in the microclimatic environment of the plant. Table 5 shows the

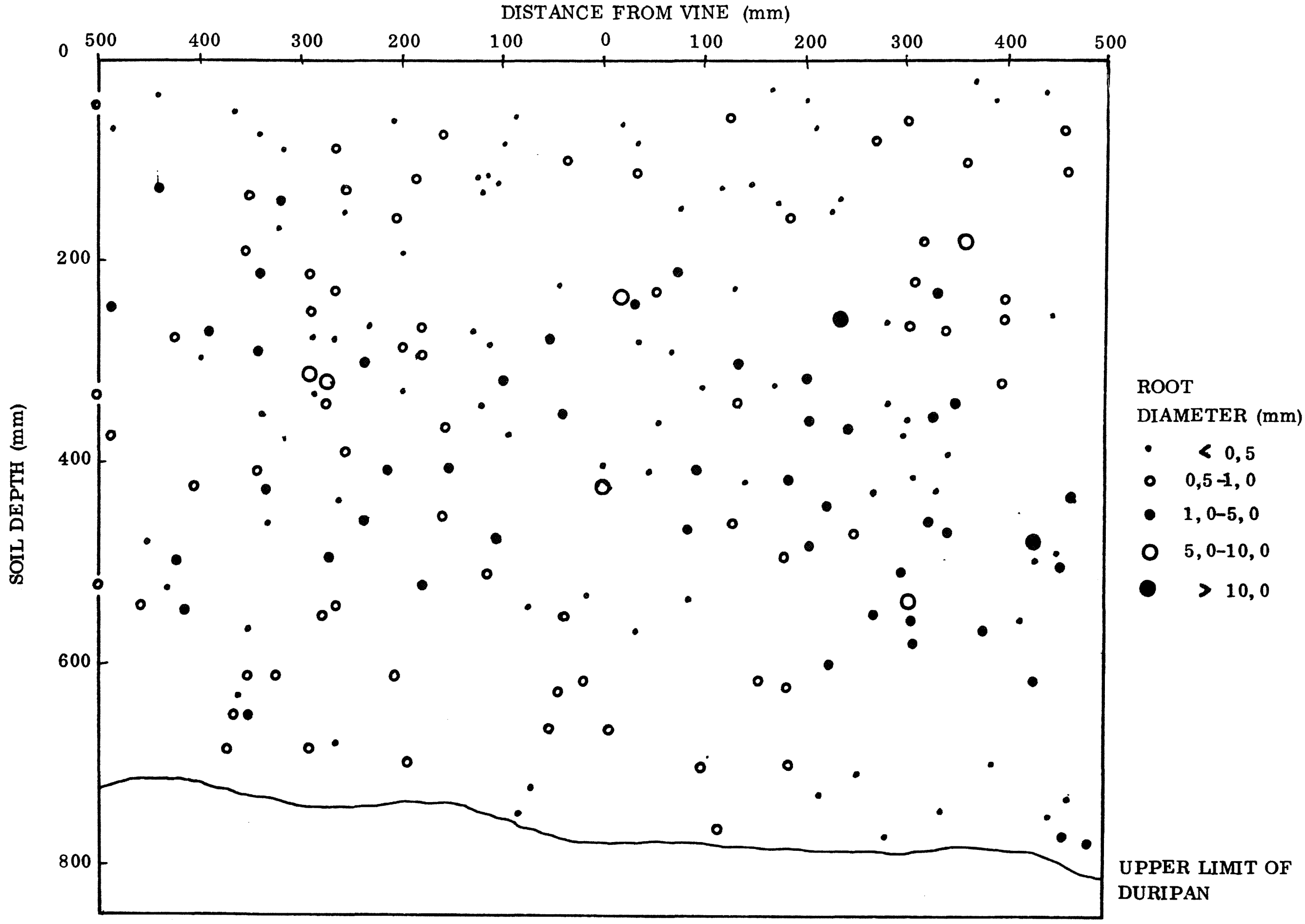


FIG. 2
Root distribution of Chenin blanc/101–14 Mgt. slanting trellis vines—Oakleaf soil, Robertson.

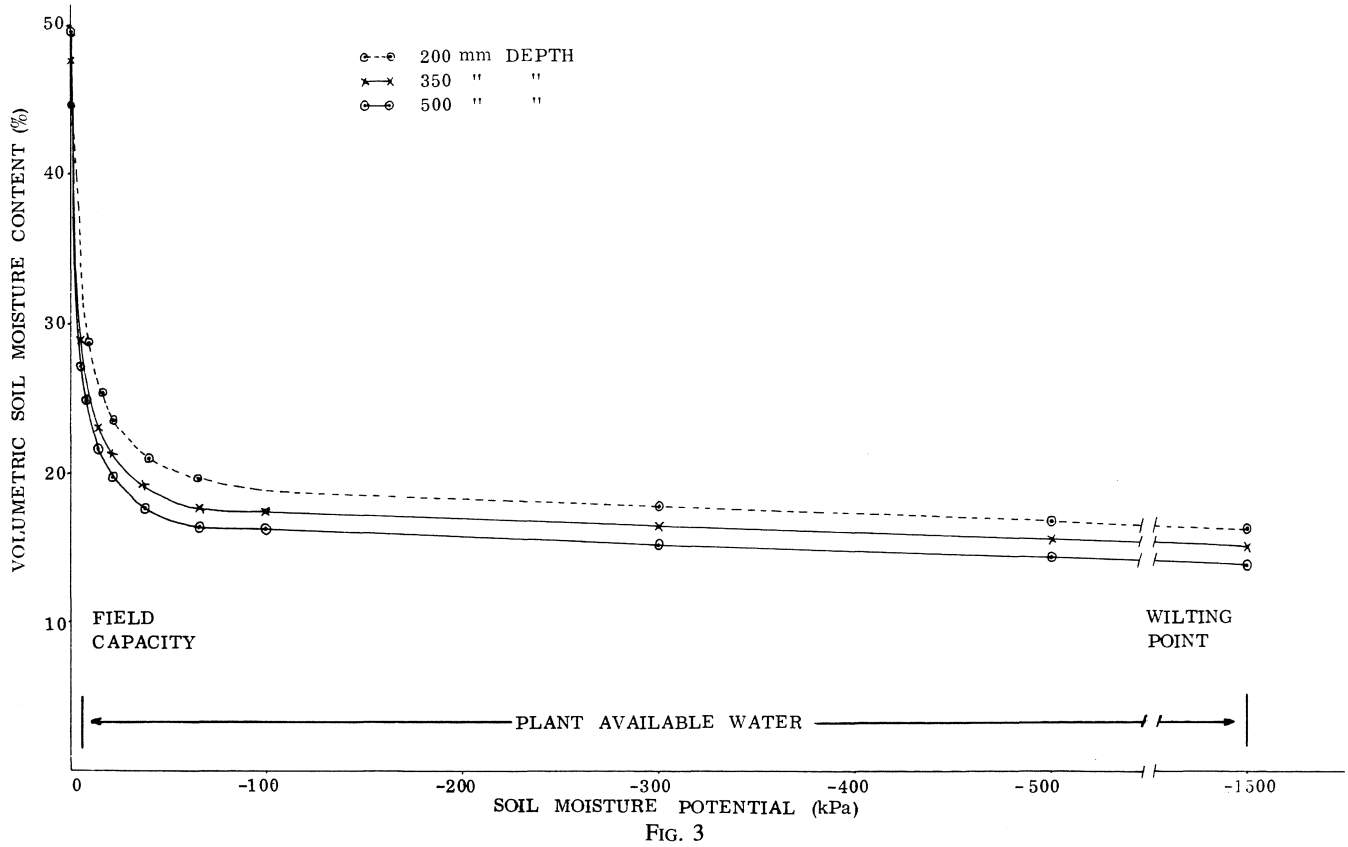


FIG. 3
Soil moisture retention curves for three depths of an Oakleaf soil, Robertson.

differences in temperature and air movement that existed between extremes in trellising systems. The higher temperature regime among the bush vines led to a faster transpiration rate, while more air movement among the bush vines enhanced both transpiration and evaporation.

TABLE 2
Crop factors for Chenin blanc/101–14 Mgt. on different trellising systems, calculated from evapotranspiration measurements and Class A-pan evaporation, during the 1977/78 season, Robertson

| Growth stage | Bush vines | 1,7 m Slanting trellis | Lengthened Perold | Perold |
|---|---|---|---|---|
| Bud burst—Flowering | 0,38 | 0,28 | 0,23 | 0,20 |
| Flowering—Fruit set | 0,33 | 0,28 | 0,27 | 0,24 |
| Fruit set—Véraison | 0,31 | 0,28 | 0,27 | 0,22 |
| Véraison—Harvesting | 0,23 | 0,18 | 0,20 | 0,16 |
| Bud burst—Harvesting | 0,31 | 0,26 | 0,24 | 0,21 |

shading in the morning and late afternoon. Not much difference existed among the latter three trellising systems with regard to shading. The slanting trellis, however, gave 90% shade during the hot part of the day (12h00–16h00) when evaporation takes place at a fast rate. Minimum shade was measured in the morning when sunlight penetrates from the open side of the slanting trellis. As the day continues, the sun shines more on the back of the slanting trellis, leaving most of the soil surface in the shade. A maximum of 97% shading was reached at 17h00 in this experiment. Shading in the hot South African climate results in diminished evaporation. Van der Westhuizen (1974) came to much the same conclusion. These results concerning the marked relationship between micro-climate and soil surface shading and water consumption explain why no obvious relation between root distribution and water use could be distinguished, as was stated earlier. Under the conditions of this experiment it was quite clear that it is principally the micro-climatic environment that controls evapotranspiration and not the root system or the direct effect of plant size. Plant-size, as far as it determines micro-climate, becomes important mainly in an indirect way.

TABLE 3
Grape yield and vegetative growth data of Chenin blanc/101–14 Mgt. 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 | 14,72 a | 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% probability level.
*Zeeman, 1975

TABLE 4
Representative leaf surface areas of Chenin blanc/101–14 Mgt. vines on different trellising systems at Robertson

| Trellising system | Bush vines | Perold | Lengthened Perold | 1,7 m Slanting trellis |
|---|---|---|---|---|
| Leaf surface area ($m^2$/vine) | 10,21 | 6,93 | 14,34 | 13,66 |

TABLE 5
Influence of trellising system on ambient temperature and air movement

| Trellising system | Mean temperature (Fruitset-harvesting) at noon in vine canopy (°C) | Mean air movement (Nov.—Jan.) (km/day) |
|---|---|---|
| Bush vines | 26,30 | 31,4 |
| Slanting trellis | 24,86 | 27,6 |

Another important factor determining consumptive water use in the different trellising systems was percentage shading of the soil surface. This was 28,5% more in the case of the slanting trellis than between the rows of the bush vines (Fig. 4). The shading patterns during the course of the day as shown in Fig. 4, are functions of the configuration of the differently trellised vines. The hedge-type Perold and lengthened Perold systems, as well as the bush vines, showed daily minima at noon with maximum

Evapotranspiration results obtained in this experiment suggest a revision of the crop factors presented by Saayman & Van Zyl (1976). To date it has been assumed that bush vines (crop factor = 0,25) use 50% less water than vines on large trellises (crop factor = 0,38). The results of this experiment indicate that the reverse is closer to reality. However, since this investigation is being continued, adaptations in existing crop factors should await the conclusion of the experiment when final results will be presented.

Values given in Table 2 do not follow the classic crop factor pattern i.e. low values during the first part of the season, reaching a maximum at full leaf development and again declining towards the end of the season (Anon., 1973). A similar unconventional sequence of crop factors for vines was found by Van Zyl (1975). This phenomenon is probably due to protective mechanisms in the plant (Kasimatis, 1967) which lower evapotranspiration relative to the increasing evaporative demand of the season. Shading of the soil surface also usually increases as the season progresses thus resulting in less moisture loss by evaporation. Despite a general decrease in crop factor values, the absolute consumptive water use did follow the evaporative demand of the atmosphere and reached a peak period during December.

Fig. 5 illustrates the decrease in crop factor value with time after an irrigation. Shortly after a water application the contribution of evaporation to water loss is large.

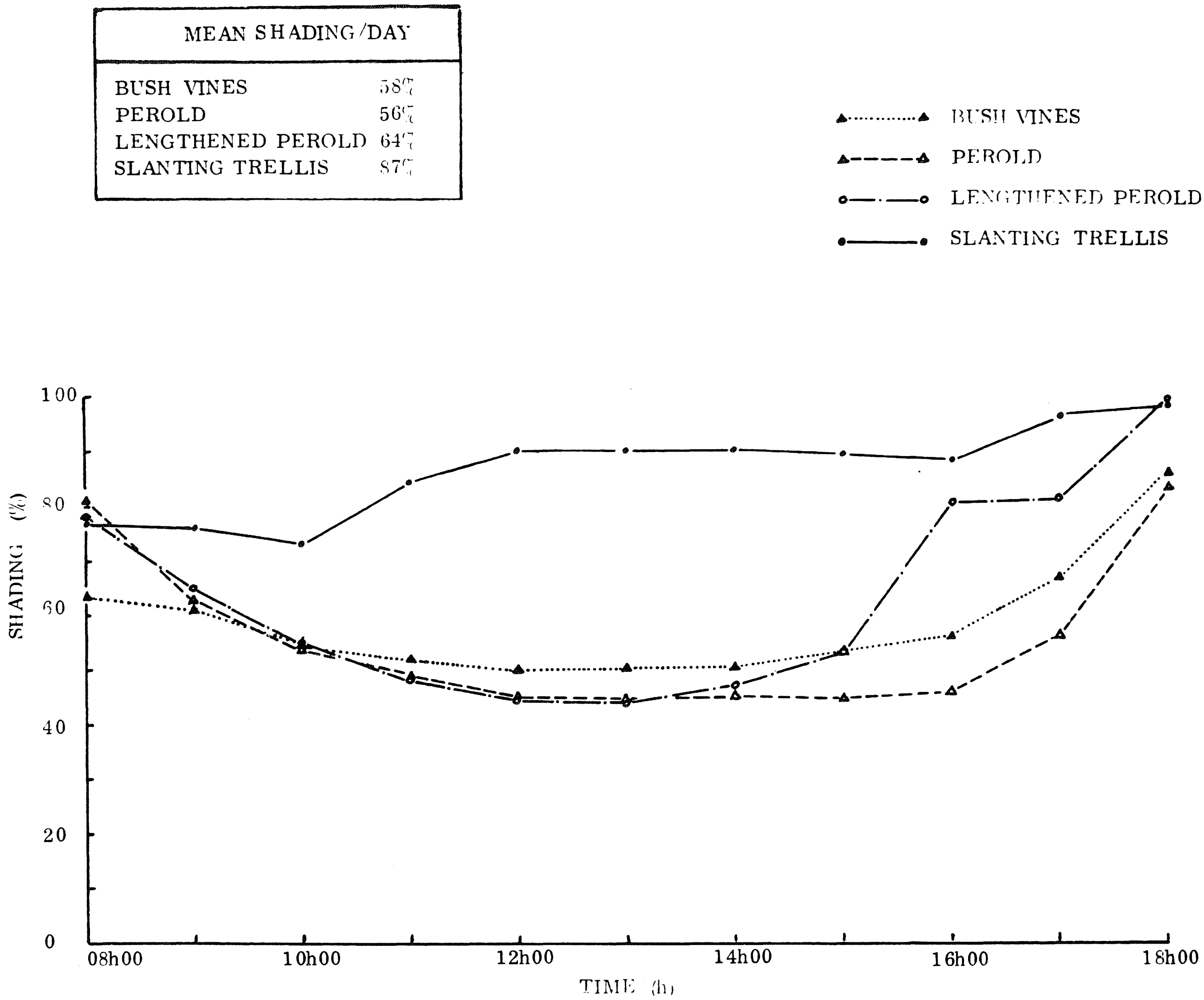


FIG. 4
Shading of soil surface by Chenin blanc on different trellising systems during the course of the day, Robertson.

Drying of the soil surface increases the resistance to evaporation (Hillel, 1971) and the crop factor decreases. Under very dry soil conditions the crop factor in this experiment dropped to values below 0,1, and there seems to be no correlation between evapotranspiration and evaporation from the Class A-pan at that stage. The change in crop factor with changing soil moisture content is of much importance when crop factors are determined experimentally. It is therefore incorrect to determine crop factors only for short periods or at the wetter or drier part of an irrigation cycle. Crop factors should be calculated for the whole period, commencing shortly after irrigation when Field Water Capacity is approached, till just before the next irrigation. Disregard of this principle might be the reason for the high factors presented in a publication of the Dept. Agric. Tech. Services & Dept. Water Affairs (Anon., 1973). Crop factors are highly dependent upon irrigation frequencies and, therefore, also upon irrigation systems. High crop factors should be used with systems operating at high frequencies and vice versa.

**Consumptive water use:** Crop factors as presented in Table 2 are much lower than those determined for most other crops (Anon., 1973), indicating that vines use water sparingly. Applying these crop factors together with average Class A-pan evaporation data for Robertson, resulted in the following nett irrigation water demand for the period bud burst to post harvest (September to March):

| | |
|---|---|
| Bush vines | 404,1 mm |
| Perold | 294,1 mm |
| Lengthened Perold | 339,2 mm |
| Slanting trellis | 351,3 mm |

Because of the low production of the bush vines (Table 3) and the high water consumption compared to the slanting trellis it is clear that the water use efficiency of the bush vines compares very unfavourably with the large trellising systems. It also follows that the Perold system with its low water use and relatively high production (Table 3) becomes a most attractive proposition to the farmer with limited water supplies. It should, however, be kept in mind that the 1,7 m slanting trellis has a higher

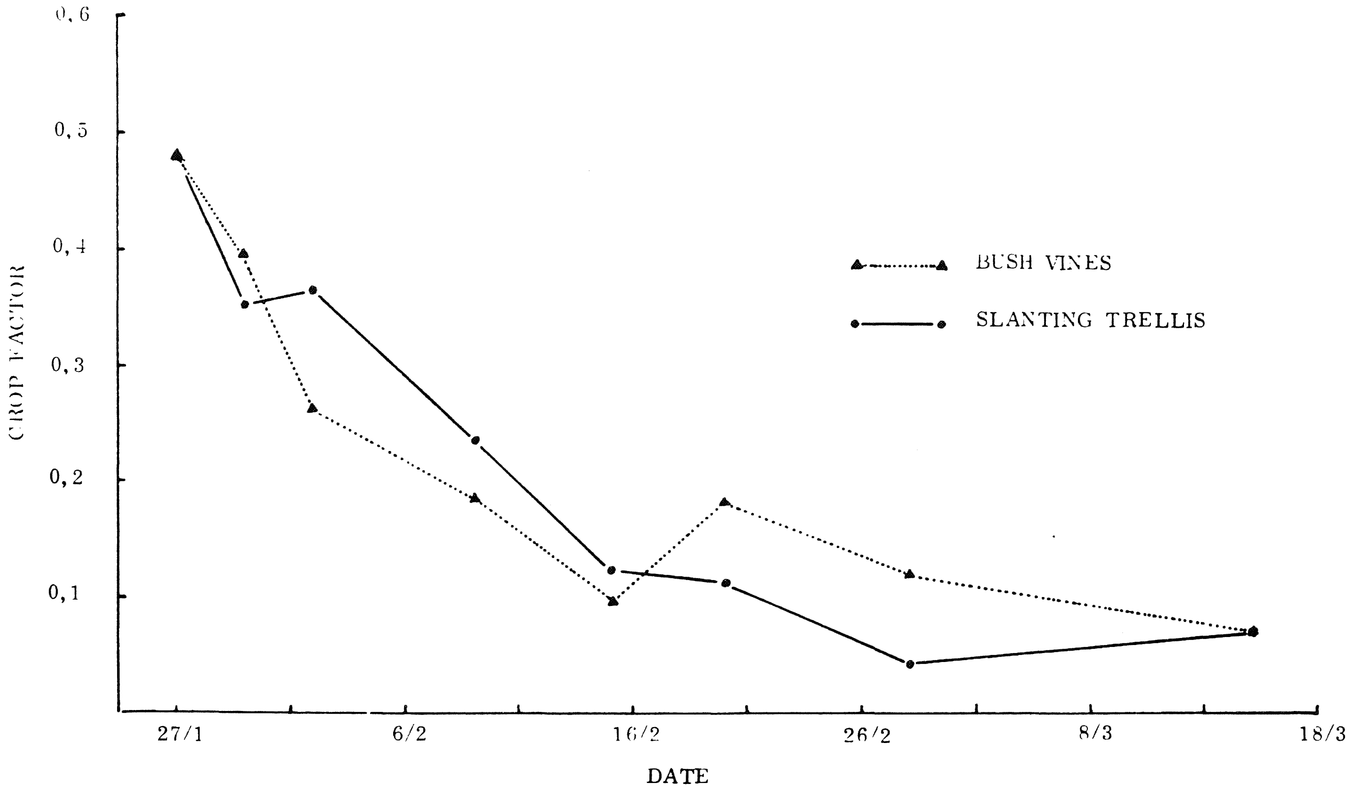


FIG. 5
Decrease in crop factors for Chenin blanc on two trellising systems at Robertson, after an irrigation on 24/1/78.

yield potential (Zeeman, 1975) than that measured during the course of this experiment. Using the 1969-73 grape yield for the slanting trellis in Table 3 and assuming no additional consumptive water use at higher cropping levels, this trellising system will give the best turnover of water to fruit.

**Incidence of *Botrytis cinerea*:** Concerning the incidence of Botrytis rot it was found that the bush vines were more prone to this disease in comparison with the larger trellising systems. As shown in Table 6 there seems to be a direct correlation between total nitrogen as well as arginine content of the must and the incidence of Botrytis rot. The reason for the higher arginine and total N content of the bush vines is not quite clear. Preliminary results concerning different cropping levels have shown a higher yield to be less prone to Botrytis infection. This is in agreement with field observations, but the mechanism involved needs further study.

TABLE 6
Incidence of botrytis rot in different trellising systems and corresponding arginine and total nitrogen content of must of Chenin blanc grapes at Robertson

| Trellising system | Botrytis rot (%) | Arginine (ppm) | Total N (ppm) | Production (t/ha) |
|---|---|---|---|---|
| Bush vines | 46 | 290 | 550 | 14,7 |
| Slanting trellis | 40 | 205 | 400 | 26,1 |
| Lengthened Perold | 34 | 185 | 362 | 26,3 |
| Perold | 32 | 115 | 367 | 23,6 |
| D-value (P = 0,05) | 9,8 | | | |

## CONCLUSION

The root distribution of the experimental vines did not follow the generally accepted genetically determined pattern, but was mainly determined by soil physical conditions. Although rooting densities differed among trellising systems, these differences seemingly did not affect water use. Results indicated that micro-climatic conditions induced by the trellising systems played a major part in determining evapotranspiration. The traditional concept which states that large plants use the most water does, therefore, not always hold true. This result implies an adaptation of the crop factors presently in use as regards irrigation scheduling by means of the American Class A-pan. The generally low factors found in this trial again emphasize the fact that vines use water more frugally than most other crops. Apparently controversial results regarding the incidence of Botrytis rot in the field experiment may be related to the nitrogen content of the grapes. This needs further study regarding the mechanism involved.

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