The Effect of Plant Spacing on the Water Status of Soil and Grapevines*

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The effect of plant spacing on soil water content and plant water status is described. The higher root densities of narrower plantings resulted in a more rapid depletion of soil water content. This resulted in a more negative leaf water potential which, in turn, resulted in earlier stomatal closure, affecting transpiration rate negatively. Consequently grapes from narrower spaced vines ripened under higher water stress conditions than those from wider spaced vines.

The effect of soil water content on plant growth has been the subject of many studies (Veihmeyer & Hendrickson, 1950, 1957; Vaadia & Kasimatis, 1961; Cowan, 1965; Kasimatis, 1967; Kramer, 1969; Berger, 1971; Hsiao, 1973; Smart, 1974; Van Zyl, 1975; Saayman & Van Zyl, 1976; Van der Westhuizen, 1980; Smart & Coombe, 1983; Van Zyl, 1984; Matthews, Anderson & Schultz, 1987). Although it is widely accepted that a shortage of water is detrimental to plant growth, crops differ as regards the amount of water needed to produce yields of acceptable quality. Veihmeyer & Hendrickson (1950) concluded that vines are more drought resistant than fruit trees, which can be ascribed to an inherent capability for a better adapted balance between water supply by the roots and water loss through the leaves. Although the vine is more drought resistant than most other commercial fruit bearing plants, a serious water deficit can be detrimental to vine performance (Van Zyl, 1975).

The success with which the vine adapts itself to conditions of water stress varies considerably according to time of day, season, climatical constraints and soil water supply (Champagnol, 1984). If the transpiration rate exceeds the rate of water supply to the leaf, stomata start closing and leaves cease transpiring at their full potential (Bidwell, 1974). Under these circumstances the rate of shoot growth decreases and shorter internodes develop (Vaadia & Kasimatis, 1961; Kasimatis, 1967). The rate of shoot growth, therefore, is a very sensitive indicator of available soil water (Van der Westhuizen, 1980). Continual water stress during summer, does not neccesarily cause vine leaves to wilt because vine roots keep on supplying water from progressively deeper soil layers (Van Zyl, 1975). The yellowing and scorched edges of older leaves are usually the first symptoms of water stress (Kasimatis, 1967).

Studies in Hungary, quoted by Smart & Coombe (1983) showed that water use by vines was highest for the period flowering to veraison. This is contrary to Van Zyl (1984) who found highest water usage in the period veraison to harvest. When soil water levels are limiting, vine leaf transpiration is less than the potential maximum because of the stomatal-closure mechanism. The water use efficiency of vines is reduced by lower transpiration rates under stress conditions mainly because the rate of photosynthesis declines with increasing water stress (Bravdo, Lavee & Samish, 1972; Loveys & Kriedemann, 1973). This stress-induced reduction in photosynthetic rate is initially caused by stomatal closure, but with prolonged stress photosynthesis is inhibited by a reduction in the activity of certain key enzymes (Smart & Coombe, 1983).

Clearly, a shortage of soil water inhibits transpiration and photosynthetic rates, thus emphasizing the importance of water uptake by the vine roots under dry-land conditions. The quality of water and nutrient uptake from the soil is, however, primarily a function of root density, i.e. the mesh of colonisation by the roots (Maertens, 1970; Champagnol, 1984). If the volume of soil between two adjacent roots is small, water and nutrients in that volume are more easily absorbed than when the volume is large (Champagnol, 1984). Although water and nitrates can diffuse over relatively long distances, phosphate and potassium must be very close to the root to be absorbed (Maertens, 1970). In poor soils (low nutrient content) a high root density is necessary to maintain an acceptable level of nutrient and water absorption. If dry-land cultivation is practiced on such soils, a high root density is necessary to ensure a more complete water absorption and adequate nutrition. This has certain advantages especially when larger quantities of water are needed during heat waves. On the other hand, high root densities under dry-land conditions, may have certain disadvantages because a higher rate of water absorption probably dessicates the soil faster which may result in unfavourable conditions later in the season when ripening takes place.

A previous study (Archer & Strauss, 1985) clearly showed marked differences in root density as induced by different planting densities. These results implied that different rates of soil water usage may exist between different plant spacings. This study was undertaken, therefore, to establish the effect of different planting densities on soil water depletion.

MATERIAL AND METHODS

Soil: The Glenrosa soil (Macvicar *et al.*, 1977), derived

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from Malmesbury shale, was typical of the Western Cape soils usually used for dry-land viticulture. To ensure the biggest possible soil water reservoir, the soil was deep delved to 1 000mm with a wing plough as described by Saayman & Van Huyssteen (1981) and limed to pH 5 (lNKCl). To conserve water as well as maintain the best possible physical conditions in the soil, minimum tillage principles as described by Van Huyssteen & Weber (1980a, 1980b) were adopted for this experiment. No irrigation was applied.

Treatments: A six year old *Vitis vinifera* L. cv Pinot noir (BK V) grafted onto 99 Richter (1/30/1) vineyard, planted to six different spacings, and trained onto a vertical trellising system, was used. Planting densities were 20 000 (1,0 x 0,5 m), 10 000 (1,0 x 1,0 m), 5 000 (2,0 x 1,0 m), 2 500 (2,0 x 2,0 m), 2 222 (3,0 x 1,5 m) and 1 111 (3,0 x 3,0 m) vines per hectare, each replicated five times. Vines were spur pruned to the same budload per unit area of soil (6 buds/m^2).

Soil water determinations: Soil water was measured at weekly intervals with a Nea Lindbergh neutron moisture probe. Standard 50 mm aluminium piping was used as access tubes. A minimum of three (for the narrower spacings) and a maximum of five tubes (for the wider spacings) each 1,30 m deep, were installed at each planting density. Neutron counts were taken at 200, 450, 750 and 1 050 mm depths for each access tube every week starting before bud-break and ending after harvest. Measurement sites for each treatment were replicated three times. For calibration purposes soil samples for gravimetric water determinations were taken at each site and measurement depth at three stages during the season, i.e. before bud-break (field capacity), pea size (semi-dry) and after harvest (dry).

Plant water determinations: Measurements of leaf water potential were taken at flowering, pea size, veraison and harvest. This was done by using a pressure chamber (Scholander *et. al.*, 1965) on a 24 hour cycle at two hour intervals. Shaded leaves in the same position in the canopy were used. During the day stomatal resistance and transpiration rate were measured on leaves in similar positions, also at two hour intervals, using a Li-cor steady state porometer (Li 1 600). Soil water data were processed using the BMD6 programme while data for stomatal resistance and transpiration rate were evaluated using standard VORI statistical programmes.

RESULTS AND DISCUSSION

Soil water content: Although measurements were recorded over two seasons the data for the 1985/86 season were used. This season was very dry and could be used, therefore, to illustrate the effect of plant spacing on soil water depletion. Although this season was preceded by a very high winter rainfall of 660 mm, Fig. 1 shows that very little rain fell during summer (40,8 mm from flowering to harvest). Evaporation during this period greatly exceeded soil water replenishment by rain. Effects on soil water content during this season can, therefore, mainly be ascribed to the influence of plant water use.

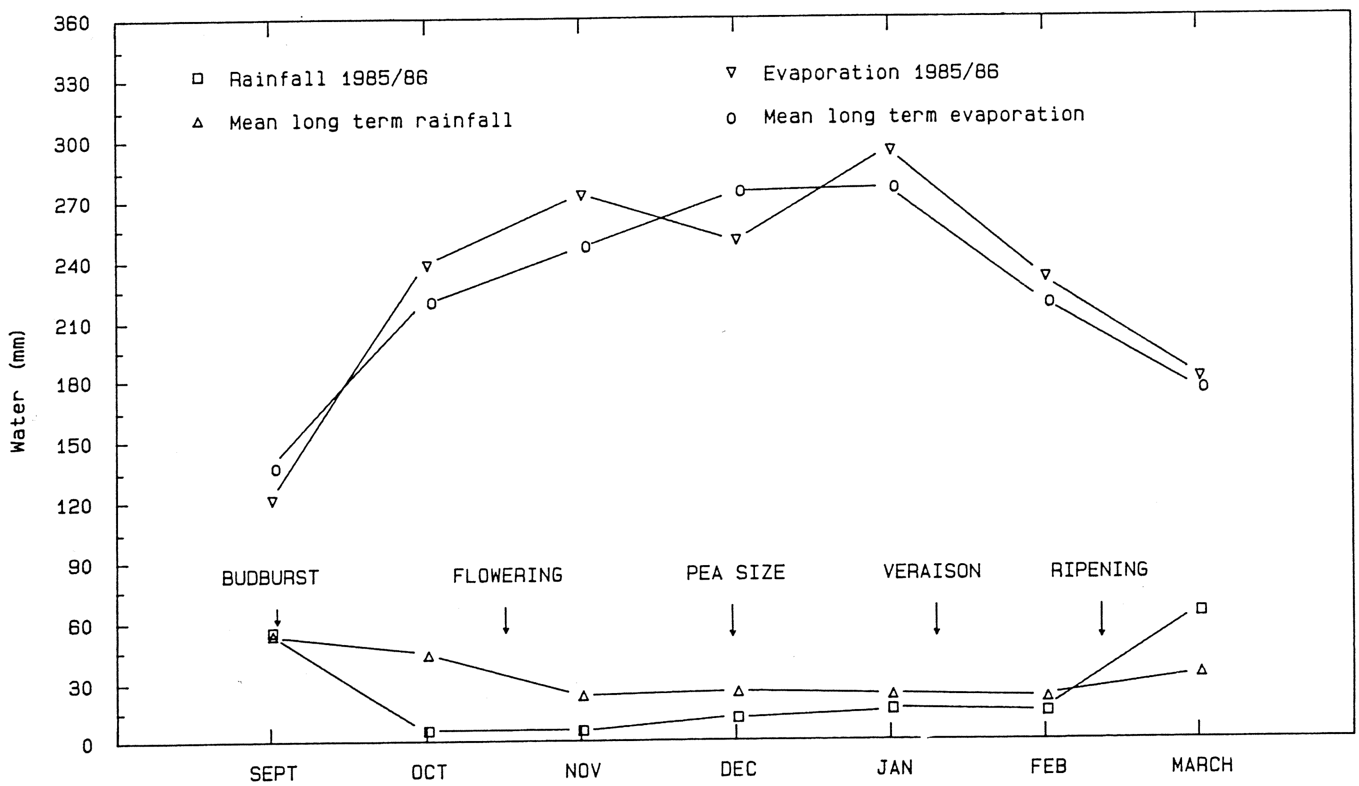

FIGURE 1
Mean long term and 1985/86 rainfall and Class A pan evaporation at Nietvoorbij.

The relative uniformity of the physical properties of the soil ensured comparable water holding capacities for all treatments at the beginning of the growing season. During the early part of the growing season the soil water content for all treatments decreased at approximately the same rate although it can be seen that the depletion rate was faster for the narrow spacings than for the wide spacings (Fig. 2). This general decline in soil water content is in accordance with results quoted by Smart & Coombe (1983). Before pea size stage, marked differences in the rate of soil water depletion occurred, the more closely spaced treatment plots dried out more rapidly than the more widely spaced treatment plots.

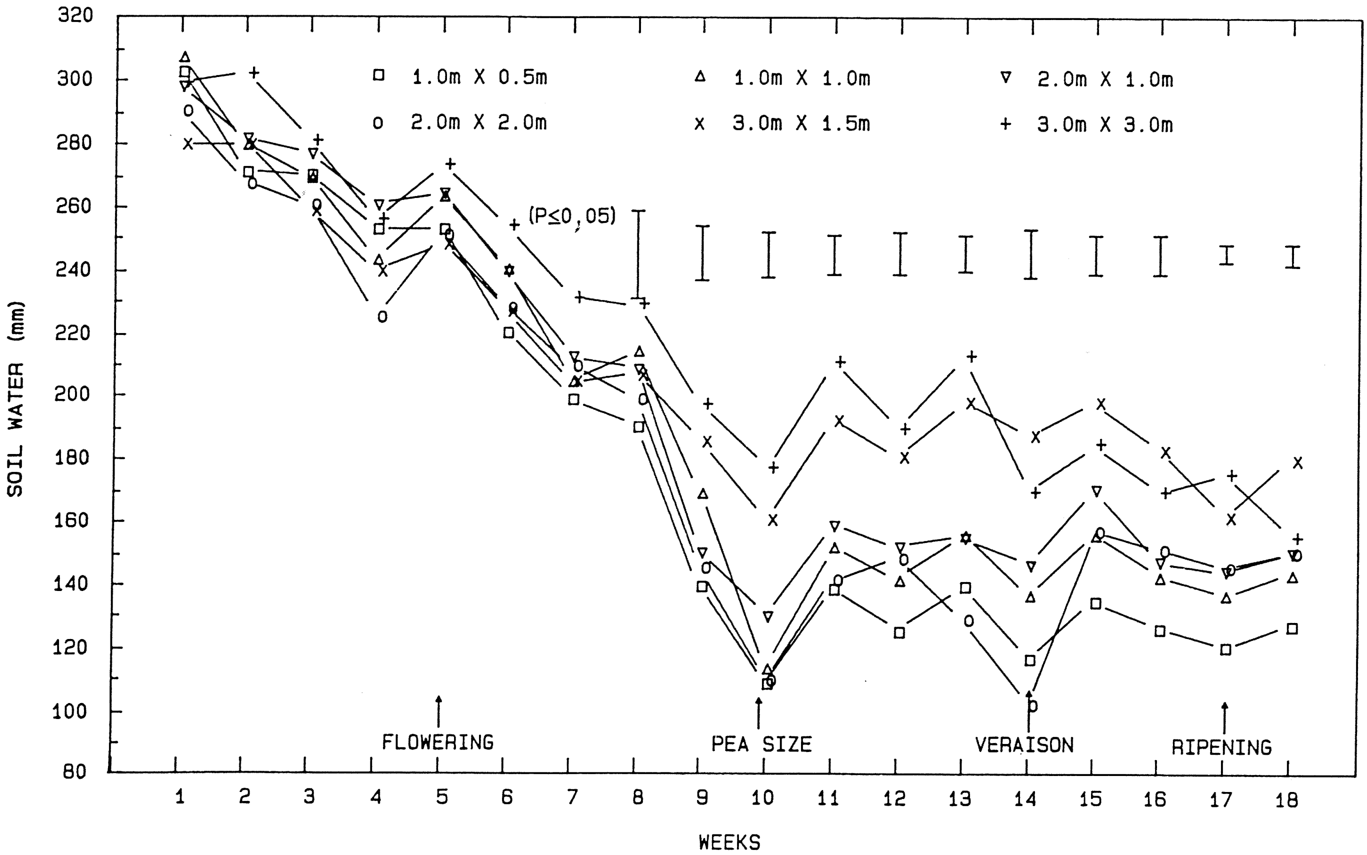

FIGURE 2

Effect of different plant spacing treatments on the soil water content of the total profile of a Glenrosa soil during the 1985/86 growing season at Nietvoorbij.

The tendency of the soil under closely spaced vines to dry out at a faster rate than in the case of wide spacings held true for all soil layers (Fig. 3). This tendency is, however, more clearly defined for the deeper soil layers (Fig. 3b, c & d) than for the 0-300 mm soil layer (Fig. 3a). These differences in soil water utilisation can probably be ascribed to the higher root densities of closely spaced vines (Table 1) resulting in more stressed ripening conditions in the case of denser plantings. The transpirational effect of the higher leaf index of narrower spaced vines (Table 1) probably made an important contribution to the higher water usage found with high root densities. This is in accordance with results quoted by Richards (1983) and Smart & Coombe (1983).

TABLE 1

The effect of plant spacing on root density and leaf index of Pinot noir/99 Richter grapevines*

Spacing (m)	Root density (m roots per m^3 soil)	Leaf index
1,0 x 0,5	8,213	2,87
1,0 x 1,0	4,887	2,78
2,0 x 1,0	3,442	2,01
2,0 x 2,0	2,017	1,53
3,0 x 1,5	1,733	1,43
3,0 x 3,0	1,105	0,69

*Adapted from Archer & Strauss (1985)

Leaf water potential: The diurnal leaf water potential during flowering, pea size, veraison and ripening as affected by planting density is depicted in Fig. 4 while the mean daily values are shown in Fig. 5. During the day, peak values were obtained between 12:00 and 14:00 which is in accordance with results obtained by Champagnol (1984) and Van Zyl (1984). Although predawn values were similar during the early part of the season, significant differences occurred during veraison and ripening (Fig. 4). This corresponded with soil water content. Vines of the narrower spaced treatment plots had less water stress during the early part of the season (Fig. 2 & 5). Just before pea size this tendency was reversed for soil water (Fig. 2) so that more closely spaced vines were less

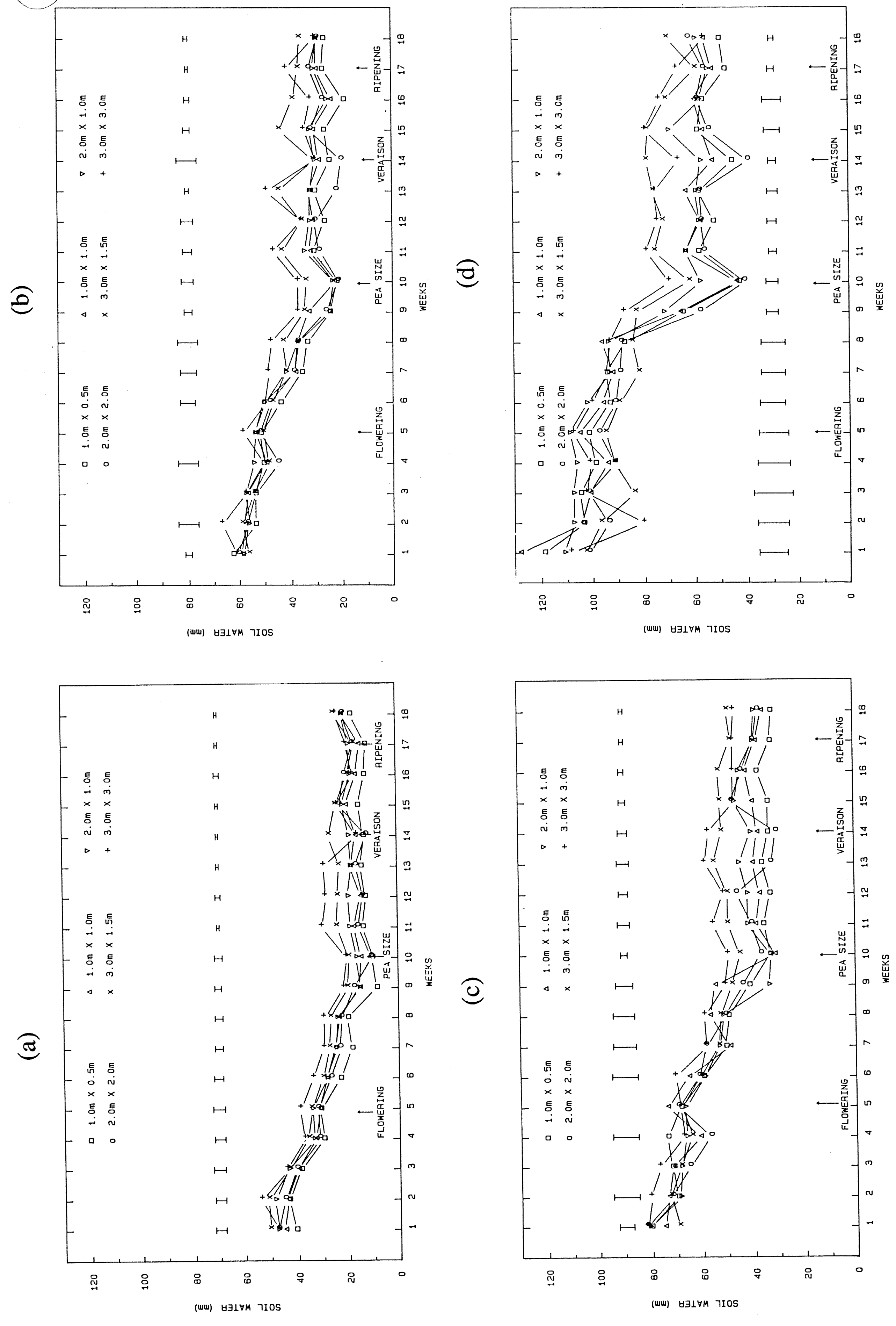

FIGURE 3

Effect of different plant spacing treatments on the soil water content of the (a) 0-300 mm (b) 300-600 mm (c) 600-900 mm and (d) 900-1 200 mm soil layer of a Glenrosa soil during the 1985/86 growing season at Nietvoorbij.

well supplied with water than more widely spaced vines. This had a somewhat delayed reaction in leaf water potential which showed a marked change between pea size and veraison (Fig. 5), indicating that grapes of more closely spaced vines ripened under higher stress conditions than those of more widely spaced vines. The higher root density of the more closely spaced vines (Table 1) probably resulted in a better water uptake early in the season when soil water was still abundant. This higher rate of exploitation depleted the soil water faster in the case of high root densities whereby a reversed effect in plant water status was obtained later in the season.

Stomatal resistance and transpiration rate: The daily stomatal resistance which occurred during flowering, pea size, veraison and ripening for the different plant spacing treatments is depicted in Fig. 6, while the corresponding transpiration rate is indicated in Fig. 7. As the season progressed, stomatal resistance increased in the vines of all treatments and the corresponding transpiration rate decreased. The increase in stomatal resistance and decrease in transpiration were more pronounced in the case of narrow plantings. This, together with the leaf water potential (Fig. 4) indicates an increase in water stress as ripening approached. It is also clear that vines in the more closely planted treatments experienced a higher water stress than those in the more widely planted treatments. The effect this had on photosynthesis will be dealt with in a later publication.

CONCLUSIONS

Because of very little rain the 1985/86 season could be used to illustrate the effect of plant spacing on soil water utilisation. The higher root density obtained with more closely spaced vines resulted in a higher depletion rate of soil water than was found with more widely spaced vines. As a result the stomatal resistance increased and the transpiration rate decreased more rapidly in the case of narrow spacings. This indicates that closely spaced vines experienced a higher water stress than widely spaced vines.

In areas where dry-land viticulture is practiced, this phenomenon may have far reaching consequences. Some soils present in local dry-land areas have a smaller water holding capacity than the experimental soil. Therefore, expecially after relatively low winter rainfall, soil water depletion by high root densities may result in excessive water stress and consequently may also affect grape yield and quality. Excessive water stress may also have a negative effect on photosynthesis. These effects must be known before a choice of plant spacing for dry-land soils can be made.

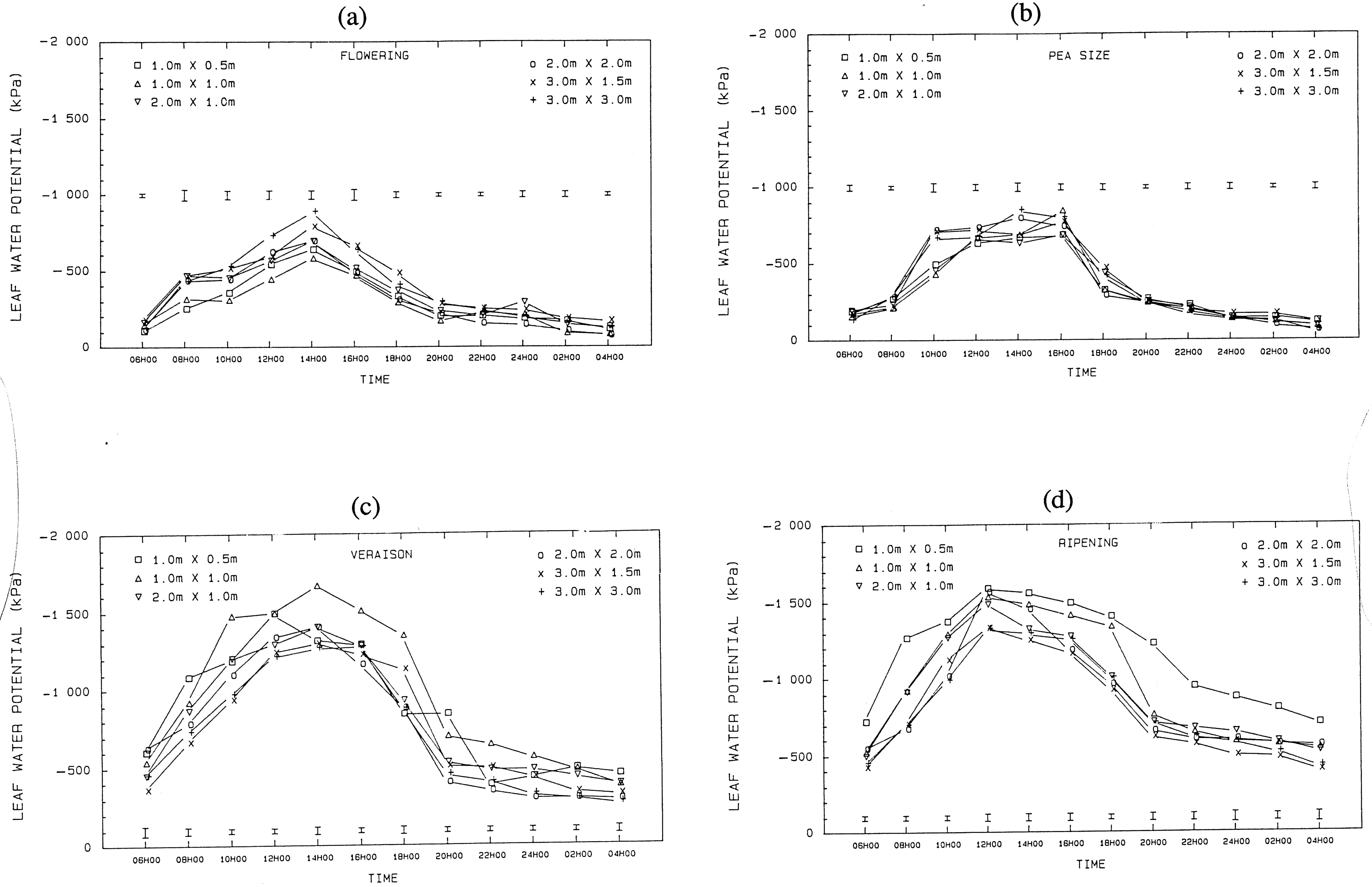

FIGURE 4
Effect of plant spacing on the diurnal leaf water potential at different phenological stages of Pinot noir/99 Richter. Nietvoorbij, 1985/86

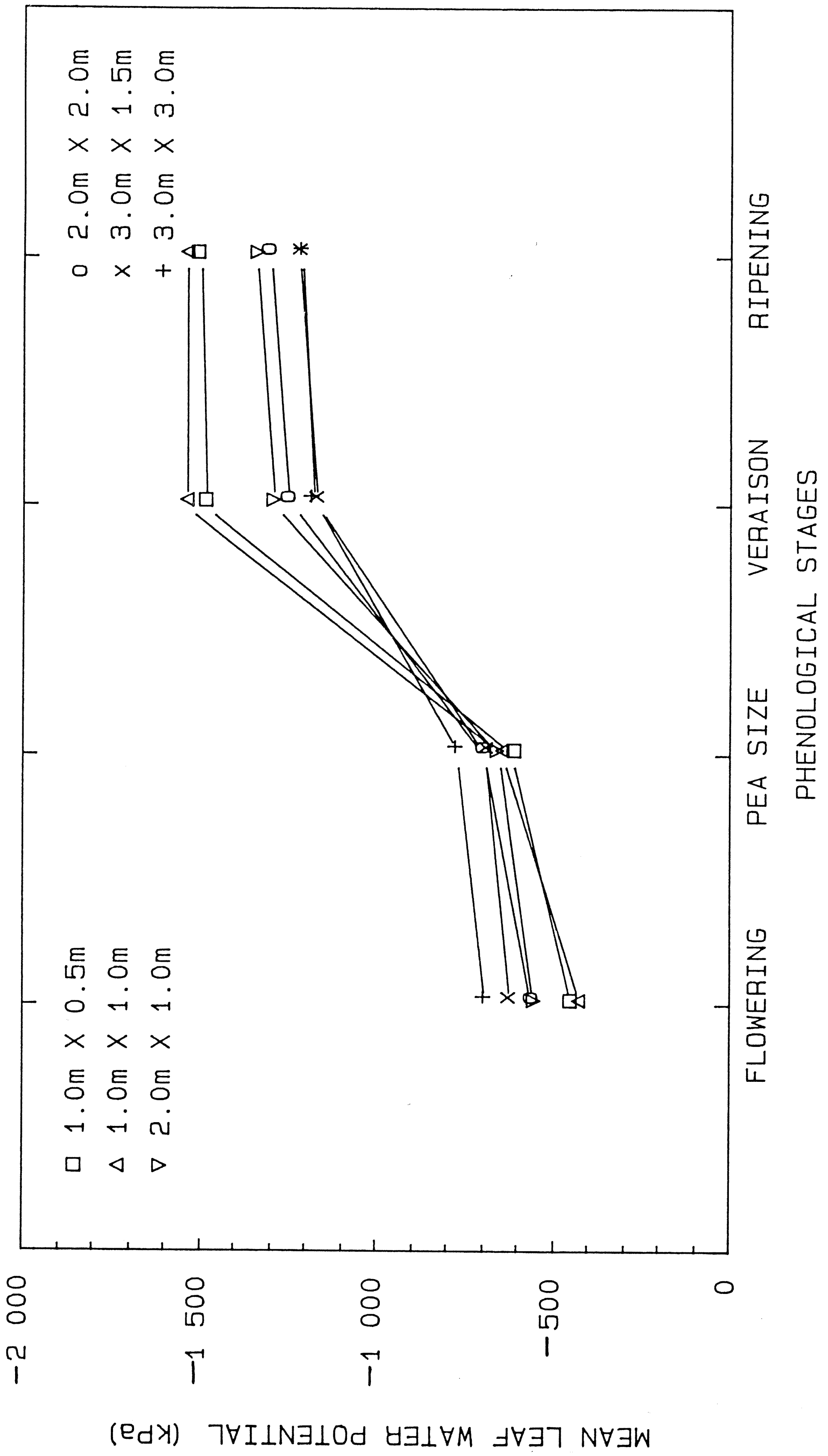

FIGURE 5
Effect of plant spacing on the mean daily leaf water potential at different phenological stages of Pinot noir/99 Richter. Nietvoorbij. 1985/86.

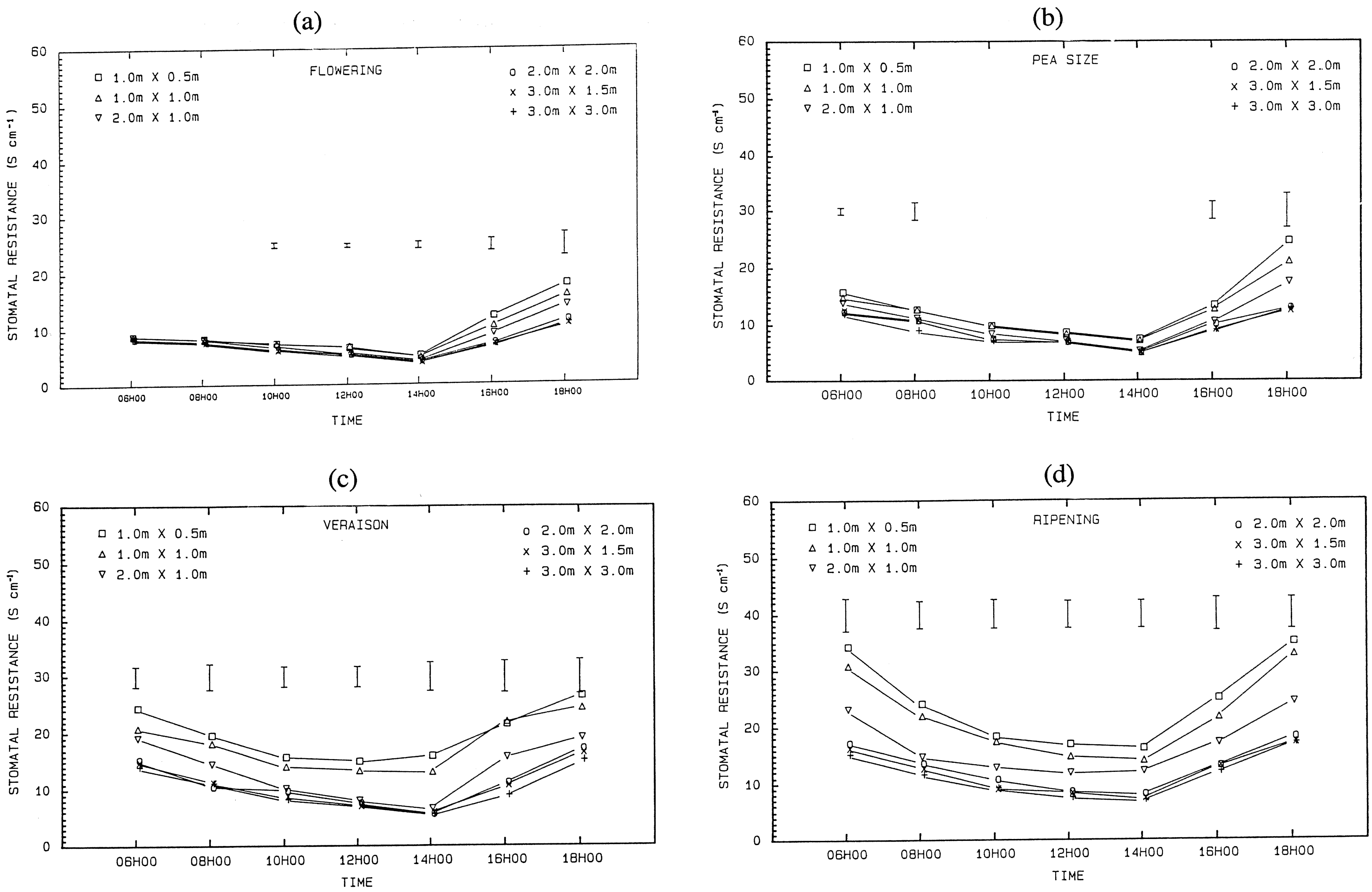

FIGURE 6

Effect of plant spacing on the diurnal stomatal resistance at different phenological stages of Pinot noir/99 Richter. Nietvoorbij, 1985/86.

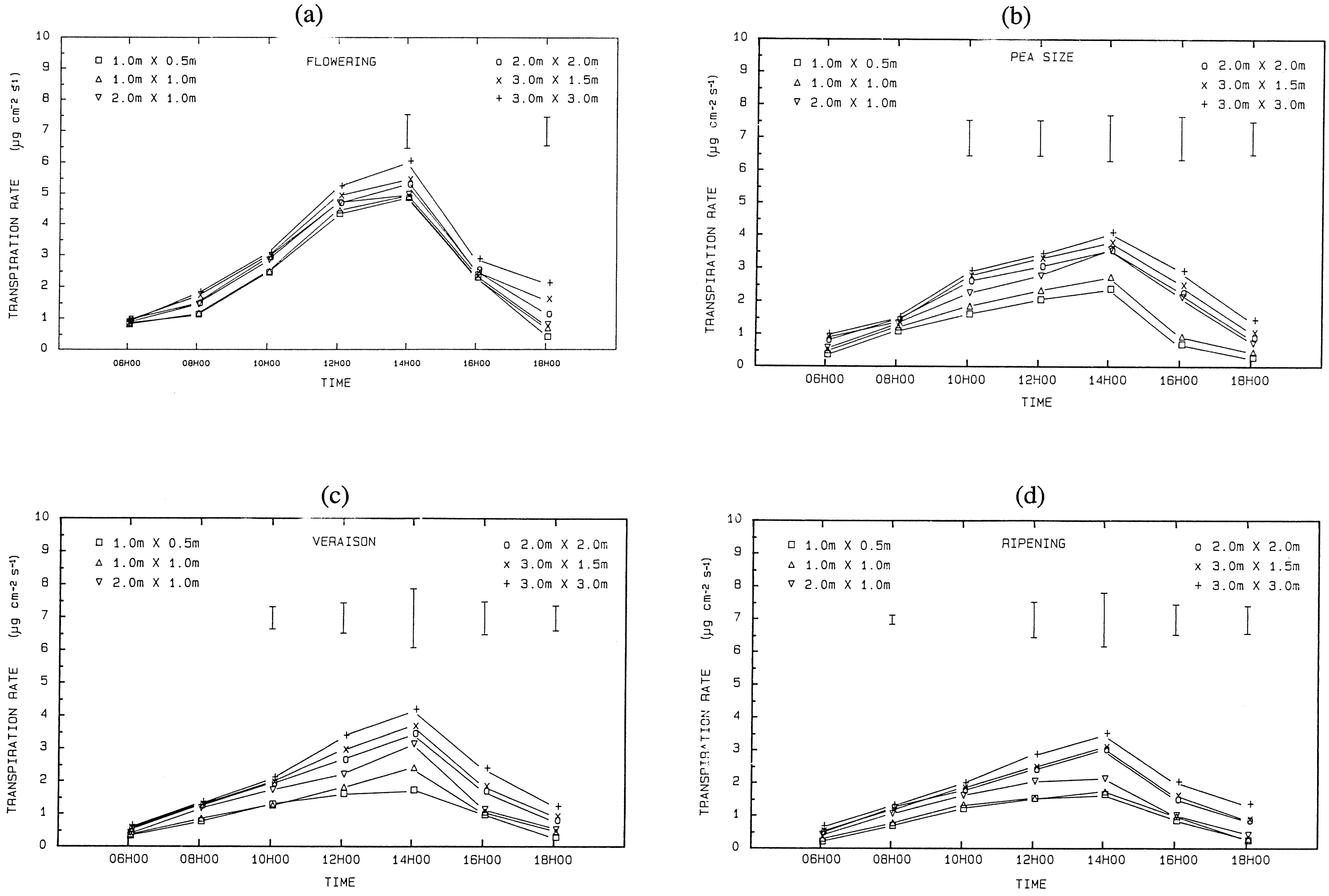

FIGURE 7
Effect of plant spacing on the diurnal transpiration rate at different phenological stages of Pinot noir/99 Richter. Nietvoorbij, 1985/86

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