The Effect of Vine Spacing on Some Physiological Aspects of *Vitis vinifera* L. (cv. Pinot noir)*

E. Archer[1] and H.C. Strauss[2]

1) Department of Viticulture, University of Stellenbosch, 7600 Stellenbosch, Republic of South Africa
2) Viticultural and Oenological Research Institute (VORI), Private Bag X5026, 7600 Stellenbosch, Republic of South Africa

The effect of vine spacing on leaf temperature, radiant energy, some canopy characteristics, leaf-water potential, stomatal conductance, the rate of transpiration and the rate of photosynthesis was measured and discussed. With more closely spaced vines, canopies were less dense than with more widely spaced vines mainly because of less vigorous shoot growth. The consequent better sunlight penetration favoured the physiology of more closely spaced vines early in the season. During the latter part of the season the situation was reversed and the physiology of more widely spaced vines was favoured mainly because of better water supply.

As with many other cultured crops, photosynthesis is probably the most important physiological process in vines. The nett photosynthetic product of a vine is the result of the contribution of a community of individual leaves, each affected by a series of environmental, biological and physiological factors. Environmental factors such as light, temperature and humidity have an important effect on the photosynthesis of grapevines and have been the subject of many studies (Kriedemann & Smart, 1971; Kliewer, 1982; Champagnol, 1984; Smart, 1985; Smart, Robinson, Due & Brien, 1985a, 1985b; Smart, 1987a, 1987b; Smart, Smith & Winchester, 1988). These environmental factors are frequently termed "microclimate" by various researchers. For maximum photosynthesis, optimum microclimate is a prerequisite.

Although various reports dealing with the effect of different cultural practices on microclimate were found, very little information could be obtained on the effect of vine spacing on the microclimate in grapevine canopies. Hedberg & Raison (1982) reported that diffused and reflected light was lower at the cordon level of more closely spaced vines than in the case of wider spacings. With orange trees, Boswell, Nauer & Atkin (1982) reported no differences in radiation measured within the canopies between narrowly and widely spaced trees. Of the total radiation reaching the vine, mainly the part between 400 to 700 nm is used for photosynthesis; this is called photosynthetic active radiation (PAR). The quality of PAR affects photosynthetic activity (Champagnol, 1984), and Smart, *et al.* (1988) reported that vine physiology is affected not only by the photosynthetic photon-fluence rate (PPFR) but also by the ratio of red to far red (R:FR).

Photosynthesis is greatly affected by light on the leaves, which in turn depends on the structure of the canopy, i.e. the spatial orientation and arrangement of the leaves within the canopy (Shaulis, Amberg & Crowe, 1966; Sparks & Larsen, 1966; Kriedemann & Smart, 1971; Smart, 1985; Smart, *et al.*, 1985a & 1985b). The arrangement of the leaves in vine canopies is affected by cultural practices such as training and trellising (Zeeman, 1981; Smart, *et al.*, 1985a), leaf removal (Peterson & Smart, 1975; Boniface & Dumartin, 1977; Carbonneau *et al.*, 1977; Williams, Biscay & Smith, 1987; Bledsoe, Kliewer & Marois, 1988; Hunter & Visser, 1988a & 1988b), shoot thinning (Guyot, 1867; Archer & Beukes, 1983; Archer, 1987; Reynolds, Pool & Mattick, 1986), and winter pruning severity (Perold, 1927; Archer & Fouché, 1987). These practices, therefore, have a direct effect on the efficient utilization of sunlight energy for photosynthesis not only by single leaves but also by canopies as a whole.

The arrangement of leaves and shoots in a canopy, frequently referred to as canopy density, is obviously affected by vine vigour. Thus, factors affecting vine vigour will also affect canopy density. Although cultural practices such as irrigation and N-fertilization have an important effect on induced vine vigour, genetic factors and climatic effects can not be overlooked. High canopy densities are obtained when the available area per vine (dictated by vine spacing and the size of the trellising system) is too small to accommodate the shoot growth of the vine. On the other hand, low canopy densities are obtained when the available area is too big for the existing vegetative capacity of a vine. Ideal canopy densities are procured when the available space (horizontal as well as vertical) can accommodate the vegetative growth without necessitating intensive canopy management techniques such as shoot thinning, topping and the removal of laterals.

Canopy density *per se* plays an important role in leaf temperature through sunlight penetration and air movement. Leaf temperature has an important effect on the rate of photosynthesis. Excessively vegetative canopies create more shade and lower leaf temperatures than sparse canopies (Smart, 1974), whereby the photosynthetic rate of especially interior leaves can be decreased, depending on ambient temperatures.

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Leaves in sparse canopies receive more radiant energy (Williams *et al.*, 1987; Hunter & Visser, 1988c), whereby the photosynthetic activity of individual leaves is increased (Smart, 1985; Hunter & Visser, 1988b). The positive effect of sparser canopies on canopy microclimate as well as on grape quality is well documented (Smart, 1987a; Williams *et al.*, 1987; Bledsoe *et al.*, 1988; Reynolds, 1989).

Sparser canopies produce ventilated leaves and clusters (Hunter & Visser, 1988c) and improved sunlight penetration (Archer 1987; Archer & Strauss, 1989; Reynolds & Wardle, 1989). Sparks & Larsen (1966) found that increased canopy density (increasing within-canopy shade) decreased the sugar concentration and also negatively affected bud fertility (Morgan, Stanley & Warrington, 1985). Smart (1987a) pointed out that sunlight can affect fruit composition through photosynthetic, thermal or phytochrome effects and that light quality could play an important role in the quality of the grape. On the other hand, grape quality can be negatively affected through high temperatures obtained in well-exposed bunches in sparse canopies with little or no air movement (Smart, 1987a; Smart & Sinclair, 1976).

Smart, Smith & Winchester (1988) and Archer & Strauss (1989) reported negative morphological and grape-compositional effects in shaded Cabernet Sauvignon fruit. An increase in within-canopy shade was responsible for a decline in berry set, sugar, skin anthocyanins and phenols, while malic acid, K-concentration and pH increased. Similarly, Bledsoe, Winkler & Marois (1988) reported a significantly negative correlation between the PPFR and the pH, malate and K-concentration.

Canopies with relatively low densities, bearing well-exposed fruit, have big advantages as far as grape and potential wine quality is concerned if water stress during ripening and direct cluster exposure do not exceed certain limits. It is not clear, however, to what extent the positive effects of sparse canopies would be offset by the negative effects of high plant water stress as obtained in vineyards with little or no irrigation. This study was undertaken to establish the effect of vine spacing on canopy characteristics and on some microclimatic and physiological aspects of vines in order to explain possible differences in grape and wine quality. The quantitative and qualitative effects of vine spacing will be dealt with in a later publication.

MATERIALS AND METHODS

Vineyard: A *Vitis vinifera* L. cv. Pinot noir (clone BKV) grafted onto 99 Richter (clone 1/30/1) (*Vitis Berlandieri* var. Las Sorres x *Vitis rupestris* var. du Lot) vineyard was planted during 1980 with spacings as indicated in Table 1.

Each spacing treatment was randomly replicated in blocks, five times, and side-effects were eliminated by border rows giving approximately 49 vines per replicate for measurement.

The vines were trained on a 4-strand Hedge system (cordon height: 600 mm; foliage height: 1 800 mm with foliage wires evenly spaced 300 mm apart). During the first two years no crop was allowed in order to obtain a complete development of the vines on the trellising system. Thereafter the vines were spur-pruned to 6,5 buds per m² soil surface. All vines were shoot-thinned at approximately 150-mm shoot length and

TABLE 1

Treatments used in a vine spacing trial with Pinot noir/99 Richter.

Inter-row spacing (m)	In-row spacing (m)	Number of vines per hectare
1,0	0,5	20 000
1,0	1,0	10 000
2,0	1,0	5 000
2,0	2,0	2 500
3,0	1,5	2 222
3,0	3,0	1 111

shoots were tipped once at a height of approximately 200 mm above the top foliage wire. The vines in different spacing treatments were differentially fertilized on the basis of crop mass and cane mass in order to replenish soil nutrients to a comparable amount for each espacement. No irrigation was applied. The soil used for the trial is described by Archer & Strauss (1989b).

Measurements: During the season when these measurements were made, the monthly rainfall was as follows: Sept. 38,9 mm, Oct. 22,7 mm, Nov. 10,6 mm, Dec. 4,3 mm, Jan. 0 mm, Feb. 1,2 mm, Mar. 8,9 mm.

The rate of photosynthesis (μMol CO_2 m^{-2} s^{-1}), stomatal conductance (mMol m^{-2} s^{-1}) and the rate of transpiration (mMol m^{-2} s^{-1}) were measured using an ADC portable photosynthesis meter (Analytical Development Co. Ltd., England). The characteristics of this apparatus are described by Hunter & Visser (1988c). Radiant energy, expressed as photosynthetic photon fluence rate (PPFR), was measured using a Li-cor Line Quantum Radiometer (Li 1188B). Five measurements per vine of five representative vines per plot were recorded. The radiometer was inserted in the canopy at cluster height in line with the cordon. The leaf temperature of four leaves for each of two representative vines per treatment plot was measured using a data logger with fixed thermocouples.

A pressure chamber (Scholander *et al.*, 1965) was used to measure leaf water potential on a 12-hour cycle. Shaded leaves in the same position in the canopy were used. All the above mentioned measurements, except those for leaf-water potential, were recorded at two-hour intervals, starting at 07:00 and ending at 17:00 on every day on which recordings were done. Leaf-water potential was also recorded at two-hour intervals, but started at 06:00 and ended at 18:00. These days were selected to coincide with flowering, pea size, véraison and ripeness.

The leaf area per vine was calculated from measurements of the total leaf area of five shoots from 10 selected vines per treatment plot. Canopy density was measured using the point quadrat method (Smart, 1988). Thirty probes per vine for five selected vines per plot were recorded at ripeness. Vineyard scoring was done during véraison using the score card as suggested by Smart (1987b). The total length per shoot of three representative shoots for each of five representative vines per treatment plot was measured at weekly intervals starting one week after budburst until ripeness (when a sugar concentration of ca. 23 °B was reached).

Data processing: Where applicable, all data sets were subjected to a standard two-way analysis of variance (Snedecor & Cochran, 1967).

RESULTS AND DISCUSSION

Leaf temperature: Although no significant differences between the leaf temperatures of the different vine-spacing treatments could be found (Table 2), certain tendencies occurred. The leaves of more closely spaced vines seemed to be cooler than those of more widely spaced vines at the beginning of the season, whereas this tendency was reversed towards the end of the season. It is postulated that this tendency occurred because of the lower canopy density of more closely spaced vines enabling better air movement through the canopy at the beginning of the season. During this period vines were also well supplied with water. As the season progressed the higher water stress in more closely spaced vines (Archer & Strauss, 1989b) overrode the cooling effect of air movement, resulting in higher leaf temperatures because stomatal conductance decreased. This may be the reason why the leaf temperature of more closely spaced vines rose as the season progressed, whereas that of more widely spaced vines more or less stabilized. Peak values of more than 30°C were frequently measured at midday (Table 3), and these high temperatures were probably detrimental to stomatal conductance (Heath & Orchard, 1957) and photosynthesis (Kriedemann, 1968).

Radiant energy (PPFR): PPFR values, measured at cluster level within the canopy, ranged from $131 \text{ m E m}^{-2} \text{s}^{-1}$ for the 2,0 m x 1,0 m treatment at ripeness to $4 \text{ m E m}^{-2} \text{s}^{-1}$ for the 2,0 m x 2,0 m treatment at flowering and are given in Fig. 1. The amount of radiant energy intercepted by the canopy appeared to increase from flowering to véraison. The changes in the pattern of radiant energy interception were probably caused by changes in canopy density and the movement of the sun as the season progressed. This will be further discussed under "canopy characteristics". In general, for all phenological stages, PPFR was relatively low in the early morning, rose to a peak during mid-morning, decreased at midday, rose to a second peak during mid-afternoon, and decreased again towards late afternoon. These trends are in accordance with results quoted by Champagnol (1984) for north-south row orientations. As the season progressed, the differences in PPFR between treatments became more pronounced. Vines in the more closely spaced treatment plots had higher PPFR values than those in the more widely spaced treatment plots. This difference was more pronounced from pea size to ripeness than earlier in the season and was probably caused by the more favourable canopy characteristics of more closely spaced vines. The highest PPFR was obtained with 2,0 m x 1,0 m vine spacing, whereas that of the 3,0 m x 3,0 m, 3,0 m x 1,5 m and 2,0 m x 2,0 m spacing was significantly lower. The relatively low values recorded at midday for all treatments were ascribed to the position of the sun, it being directly above the north-south rows at that time of the day. The peak values at mid-morning and mid-afternoon were caused by a more favourable angle of incident light for the north-south oriented canopies of the trial.

Canopy characteristics: The canopy of each treatment plot was scored twice from both sides prior to ripeness, using the vineyard scorecard (Smart, 1987b) and the results are presented in Table 4. As indicated by the scorecard, the canopies of the more closely spaced treatments showed a higher potential for producing quality grapes than those of the more widely spaced treatments. It would appear that a more favourable microclimate existed in the canopies of the more closely spaced vines than in those of the more widely spaced vines. These differences in the canopy characteristics explain why more favourable radiant energy levels was measured in the more closely spaced treatment plots.

The main differences in the canopies of the different

TABLE 2

The effect of vine spacing on the mean maximum leaf temperature during flowering, pea size, véraison and ripeness, 1988/89.

Phenological stage	Ambient temperature (°C)	Mean maximum leaf temperature (°C)					
		1,0 x 0,5	1,0 x 1,0	2,0 x 1,0	2,0 x 2,0	3,0 x 1,5	3,0 x 3,0
Flowering	31,3	26,3	26,8	26,9	26,9	27,2	27,5
Pea size	32,7	28,2	28,0	28,4	28,7	28,8	29,4
Véraison	29,8	29,1	29,3	28,9	28,6	28,8	28,0
Ripeness	33,6	29,5	29,2	29,0	28,8	28,5	27,3

TABLE 3

The effect of vine spacing on maximum leaf temperature during flowering, pea size, véraison and ripeness, 1988/89.

Phenological stage	Mean leaf temperature (°C)					
	1,0 x 0,5	1,0 x 1,0	2,0 x 1,0	2,0 x 2,0	3,0 x 1,5	3,0 x 3,0
Flowering	32,9	32,5	33,0	31,8	31,0	32,4
Pea size	35,1	34,9	34,6	34,4	33,9	35,1
Véraison	35,3	35,0	36,0	35,9	34,7	34,7
Ripeness	38,7	37,8	36,7	37,3	37,0	36,9
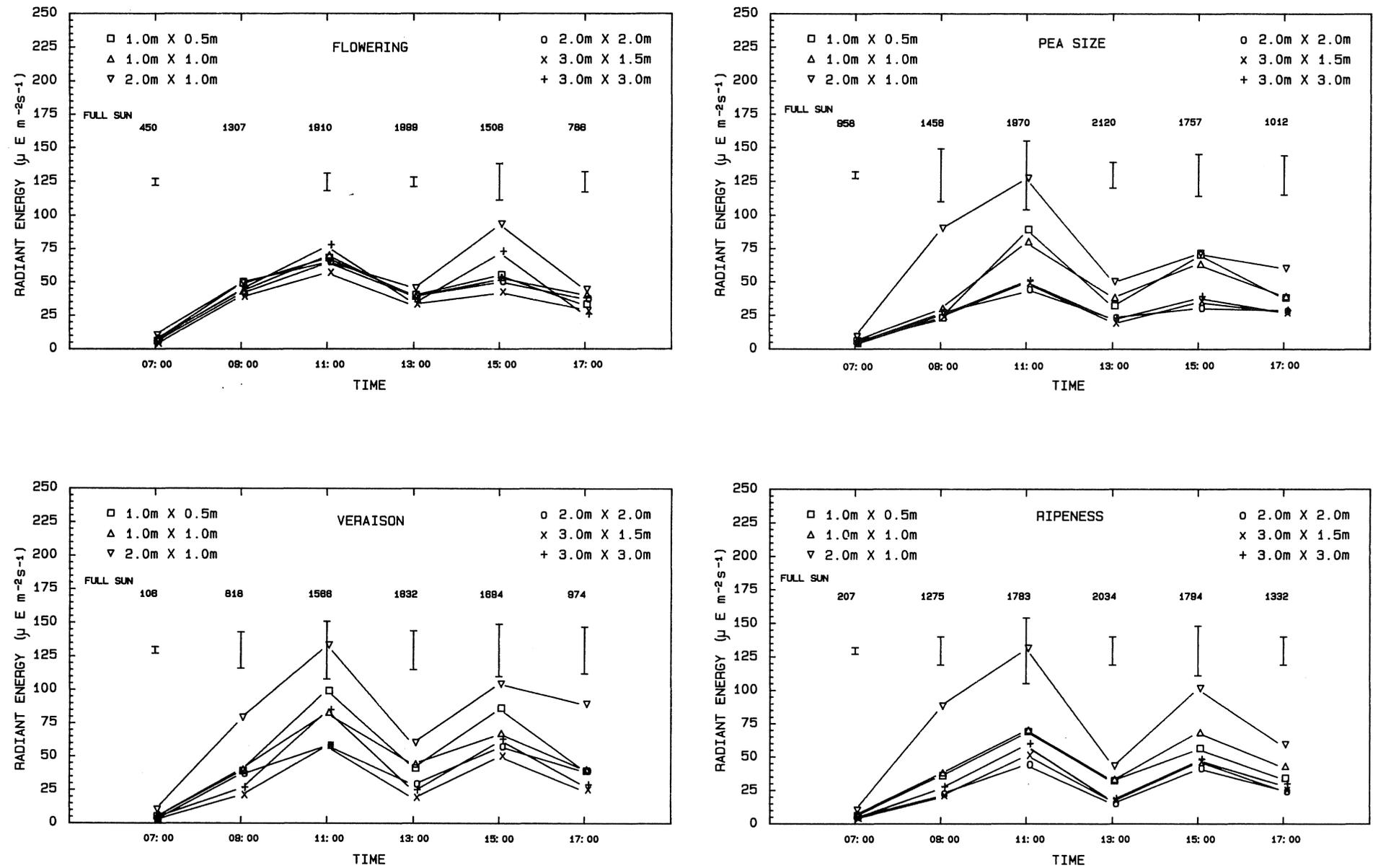
FIGURE 1

The effect of vine spacing on the radiant energy received at cluster level within the canopy of Pinot noir/99 Richter during flowering, pea size, véraison and ripeness.

TABLE 4

The effect of vine spacing on canopy characteristics of Pinot noir/99 Richter prior to ripeness, evaluated by means of vineyard scorecard (Smart, 1987b).

Parameter (ex 10)	Vine spacing						
	1,0 x 0,5 m	1,0 x 1,0 m	2,0 x 1,0 m	2,0 x 2,0 m	3,0 x 1,5 m	3,0 x 3,0 m	D-value (p ≤ 0,05)
Canopy gaps	8,0	8,5	9,2	6,5	6,0	6,0	2,3
Leaf size	9,6	9,2	9,0	8,0	7,2	6,8	ns
Leaf colour	9,5	9,6	9,6	9,0	8,5	8,0	ns
Canopy density	8,5	8,0	4,8	2,0	2,0	2,0	2,5
Fruit exposure	10,0	10,0	8,0	6,0	2,0	4,0	4,1
Shoot length	10,0	10,0	6,8	6,0	2,0	2,0	3,2
Lateral growth	10,0	10,0	9,5	2,0	2,0	6,0	4,8
Growing tips	10,0	10,0	10,0	4,0	4,0	6,0	3,4
TOTAL (as percentage)	94,5	94,1	83,6	54,4	42,1	51,0	28,03

treatment plots occurred with canopy gaps, canopy density, fruit exposure, shoot length, the amount of lateral growth and the number of growing tips present. Furthermore, the shoots of more widely spaced vines grew actively during the period véraison to ripening (Fig. 2). In addition, these shoots were characterized by more pronounced lateral growth (Table 4) with subsequent higher canopy density and less exposed fruit than in the case of the more closely spaced treatment plots. It is postulated that the higher rate of soil water depletion, which

was induced by the higher root density of closer spacings (Archer & Strauss, 1989b), gave rise to an earlier arrestment of shoot growth.

Canopy density was also measured with the point quadrat method (Smart, 1988), and the results are given in Table 5. These results verify the visual results in Table 4 and show that the canopies of more closely spaced vines were less dense than those of more widely spaced vines. The more favourable canopy characteristics of more closely spaced vines possibly
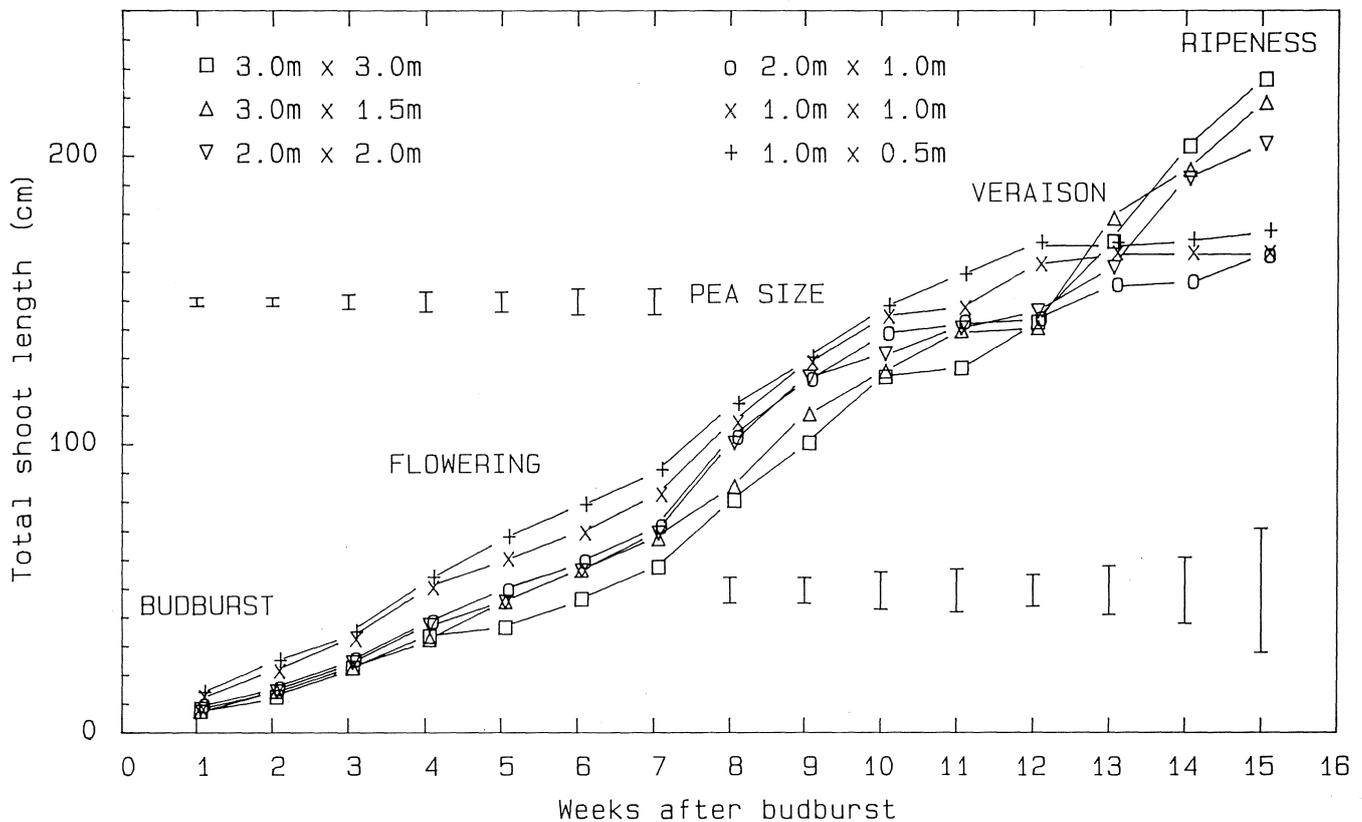
FIGURE 2

The effect of vine spacing on untrimmed shoot growth of Pinot noir/99 Richter grapevines.

FLOWERING

□ 1.0m X 0.5m
△ 1.0m X 1.0m
▽ 2.0m X 1.0m

o 2.0m X 2.0m
x 3.0m X 1.5m
+ 3.0m X 3.0m

LEAF WATER POTENTIAL (kPa)

TIME

PEA SIZE

□ 1.0m X 0.5m
△ 1.0m X 1.0m
▽ 2.0m X 1.0m

o 2.0m X 2.0m
x 3.0m X 1.5m
+ 3.0m X 3.0m

LEAF WATER POTENTIAL (kPa)

TIME

VERAISON

□ 1.0m X 0.5m
△ 1.0m X 1.0m
▽ 2.0m X 1.0m

o 2.0m X 2.0m
x 3.0m X 1.5m
+ 3.0m X 3.0m

LEAF WATER POTENTIAL (kPa)

TIME

RIPENESS

□ 1.0m X 0.5m
△ 1.0m X 1.0m
▽ 2.0m X 1.0m

o 2.0m X 2.0m
x 3.0m X 1.5m
+ 3.0m X 3.0m

LEAF WATER POTENTIAL (kPa)

TIME
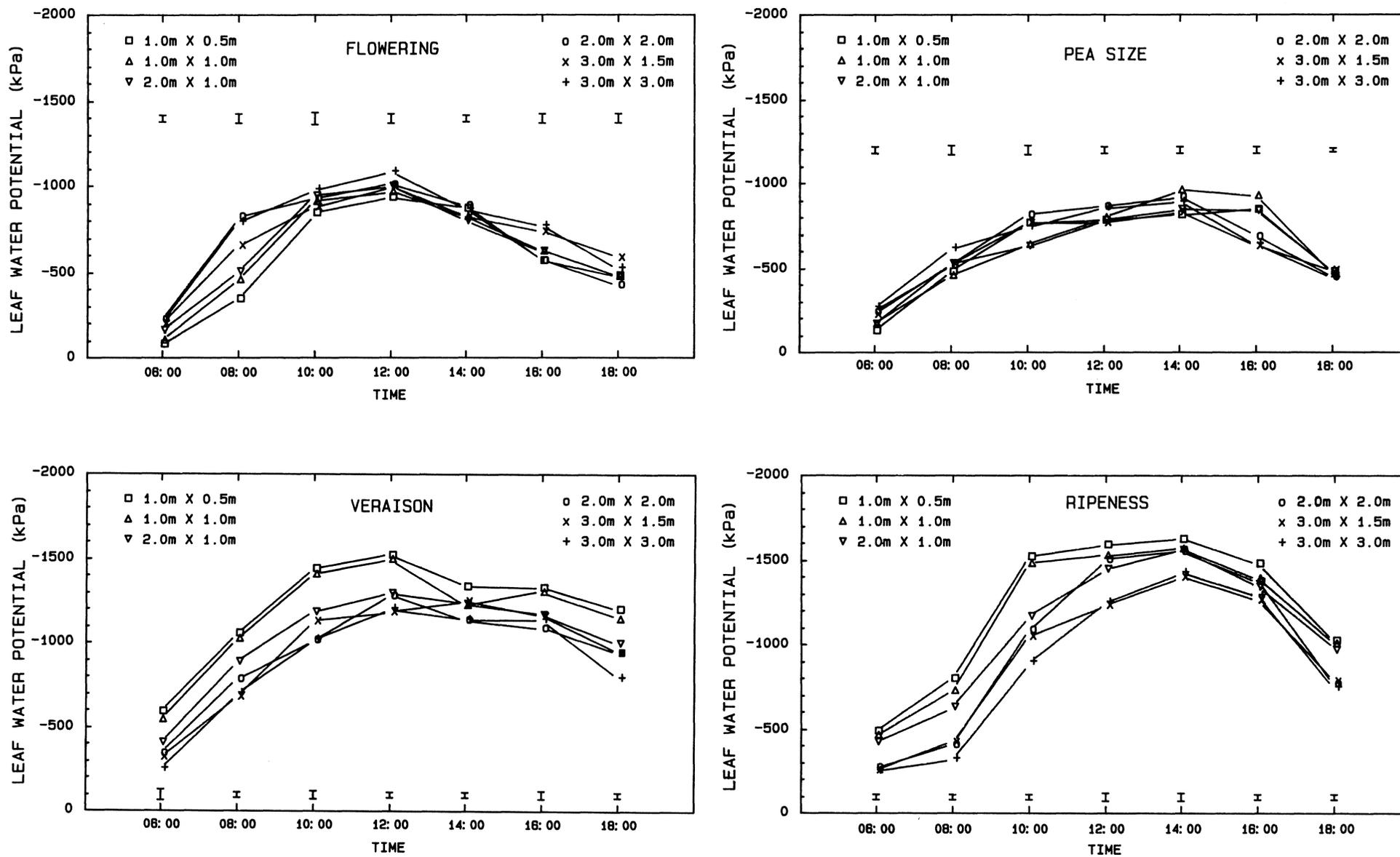
FIGURE 3

The effect of vine spacing on the daily leaf-water potential during flowering, pea size, véraison and ripeness of Pinot noir/99 Richter grapevines.

had a positive effect on the quantity and quality of the fruit produced; this will be discussed in a later publication.

TABLE 5

The effect of vine spacing on the leaf layer number of Pinot noir/99 Richter grapevines.

Vine spacing (m)	Leaf layer number
1,0 x 0,5	1,15
1,0 x 1,0	1,88
2,0 x 1,0	2,60
2,0 x 2,0	3,73
3,0 x 1,5	5,75
3,0 x 3,0	6,50
D-value (p ≤ 0,01)	2,091

Leaf-water potential: The daily leaf-water potential during the various phenological stages (flowering, pea size, véraison and ripeness), as affected by vine spacing, is depicted in Fig. 3 whereas the mean daily values are shown in Fig. 4. During the day, peak values were measured between 12:00 and 14:00, which is in accordance with results presented by Champagnol (1984), Van Zyl (1984) and Archer & Strauss (1989). Although predawn values were similar during the early part of the season, larger differences occurred during véraison and ripeness (Fig. 3). More closely spaced vines endured less water stress during the early part of the season (Fig. 4). At about pea size this tendency was reversed, more

closely spaced vines being more stressed during véraison and ripeness than more widely spaced vines (Fig. 4). These results correspond well with those reported by Archer & Strauss (1989b).

Stomatal conductance: The stomatal conductance values, which varied from 400 mMol m^{-2} s^{-1} for sunlit leaves at pea size to 40 mMol m^{-2} s^{-1} for shaded leaves at ripeness are presented in Fig. 5. In general, over all phenological stages, stomatal conductance for sunlit leaves was relatively low early in the morning, at midday and in the late afternoon, with two distinguishable peaks occurring during mid-morning and mid-afternoon. These results coincide with those of Downton, Grant & Loveys (1987). In the case of shaded leaves, stomatal conductance reached a peak in the middle of the day. These trends are in accordance with results quoted by Champagnol (1984). Stomatal conductance appeared to increase from flowering to pea size while soil water was still adequate, but apparently decreased from pea size to ripeness (Fig. 5) as a higher plant-water stress was induced by the depletion of soil water (Archer & Strauss, 1989b). Little differences in stomatal conductance occurred during the early part of the season between vines planted to different spacings, but during the ripening process (véraison to ripeness) more closely spaced vines experienced a significantly lower conductance than more widely spaced vines. This was probably caused by a higher induced plant-water stress in the case of narrow spacings (Archer & Strauss, 1989b) and is in accordance with results obtained for heat-stressed Chenin blanc vines by Sepúlveda & Kliewer (1986). The lowest stomatal conductance was obtained in vines with a spacing of 1,0 m x 0,5 m and 1,0 m x 1,0
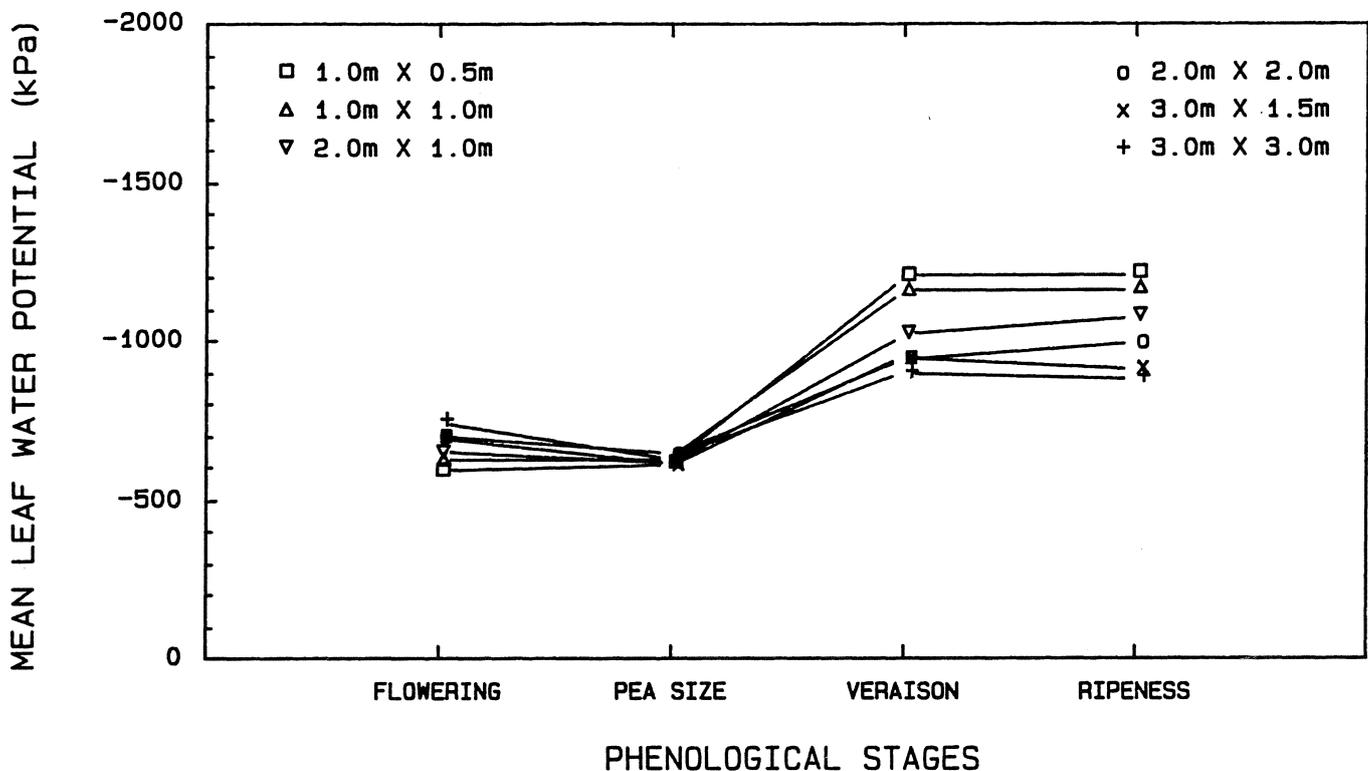
FIGURE 4

The effect of vine spacing on the mean daily leaf-water potential during flowering, pea size, véraison and ripeness of Pinot noir/99 Richter grapevines.
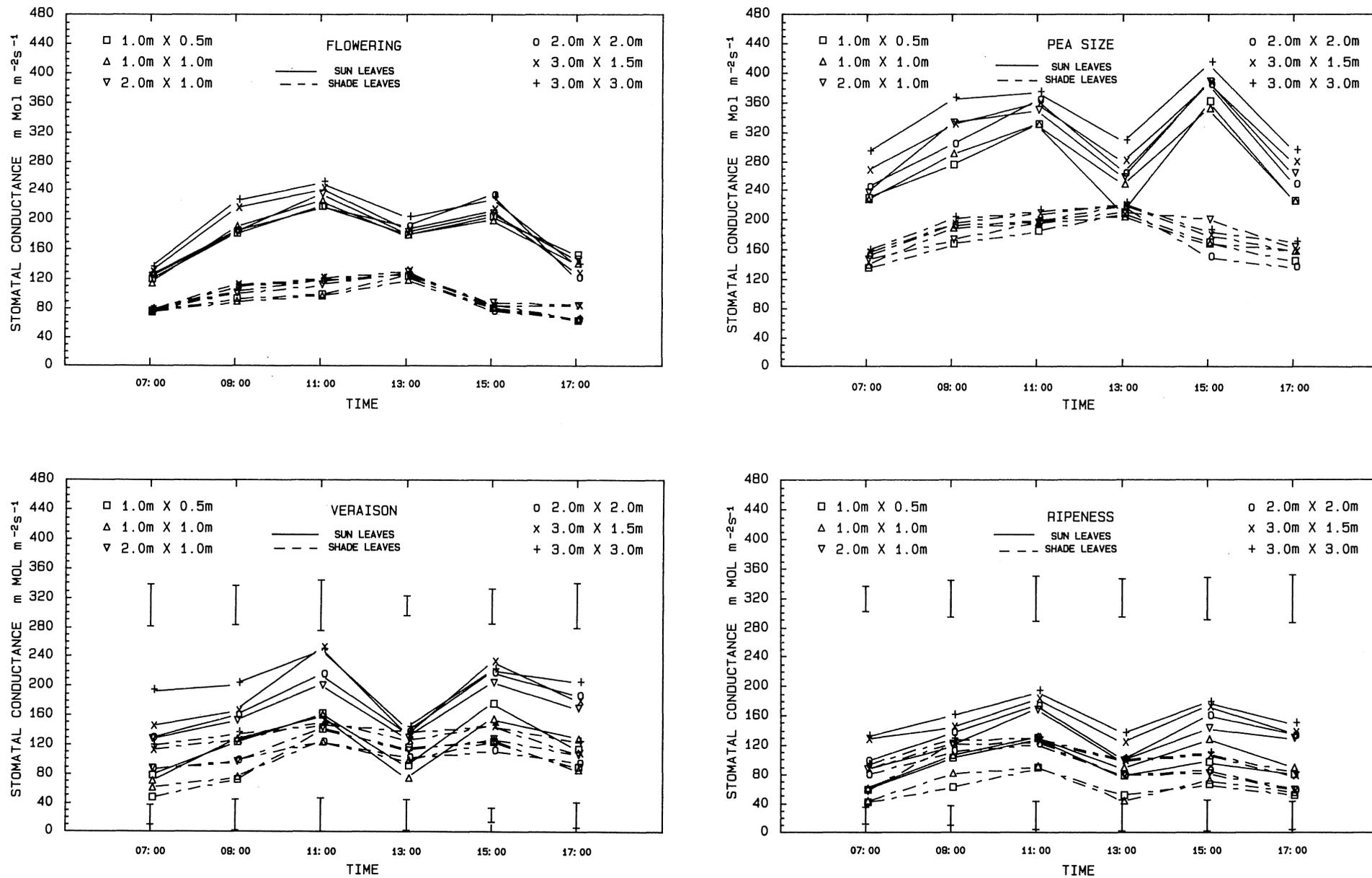
FIGURE 5

The effect of vine spacing on the daily stomatal conductance during flowering, pea size, véraison and ripeness of Pinot noir/99 Richter grapevines.
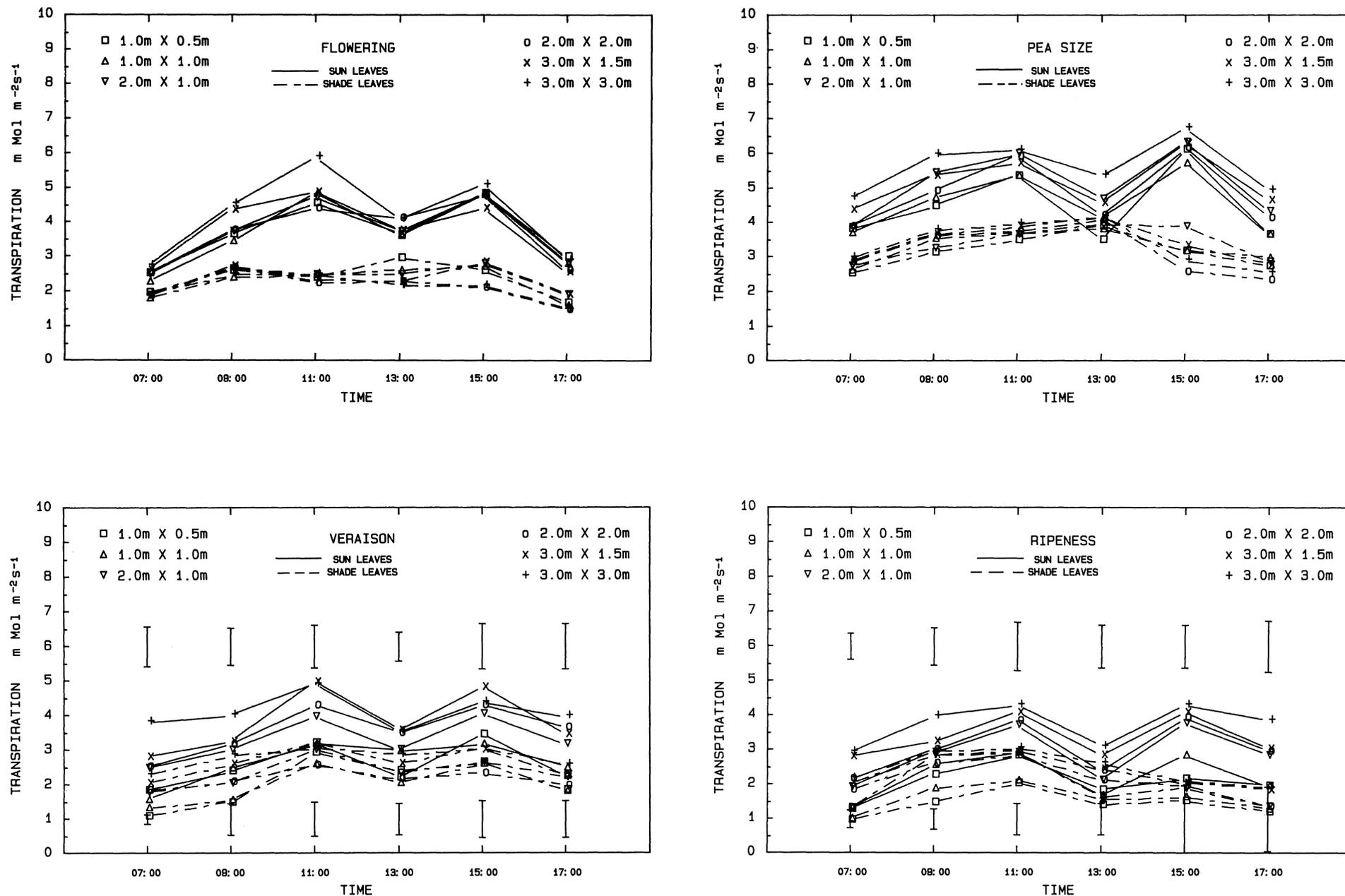
FIGURE 6

The effect of vine spacing on the daily transpiration rate during flowering, pea size, véraison and ripeness of Pinot noir/99 Richter grapevines.

m, and the highest conductance was recorded with a spacing of 3,0 m x 3,0 m. Shaded leaves appeared to have contributed more to the total stomatal conductance in the case of more closely spaced vines during ripeness (Fig. 5) than in the case of more widely spaced vines. The decrease in stomatal conductance at midday can probably be ascribed to low leaf-water potential, induced by high leaf temperature, forcing stomata to close (Sepúlveda & Kliewer, 1986).

Rate of transpiration: The transpiration rate followed a very similar pattern to that of stomatal conductance. Values for the rate of transpiration varied from 1,1 mMol m^{-2} s^{-1} at ripeness to 6,6 mMol $m^{-2}s^{-1}$ at pea size for sunlit leaves (Fig. 6). For shaded leaves this value varied from 0,9 mMol m^{-2} s^{-1} at ripeness to 4 mMol m^{-2} s^{-1} at pea size (Fig 6). Similar to results obtained by Alleweldt, Eibach & Rühl (1982) as well as Fails, Lewis & Barden (1982), the rate of transpiration for sunlit leaves in this trial was relatively lower early in the morning, at midday and in the late afternoon and reached a peak during mid-morning as well as during mid-afternoon. For shaded leaves the rate of transpiration reached a peak during the middle of the day. These trends are in accordance with results quoted by Champagnol (1984). Dictated by stomatal conductance, the rate of transpiration apparently increased from flowering to pea size for all treatments but decreased from pea size to ripeness. Although no statistical differences could be found in the rate of transpiration between different spacings during the early part of the season, marked differences occurred in both shaded and sunlit leaves during véraison and ripeness (Fig. 6). At these stages the more closely spaced vines showed a significantly lower transpiration rate than those in wider spacings. As with stomatal conductance, this was also associated with a more negative leaf-water potential in the case of narrow vine spacings (Fig. 3). The lowest rate of transpiration was recorded in vines spaced 1,0 m x 0,5 m and 1,0 m x 1,0 m, the highest in vines with a spacing of 3,0 m x 3,0 m.

Rate of Photosynthesis: The rate of photosynthesis followed a similar pattern to those of stomatal conductance and rate of transpiration. Values for the rate of photosynthesis varied from 1,7 μMol m^{-2} s^{-1} for shaded leaves at ripeness to 16,5 μMol m^{-2} 2^{-1} for sunlit leaves at pea size (Fig. 7). In general, over all phenological stages, the rate of photosynthesis for sun leaves was lowest in the early morning and highest at mid-morning. After declining at midday, a second, somewhat lower, peak was reached during mid-afternoon, after which the rate declined towards late afternoon. These results coincide with those found by Downton, Grant & Loveys (1987). With shaded leaves, these peaks were not as accentuated as in the case of sunlit leaves. These trends are in accordance with results quoted by Champagnol (1984). Similarly to stomatal conductance, the rate of photosynthesis appeared to increase from flowering to pea size and to decrease from pea size to ripeness (Fig. 7), as was the case with the rate of transpiration. This decrease during the latter part of the growing season can probably be ascribed to an increase in plant-water stress as was indicated by Archer & Strauss (1989b) and in Figs. 3 & 4. This decrease agrees with results obtained by Hofäcker (1976) and Alleweldt & Rühl (1982). Lower interior light intensity as well as high leaf temperature at midday,

which induced lower leaf-water potentials, exerted a negative effect on the rate of photosynthesis through stomatal movement, and this was evident throughout the growing season. The decline in the rate of photosynthesis over the growing season was also reported by Kriedemann (1977) and Hunter & Visser (1988a, 1988b, 1988c).

CONCLUSIONS

Under the conditions of this experiment (dry-land, low-potential soil, vertical trellis), the canopies of more closely spaced vines were less dense than those of more widely spaced vines. This was due mainly to the less vigorous shoot growth induced by intervine competition for soil water and nutrients in the relatively restricted soil depth. Consequently, fewer and shorter shoots (restricted budburst and growth of collar buds and water shoots) and restricted lateral shoot development occurred in more closely spaced vines. Vines in the more closely spaced treatment plots thus had a better balance between shoot growth and yield, which contributed to less dense canopies.

The more open canopies of the more closely spaced vines allowed better penetration of sunlight into the fruit zone, whereby stomatal conductance, transpiration and photosynthesis were favoured during the early part of the season. As the season progressed, however, more severe competition for declining soil water caused an increase in plant-water stress which was accentuated in the case of more closely spaced vines. This resulted in a reversal in stomatal conductance, transpiration and photosynthesis, in respect of which vines in the more closely spaced treatment plots were less active than more widely spaced vines during the latter part of the season.

The 2,0 m x 1,0 m spaced vines had thin, open canopies similar to more closely spaced vines, but the inter-row space was wider, resulting in better sunlight penetration. Less cross-row shading occurred especially during early to mid-morning and mid- to late-afternoon. The relatively low values measured at midday could be ascribed to the sun being directly above the north-south oriented rows and the measurement being done in the middle of the canopy at cluster level. The decline at midday in the rates of stomatal conductance, transpiration and photosynthesis are probably related to temperature and light.

The physiological activity of grapevines is strongly related to physical soil properties such as water-holding capacity and the supplying of water to the vine root. For the soil in this trial, water uptake by vine roots was dominated mainly by high root density, which eventually led to the more closely spaced vines having more open canopy characteristics than the more widely spaced vines. Under more luxurious conditions (higher soil potential, irrigation, higher N-nutrition, etc.), decreased water stress might cause stronger shoot growth, resulting in different canopy characteristics. This will probably lead to wider spacings obtaining less dense canopies than closer spacings. It is postulated that more fertile conditions will need wider in-row spacings to achieve optimal yield and quality than was the case with more closely spaced vines in this trial.

Vine physiology, as affected by vine spacing, will affect the growth, yield and quality of Pinot noir grapes. These aspects require further investigation.
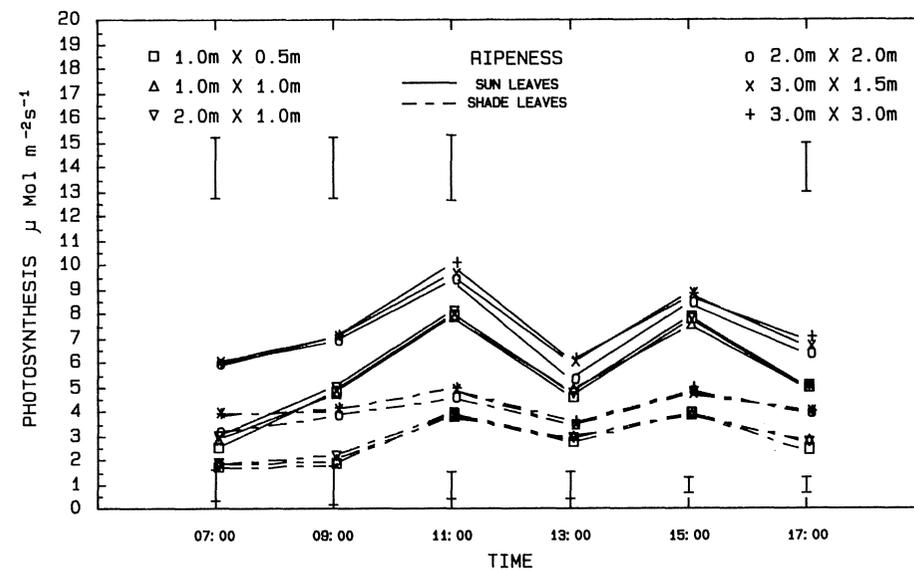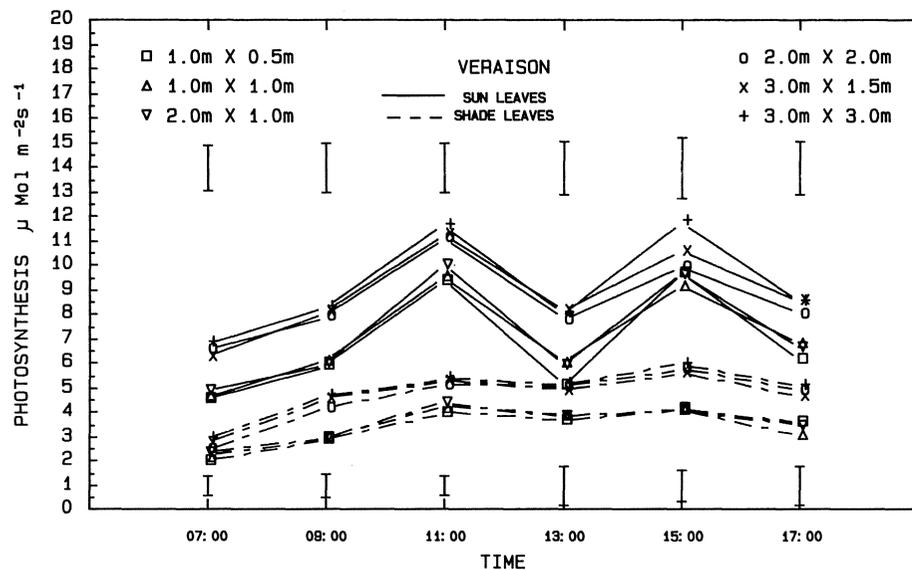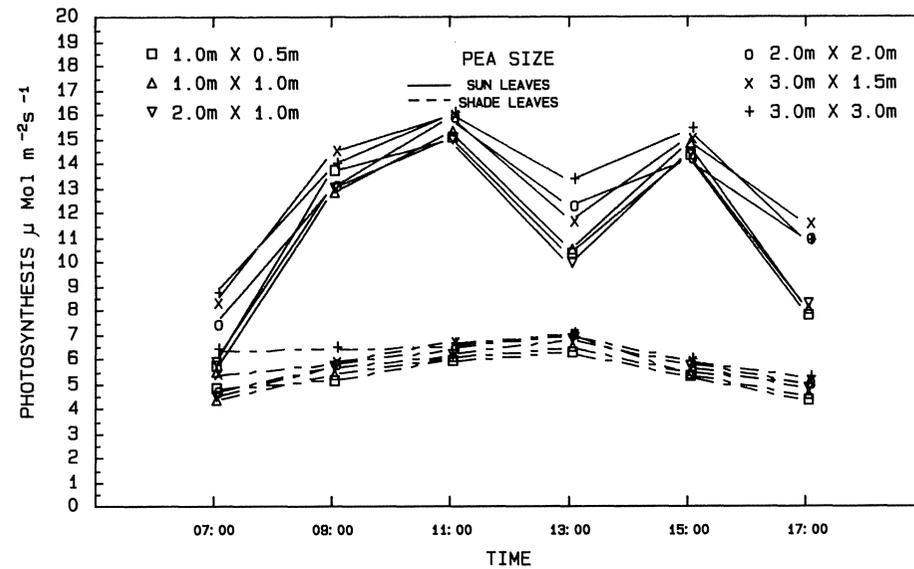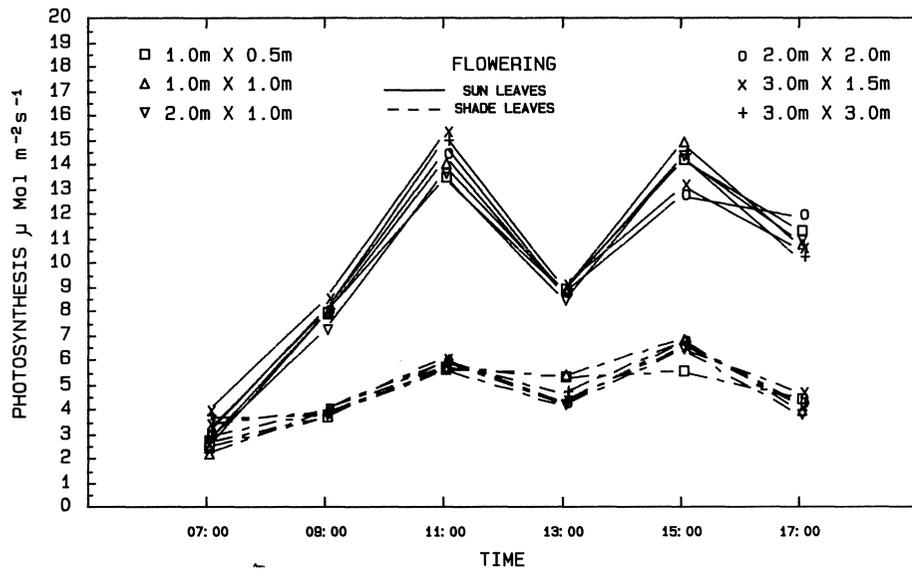
FIGURE 7

The effect of vine spacing on the rate of photosynthesis during flowering, pea size, véraison and ripeness of Pinot noir/99 Richter grapevines.

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