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MANAGEMENT OF TRICKLE IRRIGATED ORCHARDS FOR INCREASED WATER-USE EFFICIENCY

Volume I

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ABSTRACT

Plant Responses of Drip Irrigated Trees to Climate and Water Stress.

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Past irrigation research has shown that peach (prunus persica) trees vary in their field response to water stress, and the degree of stress is a function of the plants' environment. Water deficits reduce plant growth and crop yields, therefore, measurements of plant water stress are fundamental in understanding how the environment affects plant performance. This in turn will facilitate the irrigator to have very precise water control and to determine optimum irrigation quantities.

This research examined the effect of environmental variables on leaf water potential, leaf resistance, canopy resistance and transpiration rate; and evaluated their ultimate effect on yield, water use efficiency and pruning weights for trees under four drip irrigation regimes at Stephenville, Texas. Treatments selected were instrumented with 1-, 2-, 3- and 4-emitters per tree, and single trees from each treatment were instrumented with ground covers. Plant responses were measured hourly on sunlit and shaded leaves of each treatment.

Leaf water potentials and leaf resistances were higher in shaded leaves, resulting in reduced transpiration. An increase in early morning leaf water potentials indicated irrigation had decreased stress. Lower leaf water potentials and higher leaf resistance indicated the tress were being severely stressed prior to harvest.

Leaf water potentials decreased linearly, whereas leaf resistance decreased exponentially, with increasing solar radiation. In stressed trees critical leaf water potentials were lower suggesting some degree of adaptation to stress. Leaf water potentials decreased linearly with increasing transpiration. Total resistance (sum of plant and soil resistance) increased with increasing severity of stress.

The 3-emitter tree was recommended, since yield and water use efficiency are relatively high. Proper irrigation increased total yields and also the number of fruit within a marketable size range, while maintaining high water use efficiency, resulting in economic benefits to the farmer.

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INTRODUCTION

The peach industry in Texas increased from $3,520,000 in 1975 to $6,444,000 in 1977. Peach production in Texas requires supplemental irrigation during a part of the growing season. Irrigation can increase the yield of high quality fruit by lengthening the competitive growing season in late August and early September. During this time rainfall is usually not sufficient to develop desirable fruit size, quality and yield.

Drip irrigation has proven very effective in areas with low rainfall during the irrigation season and is a highly controlled method of water application; supplying water to the root zone frequently and at very low rates. The scarcity of water, both physical and economic, makes drip irrigation advantageous for use in spaced perennial plantings such as orchards and vineyards (Lindsey and Sutemeier, 1977; Hiler, 1975; Levin et al., 1974; and Shani, 1974). One such advantage is that water can be easily applied in small quantities to individual plants without watering the entire orchard floor.

Literature citations in this thesis follows the style of the <u>Transactions</u> <u>of</u> <u>the</u> <u>ASAE</u> (American Society of Agricultural Engineers).

A properly designed drip irrigation system will replace water as it is lost by evaporation from the soil and by transpiration, so that stress conditions are avoided. An estimation or prediction of evapotranspiration is thus important in designing irrigation systems, and in determining when to irrigate and the proper quantity to apply.

Plant growth and yields are generally greater with drip irrigation, since the plants are not subjected to extreme soil wetting and drying which normally occurs using other irrigation methods. Other potential advantages of a drip system are: (i) water conservation, (ii) better weed control, (iii) use of poor quality water, (iv) simultaneous application of fertilizers through the system with water, (v) reduced labor requirements, and (vi) minimum water distribution and evaporation losses. On the other hand drip systems have some disadvantages: (i) clogging of the emitters, (ii) salt accumulation in the soil near the emitters, and (iii) possibility of water logging the root zone which can cause root diseases.

Effect of Drip Irrigation

Studies conducted on peach orchards at the Texas Agricultural Experiment Station in Montague by Reeder et al. (1976), indicated that more pounds of fruit per tree, larger fruit size, increased trunk growth and increased number of fruit buds were possible with drip irrigation. They concluded that an irrigation rate 1.5 times the calculated water loss produced significantly larger peaches. Harrison et al. (1976) stated that 2-emitters per tree or 76 l/day per tree, was the optimum rate of supplemental water required to produce quality fruit in Florida. Hendrickson and Veihmeyer (1934) found that it was important for the trees to be kept supplied with water throughout the season in order to obtain larger sizes of peaches. Kent (1979) in a study on the effects of irrigation on peach quality found irrigation was more effective in the latter stages of growth and maturation for high quality peaches.

Aljibury et al. (1974) found that drip irrigation increased yield of apples, peaches and apricots from 30 to 100 percent more than sprinkler or furrow. Menzies and Smith (1978) calculated that the cost of a trickle irrigation system could be recovered in one dry season by increasing peach fruit diameter from 5 cm to 6 cm. Drip irrigated lemon trees were taller and more densely foliated than similar trees which were flood irrigated (Davis and Pugh, 1974). Citrus trees irrigated by drip and basin methods required less water and produced more growth than limited coverage sprinkler or border irrigation methods (Levy et al., 1978). Drip irrigated olive trees had higher and earlier yields before attaining full maturity than trees under different methods of irrigation (Dau, 1974). Yield and fruit quality of grapes were increased with trickle irrigation using 2-emitters per vine compared to furrow irrigation (Bucks et al.,1974). Yield of drip irrigated citrus trees in deep sandy soils were higher than flood irrigated trees (Cole and Till, 1974).

Black and West (1976) reported water losses from trees with 25 percent of their root system in moist soil were equal to that from trees with their entire root system in moist soil. Ismail (1978) found pecans responded best when 454 l/day of water was applied and it appeared that the trees were able to perform well with only 40 percent of the soil surface over the root system being wetted. Middleton et al. (1975) reported that bearing Early Italian prune trees performed normally at 227 and 303 l/day per tree using continuous drip irrigation. However, 76 and 152 l/day per tree resulted in fruit that was smaller, better colored, matured earlier and contained a higher content of soluble solids.

Willoughby and Cockroft (1974) reported that drip irrigation influenced root distribution of peach trees that were converted from flood to drip irrigation. Roots in the dry soil and in the heavily saturated soil around the emitters died. However, the trees established new root systems in soil that was adequately supplied with water, and continued to produce heavy crops. In a study on young peach trees, Black et al. (1977) reported that 95 percent of maximum growth response occurred when irrigation rates were

2.5 and 3.5 l per cm^2 of trunk area. Mitchell and Black (1974) observed that under drip irrigation young peach trees exhibited a significant linear relationship between trunk area increase and water applied per unit of evaporation.

Bartholic et al. (1976) found most of the water removed by a peach tree was from the surface 0.61 m. Rodrigue (1980) attempted to quantify the evapotranspiration rate from a mature peach orchard. The estimated transpiration rate of the 1-emitter tree was 1.6 mm/day and that of the 2-emitter tree was 3.5 mm/day. Each emitter supplied 6.3 l/hr. Detailed moisture extraction patterns indicated that the 2-emitter tree had a more extensive root distribution than the 1-emitter tree. In a detailed study of root distribution patterns Lyons and Krezdon (1962) found 68 percent of the roots of young peach trees in Lakeland fine sand were in the top 30 cm of soil, 19.5 percent in the second 30 cm and only 12.5 percent below 60 cm. Based on these findings, over 87 percent of the root will be taken into consideration when a 60 cm root zone is used in computing moisture needs, amounts, and frequency of application.

Current Status of the Problem

The major portion of water lost by plants is through the process of transpiration. The rate of transpiration is affected by leaf area and structure, stomatal aperture and environmental conditions. Monteith (1965) indicated that a turgid leaf exposed to bright sunshine can transpire an amount of water several times its own weight during a summer day. High transpiration rates are sustained by a supply of heat from the atmosphere and by the movement of water within the plant preventing the desiccation of leaf tissue. Thus atmospheric evaporative demand determined by net radiation, vapour pressure deficit, wind speed and air temperatures is the major determinant of transpiration rate. However, high evaporative demands on plants result in stomates closing which increases stomatal resistance and consequently reduces transpiration rate.

Teare et al. (1973) demonstrated that the extent of stomatal control of transpiration rate varies among plants. They used a diffusion porometer to show that under the same atmospheric conditions, the stomata of sorghum close more than those of soybeans, even though sorghum has approximately twice the weight of roots per unit volume of soil as soybeans and more water in its soil profile than soybeans due to its reduced evapotranspiration.

Stomata are pores in the epidermis of a leaf, which normally close in darkness and open in light to allow the uptake of CO2 for photosynthesis. Water vapour diffuses outward through the stomata in the process of transpiration. When absorption of water by the roots equals the rate of transpiration, leaf cells remain turgid and stomata stay open. However, when the soil around the roots is dry, or when transpiration rate exceeds water uptake by the roots, the leaf cells lose turgidity and their stomata begin to close. This behaviour helps the plant to conserve water but restricts the supply of CO2 to the chloroplasts (Monteith et al., 1965). It has also been suggested that transpiration may vary indepndently of stomatal aperture. However, Slatyer (1966) concluded that non-stomatal mechanisms do not have a significant effect on transpiration under normal conditions. Only if severe desiccation occurs is direct control by such mechanisms possible, but under such conditions there would be complete stomatal closure.

Peach trees vary in their field response to water stress and the degree of stress is a function of the plants' environment. Measurements of plant water stress are fundamental in understanding how the environment affects plant performance. Smart and Barrs (1973) suggested that a close relationship exists between diurnal patterns of leaf water potential and environmental factors regulating transpiration. This relationship in turn would be dependent on soil water status. They also reported that little data are available on plant water status as a function of ambient environment and soil water availability.

Powell (1974) noted that the water status of plant tissue rather than the rate of transpiration from the leaves affects growth and development. Shawcroft (1971) pointed out that plant processes react to the degree of decline in water potential with the end result being an integration of all these effects on growth. Therefore when discussing the effects of water stress the distinction between effects on growth or the effects on a specific plant process must be kept in mind. Shawcroft (1971) also suggested that the gross effects of changing water supply might be evaluated by simultaneous measurement of photosynthesis, transpiration, stomatal aperture, and soil and plant water status.

Cowan and Milthorpe (1968) stated that there is a need for more measurements of the diurnal and spatial variation of stomatal diffusion resistance. Quantitative measurements of this plant parameter would aid in developing more realistic models involving the microclimate of the crop.

Hiler et al. (1971) showed that irrigation water can be utilized more efficiently if plant water stress criteria are available as the basis for evaluating the need for irrigation. Since drip irrigation provides for very precise water control, a definite need exists to be able to calculate water requirements with greater precision. Hiler et al. (1972) stated that plant water deficit can be characterized directly by measuring leaf water potential, however, the levels of leaf water potential limiting plant growth are not generally known and must be determined for each species or crop. Rodrigue et al. (1980), and Chalmers and Wilson (1978) have pointed out the need to develop stress criteria for peach trees in order to determine optimum irrigation quantities. Ideally the plant should signal when to irrigate and the soil should indicate how much water to apply.

Objectives

Little research has been done on the effect of climate and water stress on leaf water potential (wl) and leaf resistance (rl) of drip irrigated peach trees, and no attempts to relate changes in wl and rl to transpiration rate by concurrent measurements of the above-mentioned factors have been made. There have been relatively few integrated field studies of stomatal aperture and its modulation by the environment (Jarvis, 1976; Hinckley et al., 1975). Due to non-linear responses of stomata to environmental factors, it has been difficult to develop precise relationships in the field between rl and the environmental factors that influence it. However, reliable prediction of rl is essential if accurate predictions of plant water uptake, evapotranspiration and photosynthesis by simulation models are to be made:

The objectives of this study were:

1. To determine the effect of solar radiation, air temperature, and vapour pressure deficit on the leaf water potential and leaf resistance for peach trees under four irrigation regimes.
2. To determine the effect of soil water deficit on the diurnal trends of leaf transpiration, leaf water potential and leaf resistance, and to examine the effect on transpiration rate of changing leaf resistance and leaf water potential.
3. To use a simplified model of water flow in plants to determine the internal plant resistance from the relationship between leaf water potential and leaf transpiration.
4. To determine canopy resistance and evapotranspiration, and to evaluate the yield and water use efficiency of peach trees under four drip irrigation regimes.

MATERIALS AND METHODS

Site Description and Treatments

This research was conducted on an experimental drip irrigated peach (prunus persica) orchard of the Texas A&M Agricultural Experiment Station at Stephenville, Texas, during the growing season of 1981. The orchard consists of 9-year-old trees in rows 400 m long, oriented east-west. In the transverse direction the orchard is about 300 m long. The trees are spaced 7.62 m by 7.62 m (25 ft by 25 ft). The trees were pruned to 2.4 m (8 ft.) in late fall, 1980.

Four test plots were installed in the orchard during July of the previous year. Each plot consisted of four trees. Single trees from each plot were selected adjacent to one another, and evaporation losses and rainfall gains at the soil surface were eliminated with a rubber ground cover extending to a distance of about 1.25 times the canopy radii. The ground cover in turn was covered with the surrounding soil to avoid drastically changing the energy balance.

Four treatments were selected and implemented on July 9, 1980. Each treatment was instrumented with 1-, 2-, 3-, and 4-emitters per tree, respectively. The field layout is shown in Figure 1. Controlled scheduling of trickle emitters beneath the plastic ground cover applied water at 1/4, 1/2, 3/4, and 4/4 of the calculated pan evaporation rate to the 1-, 2-, 3-, and 4-emitter trees, respecively. The pan evaporation rate was calculated using a crop coefficient of 0.7 multiplied by the daily pan evaporation. An additional plot of four trees with 0-emitters was also established, these were not instrumented with ground covers.

Daily evaporation (Epan) from a free water surface was recorded from a standard U.S.W.B. Class A Pan. Pan evaporation recorded for the previous day was used to determine the amount of water to be applied to the trees. The length of time the system remained in operation depended on the value of Epan measured. The total amount of irrigation water applied to the trees was determined by the following method.

$$Q = Fc.Kc.Ac.Epan \qquad \ldots\ldots\ldots\ldots\ldots[22]$$

where: Q = volume of irrigation water (l/day)

Fc = fraction of water to be applied (1/4, 1/2, 3/4, or 4/4) (dimensionless)

kc = crop coefficient (0.7) (dimensionless)

Ac = area covered by canopy (m^2)

Epan = pan evaporation (mm/day)

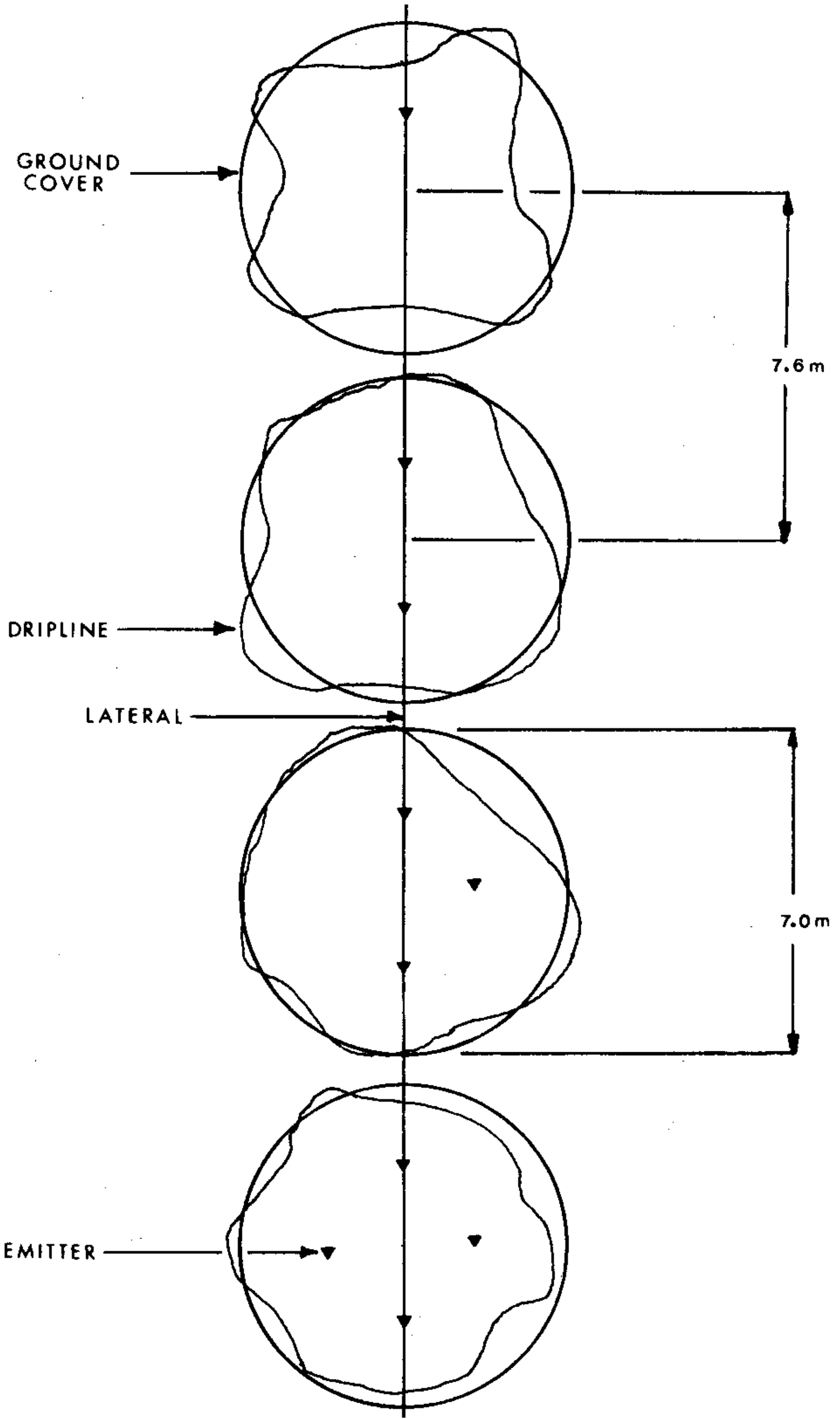

Figure 1: Field layout of treated trees showing ground covers, dripline, and number of emitters.

All test plots were installed and treatments implemented a full year before the actual study was begun in order to give the trees sufficient time to adjust to the treatment. With no additional moisture gains or losses, changes in soil moisture storage were determined by the transpiration rate of the peach trees.

Irrigation lateral lines were 13 mm (0.5 in) polyethylene. Emitters were approximately 1.25 m (4.1 ft) from the base of the tree on one, two , three, or four sides depending upon the number specified per tree.

The soil profile consists of a sand layer on the surface approximately 25 cm thick, below the sand layer the profile consists of clay with an almost impermeable layer at 150 cm depth.

Climatological Measurements

Weather data were collected at a site located approximately 300 m from the orchard area.

All of the meteorological instruments were mounted on a CM-10* tripod (Campbell Scientific Inc.). The tripod was an all-purpose instrument mount, and was used for mounting the

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* Trade names are used in this publication solely for the purpose of providing specific information. Mention of a trade name does not constitute a guarantee or warranty of the product by the Texas A&M University System or an endorsement by the University over other products not mentioned.

wind sensor, temperature and dewpoint sensors, and pyranometer.

A silicon pyranometer (LI-200S, LICOR, Inc.) was used for measuring solar radiation received from a whole hemisphere. The LI-200S pyranometer sensor consists of a silicon detector mounted in a fully cosine corrected miniature head.

Solar radiation varies significantly from region to region. Factors that can cause variations in the pyranometer output are season, time of day, atmospheric conditions, surrounding terrain elevation, man-made obstructions, and surrounding trees. For these reasons the pyranometer sensor was mounted with a mounting and leveling fixture on level surface free from any obstructions to either diffuse or direct radiation at a height of 3.5 m above the soil surface. The LI-200S measured global sun plus sky radiation, which is the energy flux density of both direct beam and diffuse sky radiation passing through a horizontal plane of known unit area. The sensor was cleaned periodically to maintain accuracy of calibration and to maintain appropriate cosine correction.

The windspeed sensor was mounted at a height of 3.5 m above the soil surface. The windspeed sensor was a three cup totalizing anemometer.

The temperature and relative humidity probe with temperature compensation was mounted in a sensor shield at 1.5 m above the soil surface.

A Sierra tipping bucket raingauge was used to measure rainfall. The tipping bucket mechanism activated a sealed mercury switch that produced a contact closure for each millimeter of rainfall.

The micrometeorological data were recorded on a CR-21 micrologger which is a miniature battery-operated computing data recorder for environmental applications. The inputs were scanned at 15 minutes intervals and outputted on a portable printer and a cassette recorder.

Plant Response Measurement

Leaf Water Potential Measurement

A pressure bomb (Scholander, 1965) was used to measure leaf water potentials (wl), bars. This technique provided the optimum combination of accuracy and practicality for measuring water potentials in the field.

Two sunlit and two shaded leaves from each of the four monitered trees were removed for measurement. Measurements on each of the monitered trees were made hourly from 7 a.m. to 8 p.m., and were taken for two days each week from 18 June until after the tree had been harvested. Only two of the four treatments were selected for measurement each day;

this was done in order to have a manageable proportion of measurements.

Sunlit and shaded leaves were selected because they provided an adequate representation of leaf water stress variability for each tree. Each hourly reading of each tree represented the average of two measurements. Leaves were taken from foliage exposed to direct sunlight, necessitating sampling around the trees to counter variation in solar altitude and azimuth. The shaded leaves were selected from well inside the canopy.

Small plastic bags were placed on the leaves to be measured while they were still on the tree. The leaves were then cut off and transferred to the pressure chamber as rapidly as possible. The measurement was performed by placing the leaf in the chamber with the petiole protruding out the top. A rubber packing gland was tightened around the stem to seal the leaf in the chamber. After securing the lid pressurized nitrogen with a maximum pressure of 34 bars (500 psi) was applied to the chamber at a rate of approximately 0.68 bar s^{-1} (10 psi s^{-1}) until tree sap exuded from the xylem tissue at the cut surface of the petiole. The balancing pressure at which the crescent of the xylem first appeared wet was taken to represent the negative hydrostatic pressure which existed in the plant just before it was cut. Boyer (1967) stated that the pressure bomb method measures the hydrostatic water potential and does not include the osmotic potential which is usually very small.

Boyer (1967), Waring and Cleary (1967), De Roo(1969), have evaluated this method with more elaborate techniques and have found very favorable agreement. They further state that it is the best and most convenient field method available for use today. Previous work by several authors Punthakey et al.(1981), Goode and Higgs (1973), Chalmers and Wilson (1978) showed that differences could be observed in the pressure required to produce free liquid at ends of petiole xylem tissue of leaves of water stressed trees. Smart and Barrs (1973), have demonstrated that differences do exist in the diurnal pattern of wl of four horticultural species, and that there were differences in the minimum wl of each species.

On partly cloudy days it was important to take readings only after a tree has been exposed to direct sunlight for several minutes. If, however, a cloud cover was present during the time when the readings were taken, then all such readings were taken to include the effects of the cloud cover (Smart and Bars, 1973; Ryan et al., 1976). To minimize variability due to physiological characteristics and age, only young mature leaves were selected and the criterion established earlier was to choose sunlit and shaded leaves. It was determined that two leaves per tree for each measurement were the minimum number that would yield reliable results.

Leaf Resistance and Transpiration Measurement

A LI-1600 steady state porometer manufactured by LICOR, INC., Lincoln, Nebraska, was used to measure leaf resistance and transpiration rate of the lower surface of the peach leaves. The LI-1600 gives precise measurements of water loss and diffusive resistance. It consists of two parts, the readout-control console, and the sensor head. An open broad leaf aperture clamp was used, since it is effective in eliminating greenhouse effect during high ambient temperature within 3.5 °C (LICOR, 1980).

The empirical measurment of the mass flow rate of water vapour entering the cuvette from all sources (Mwi) is used to determine the transpiration rate by the following relationship:

$$Tr = Mwi/A \qquad \text{...............[23]}$$

where: Tr = transpiration rate ($ug.cm^{-2}.s^{-1}$)

Mwi = massflow rate of water vapour entering the cuvette from all sources ($ug.s^{-1}$)

A = aperture area of the aperture cap (cm^2)

The LI-1600 will determine stomatal resistance based on the relationship between the mass flow rate and the physiological definition of stomatal resistance.

$$rl = (el - RHc\ ecv)/Tr - rbo \qquad [24]$$

where: el = saturation water vapour density at leaf temperature ($ug.cm^{-3}$)

ecv = saturation water vapour density at cuvette temperature ($ug.cm^{-3}$)

RHc = relative humidity of cuvette (dimensionless)

rbo = boundary layer resistance ($s.cm^{-1}$)

In the above equation it is assumed that the diffusive force caused by a vapour density gradient is the only driving force of the measured transpiration rate. A further assumption is that the internal leaf humidity is 100 percent. However this may not be the case, depending on the water potential of the leaf.

Leaf resistance and transpiration rates are calculated under ambient conditions from measurements of leaf temperature, cuvette temperature and relative humidity, and dry air flow rate. The LI-1600 using the steady state technique has distinct advantages over other diffusion porometers. First, a wide range of diffusive resistance can be measured; this is generally not possible with transient techniques. Second, diffusive resistance and transpiration are determined from primary measurements (RH, temperature, air flow), therefore, calibration curves are not needed. Third, humidity measurements are precise, and boundary layer resistance is low.

There are many factors affecting stomatal resistance such as, light level, carbon dioxide level, relative humidity, ambient temperature, leaf temperature, windspeed, and leaf water potential (Rashke, 1975). Any instrument used to measure stomatal resistance should attempt not to disturb the environment of the leaf. The LI-1600 has been designed to minimize disturbing the light level, relative humidity, ambient temperature, and leaf temperature. Preventing alteration of the wind environment (boundary layer resistance) is not practical, and a value of 0.15 $s.cm^{-1}$ is subtracted from the measurement of leaf resistance. The CO2 level is also affected, thus it is recommended that stomatal resistance measurements be made within a period of 30 to 60 seconds before it changes due to the changed environment (LICOR, 1980).

Leaf temperature is measured by a 0.051 mm (0.002 in) diameter chromel-constantan thermocouple. The reference junction is maintained at the cuvette temperature. The temperature of the thermocouple bead in contact with the leaf is displayed. The range of temperature measured is from 0 to 63.7 °C and cannot exceed +/- 12.8°C from the value of the cuvette temperature (LICOR, 1980).

Relative humidity inside the cuvette is displayed, and should be kept between 20 percent and 80 percent. Outside these limits, the error in resistance measurements can be very high (LICOR, 1980).

The LI-1600 was used to make hourly measurements of transpiration, leaf resistance, and leaf temperature, of sunlit and shaded leaves on each of the four treated trees. Hourly measurements were made from 7 a.m. to 8 p.m. for two days each week from 18 June until after the trees had been harvested. Only two of the four treated trees were selected for measurement each day, this was done in order to have a manageable proportion of measurements.

Measurements on sunlit and shaded leaves provide an adequate representation of leaf water stress variability for each tree, and can be used with concurrent measurements of leaf water potential of sunlit and shaded leaves.

Procedure

Evapotranspiration Determination

Potential evapotranspiration (Eo) was calculated with the combination equation developed by van Bavel and Hillel (1976). Weather data such as windspeed, solar radiation, net radiation, air temperature, and absolute humidity were utilized. Potential evapotranspiration was calculated in the standard manner by setting the canopy resistance (rc), to zero. Potential evapotranspiration was determined for one-hour periods, and also on a daily basis.

Actual evapotranspiration (Ea) was computed by including a value for rc in the combination equation. This method is well documented by Szeicz et al. (1969), Van Bavel (1967), van Bavel et al. (1967), and Monteith (1965). Canopy Resistance was computed by three different methods and results from each method compared. The first method is empirical and relates rc to leaf resistance (rl) and the leaf area index (LAI) (Szeicz et al., 1973; Szeicz and Long (1969). The second method is a modification of the energy balance method, and rc was determined from the ratio of Eo and Ea (Szeicz and Long, 1969). The third method is the residual method and uses the relationship between transpiration, vapour pressure deficit and aerodynamic resistance to determine rc, (Szeicz and Long, 1969; van Bavel and Ehrler, 1968; and Aston, 1963).

Graphical and linear regression analysis was used to compare measured and calculated values of transpiration and leaf temperatures.

Evaluating Plant Responses

The data collected were analyzed to examine the effect of climate and water stress on the wl, rl and transpiration rate of the leaves. Waller-Duncan K-Ratio t test were performed on wl, rl and Tr to evaluate the effect of each treatment. Relationships between wl and Rs, rl and Rs, wl and rl, and wl and Tr were also evaluated for each treatment. Total resistances were obtained from the slope of wl vs. Tr for each treatment.

Yield Determination

Yields of each of the four irrigated treatments along with the amount of water applied to each treatment was used to determine water use efficiency. Yields of the non-irrigated treatment was also evaluated. Water use efficiency is the yield produced per unit depth of applied water, and gives an indication of how well a plant produces a yield for a certain amount of availabe water or applied water. Yields within a marketable size range were evaluated to determine the effect each treatment had on yield. Pruning weights of all treatments were evaluated to determine the effect of ground covers on vegetative growth.

RESULTS AND DISCUSSION

Effects of Diurnal Changes in Plant Responses

Diurnal changes in leaf water potential (wl), leaf resistance (rl), transpiration rate (Tr), and leaf temperature (Tl) are plotted in Figures 2 through 13 along with selected environmental variables. Only days that showed pronounced changes during the irrigation season were selected.

Before Irrigation

Measurements on 19 and 20 June are plotted in Figures 2, 3 and 4. These measurements were taken before the trees were placed on selected treatments, and represent the condition of the trees before the start of the irrigation season.

Leaf water potentials of exposed leaves indicated that each of the four selected trees followed a similar diurnal path. There was little difference between wl of the trees at any given time of day. Leaf water potentials of shaded leaves also followed a similar diurnal path. However, wl values for shaded leaves were higher (under less stress) than those of exposed leaves. Leaf water potentials of both

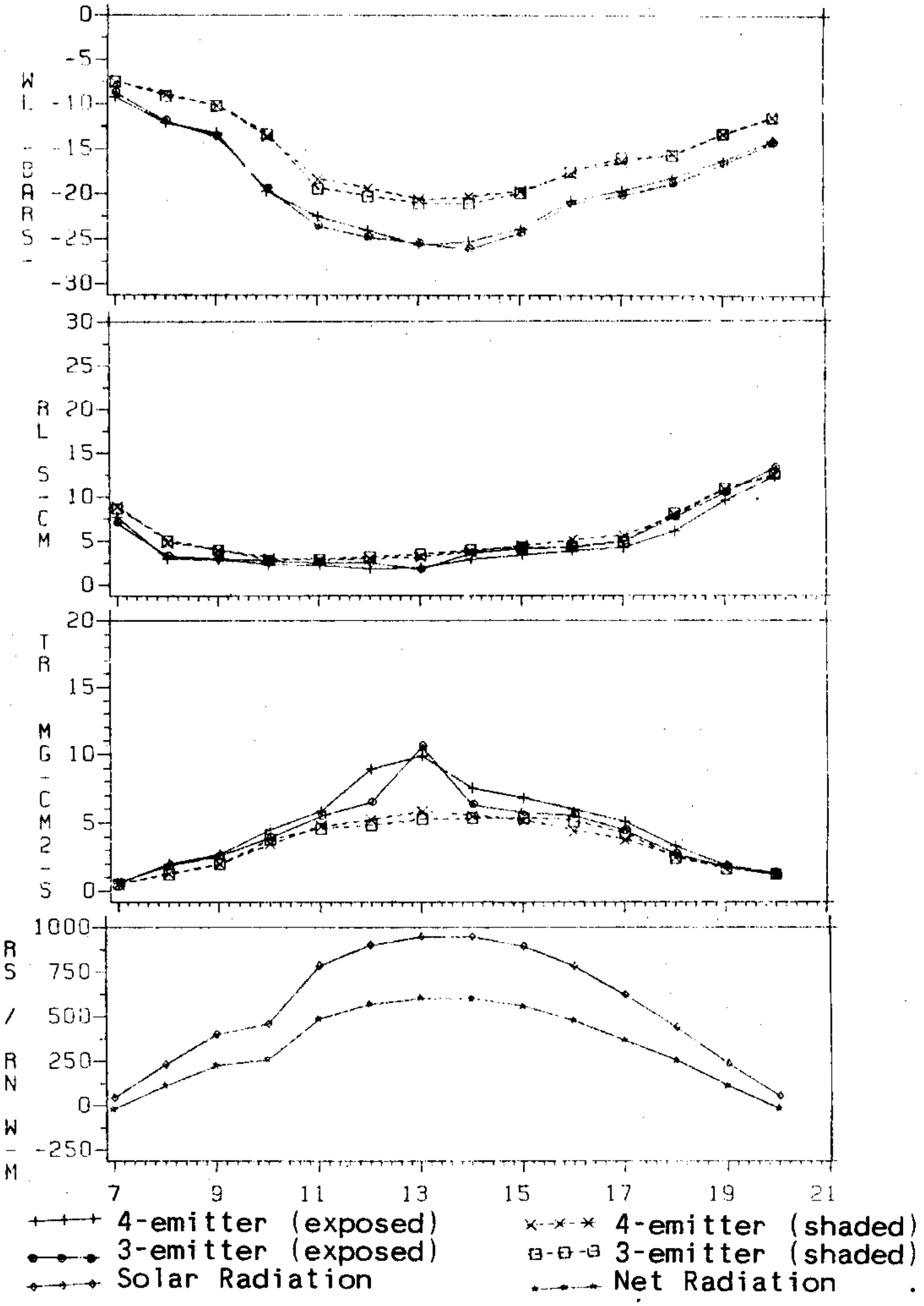

Figure 2: Diurnal Trends in Plant Responses and Selected Environmental Variables for the 4- and 3-emitter Trees on Day 170 Before Irrigation Treatment.

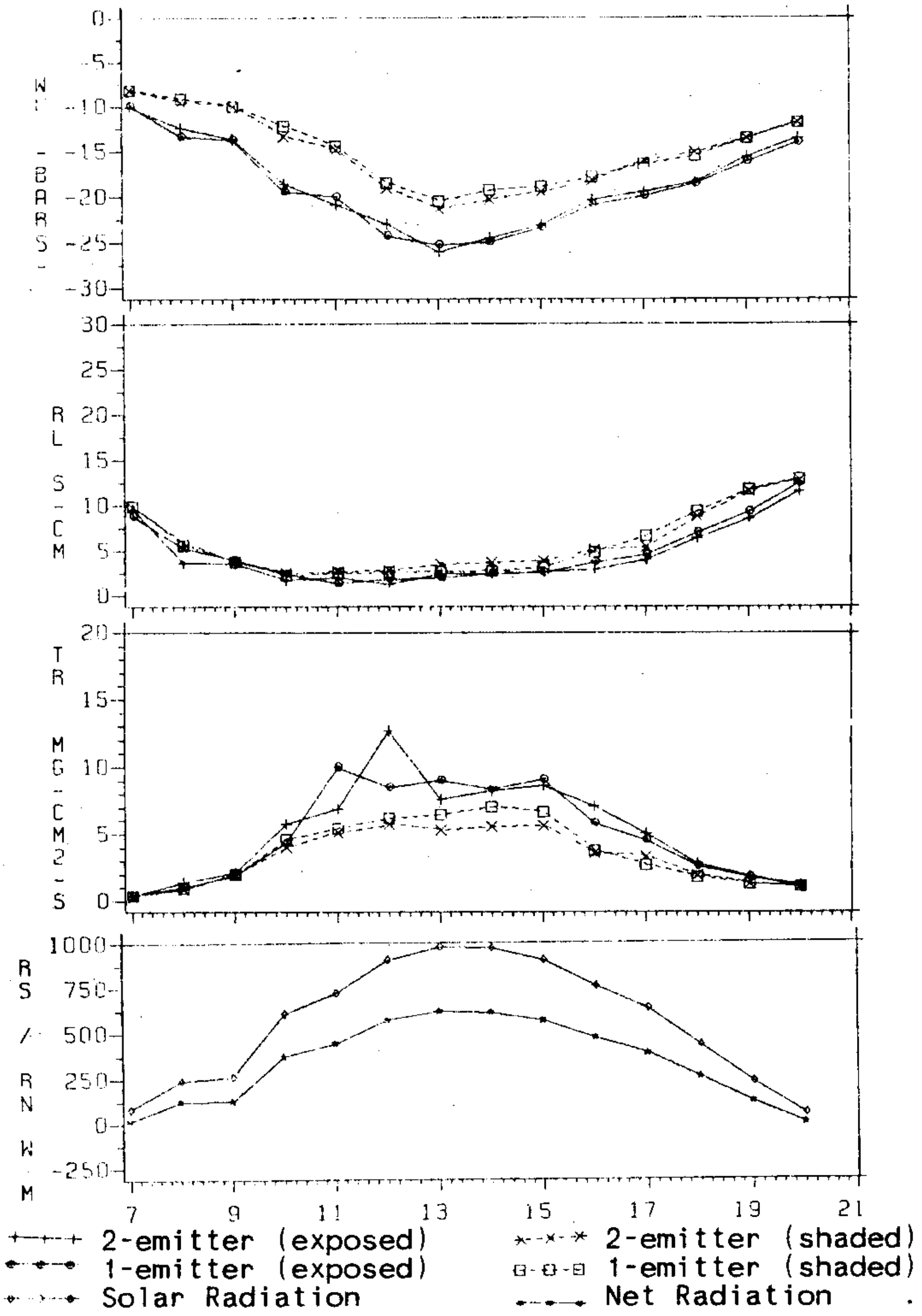

Figure 3: Diurnal Trends in Plant Responses and Selected Environmental Variables for 2- and 1-emitter Trees on Day 171 Before Irrigation Treatment.

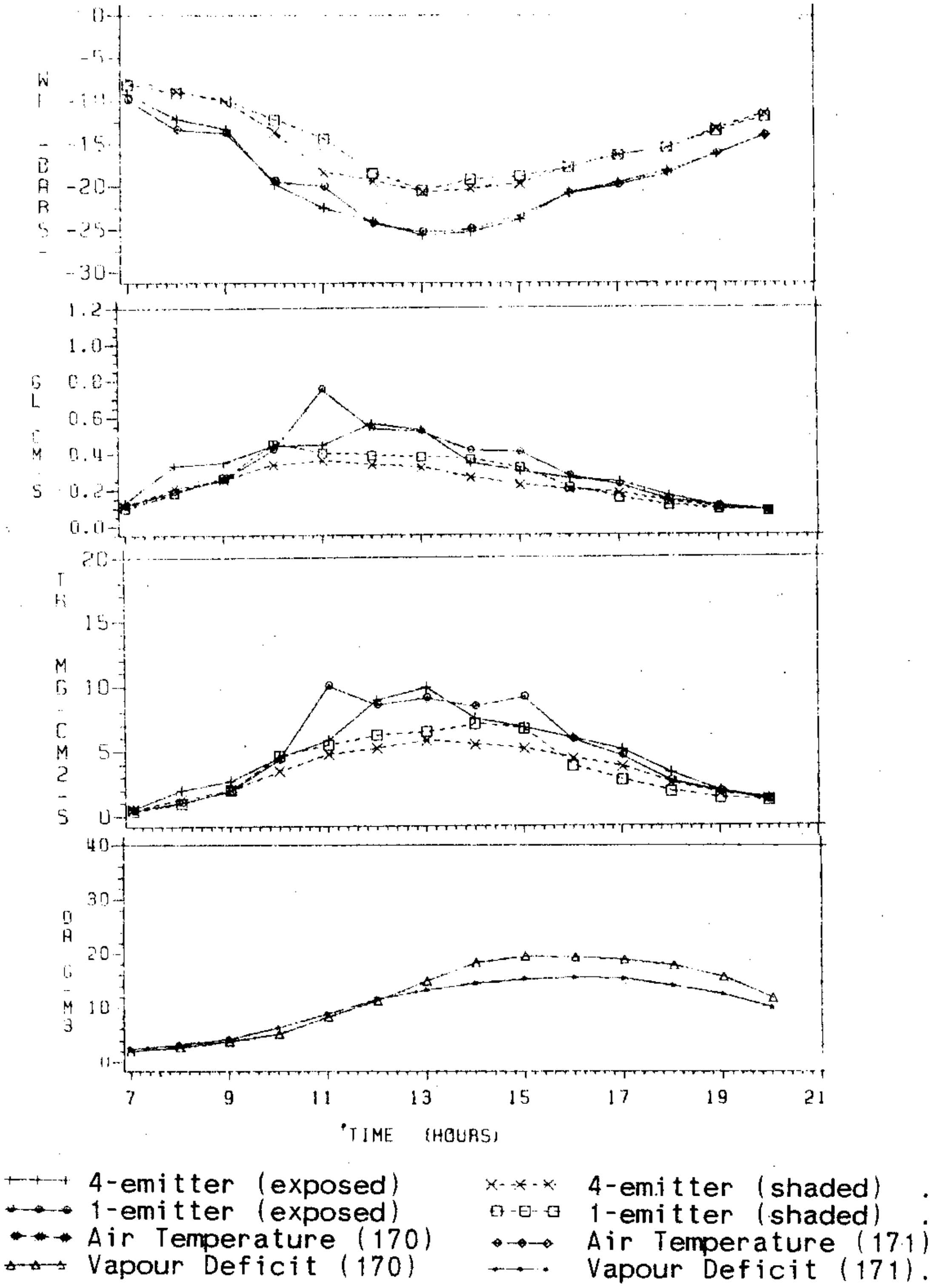

Figure 4: Diurnal Trends in Plant Responses and Selected Environmental Variables for the 4- and 1-emitter trees on Day 170 and 171 Before Irrigation Treatment.

exposed and shaded leaves exhibited a pronounced diurnal cycle. As the energy load on the trees increased around 0900 hours, the wl dropped. At local solar noon the wl of all leaves were generally the minimum value measured. After local solar noon wl for all trees increased slowly at first and later more rapidly as the energy demand on the trees decreased.

Leaf resistance of all trees followed similar diurnal trends. Rapid decrease in rl occurred between 0700 and 0800 hours, and after 1700 hours a rapid increase occurred in rl. Between 0800 and 1700 hours there was little change in rl for all trees. The shaded leaves exhibited slightly higher values of rl during the course of the day as compared to rl of exposed leaves.

Leaf water potentials measured at 2000 hours had not fully recovered to their morning value, indicating a lag time during the recovery period. Concurrent measurements of rl indicated considerably higher values at 2000 hours than at 0700 hours. Higher values of rl should result in higher values of wl, however, this does not occur at 2000 hours. This effect cannot be attributed to radiation since the energy load decreases at a rapid rate after local solar noon and has about the same values at 0700 and 2000 hours. Leaf and air temperatures are much higher at 2000 hours than at 0700 hours. The leaf and air temperatures reach a maximum about 1600 hours, therefore by 2000 hours they have not decreased sufficiently and are about 9 °C higher than at 0700 hours. Relative humidity is considerably lower at 2000 hours than at 0700 hours. Thus high temperatures and low relative humidity at 2000 hours cause the vapour pressure deficit to be much higher at that time. The combined effects of high temperatures and vapour deficits cause wl to be lower at 2000 than at 0700 hours.

Comparison of 4- and 1-emitter trees are presented in Figure 4. Plots of diurnal trends in leaf conductance (gl) indicate a pronounced difference between exposed and shaded leaves. Leaf conductance of exposed leaves was higher and showed more variation during the course of the day. The shaded leaves of the 1-emitter tree had a higher gl between 0900 and 1600 hours as compared to the shaded leaves of the 4-emitter tree.

Changes in gl are proportional to changes in Tr. Peaks in Tr occurred at 1300 hours for the 4- and 3-emitter tree, whereas peaks in gl occurred at 1200 hours for the 4-emitter tree and 1300 hours for the 3-emitter tree. Peak Tr rates for the 2- and 1- emitter trees occurred earlier in the day at 1100 and 1200 hours respectively. Transpiration of the shaded leaves were lower throughout most of the day as compared to Tr rates of exposed leaves. Values of Tr for exposed and shaded leaves were low at 0700 and 2000 hours.

After Irrigation

Measurements on 4 and 5 July are plotted in Figure 5, 6, and 7. These measurements were taken ten days after the trees had been placed on selected drip irrigation treatments.

Leaf water potentials measured on exposed leaves of the 4 and 3-emitter trees followed a similar diurnal path with shaded leaves having wl values that were being consistently higher during the day. The increase in wl can be attributed in part to lowered radiation for 4 July. The sharp increase in wl of both 4- and 3-emitter trees at 1200 hours is due to the sharp decrease in incoming radiation due to cloud cover. The effect on wl values for exposed leaves is far more pronounced than for the shaded leaves where the curve tends to level off. This result is expected since a decrease in radiation for a short time would not be expected to produce any significant effect on a fully shaded leaf.

Figure 6 illustrates the diurnal variation of wl for the 2- and 1-emitter trees. Both exposed and shaded leaves of the 1-emitter tree have lower wl throughout the day than the 2-emitter tree. The 1-emitter tree indicated lower wl for both exposed and shaded leaves.

Comparisons of wl for the 4- and 1-emitter trees in Figure 7 indicated that the shaded leaves of the 1-emitter tree wl decreased below that of the exposed leaves of the

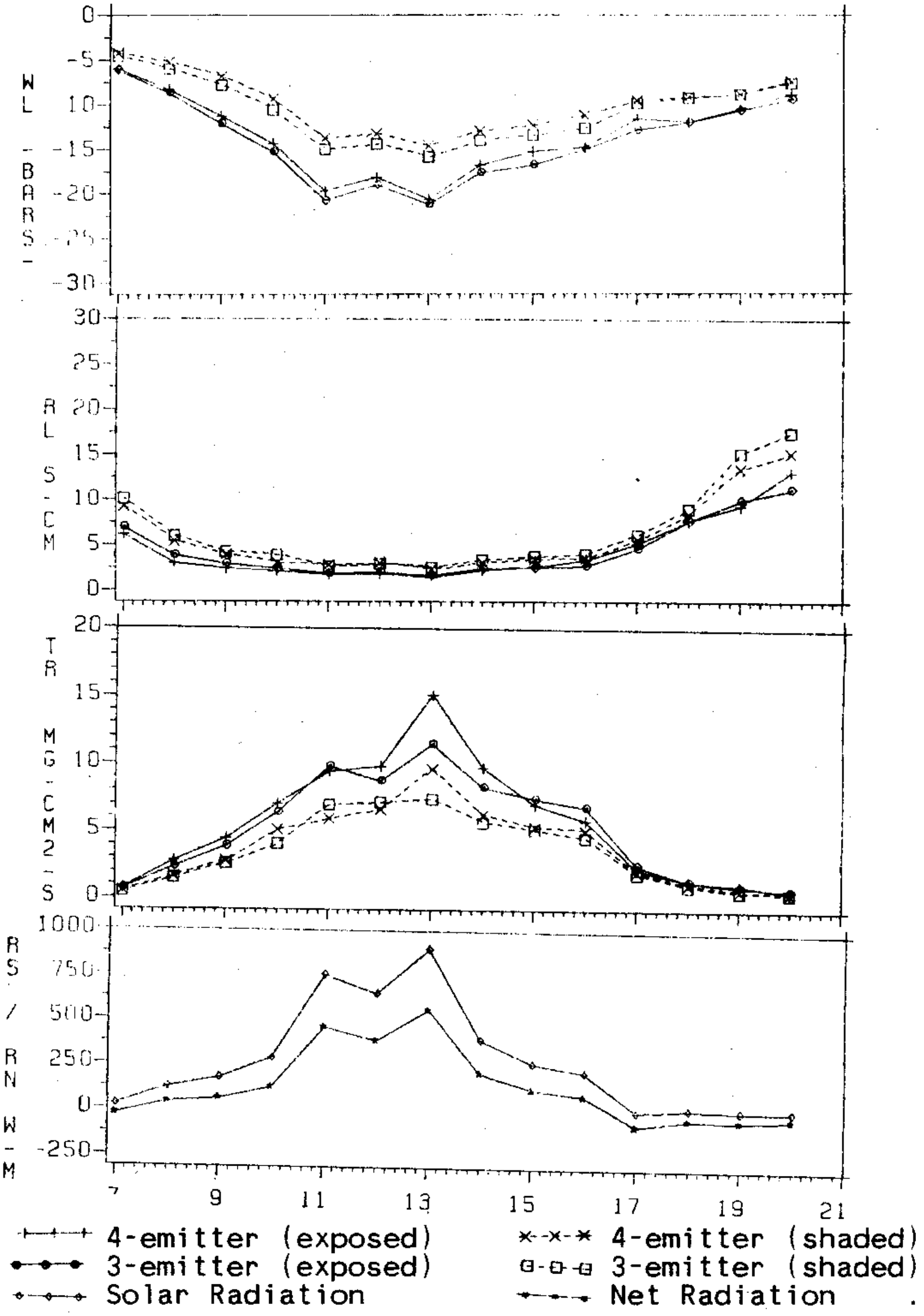

Figure 5: Diurnal Trends in Plant Responses and Selected Environmental Variables for 4- and 3-emitter Trees on Day 185 After Irrigation Treatment.

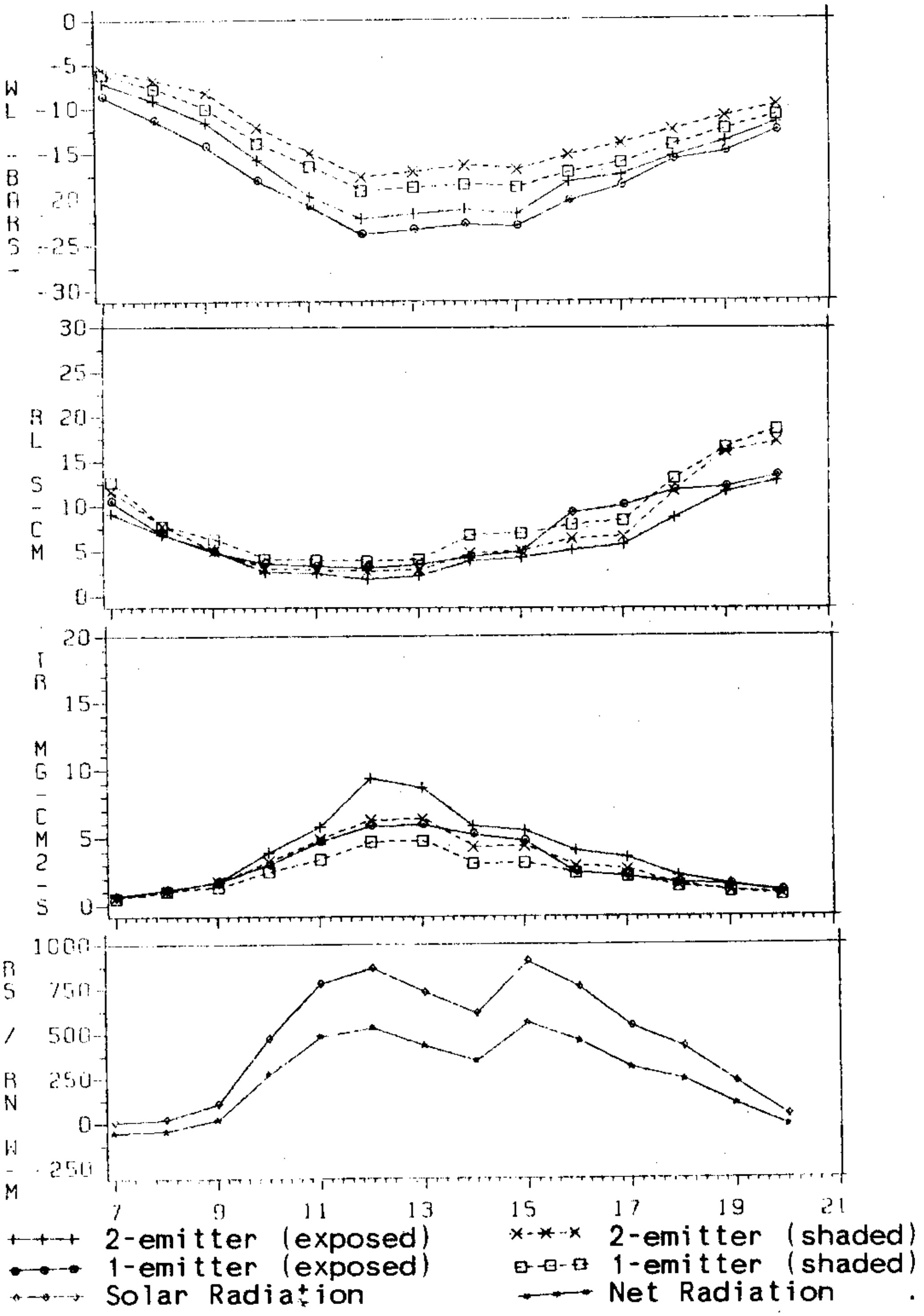

Figure 6: Diurnal Trends in Plant Responses and Selected Environmental Variables for the 2- and 1-emitter Trees on Day 186 After Irrigation Treatment.

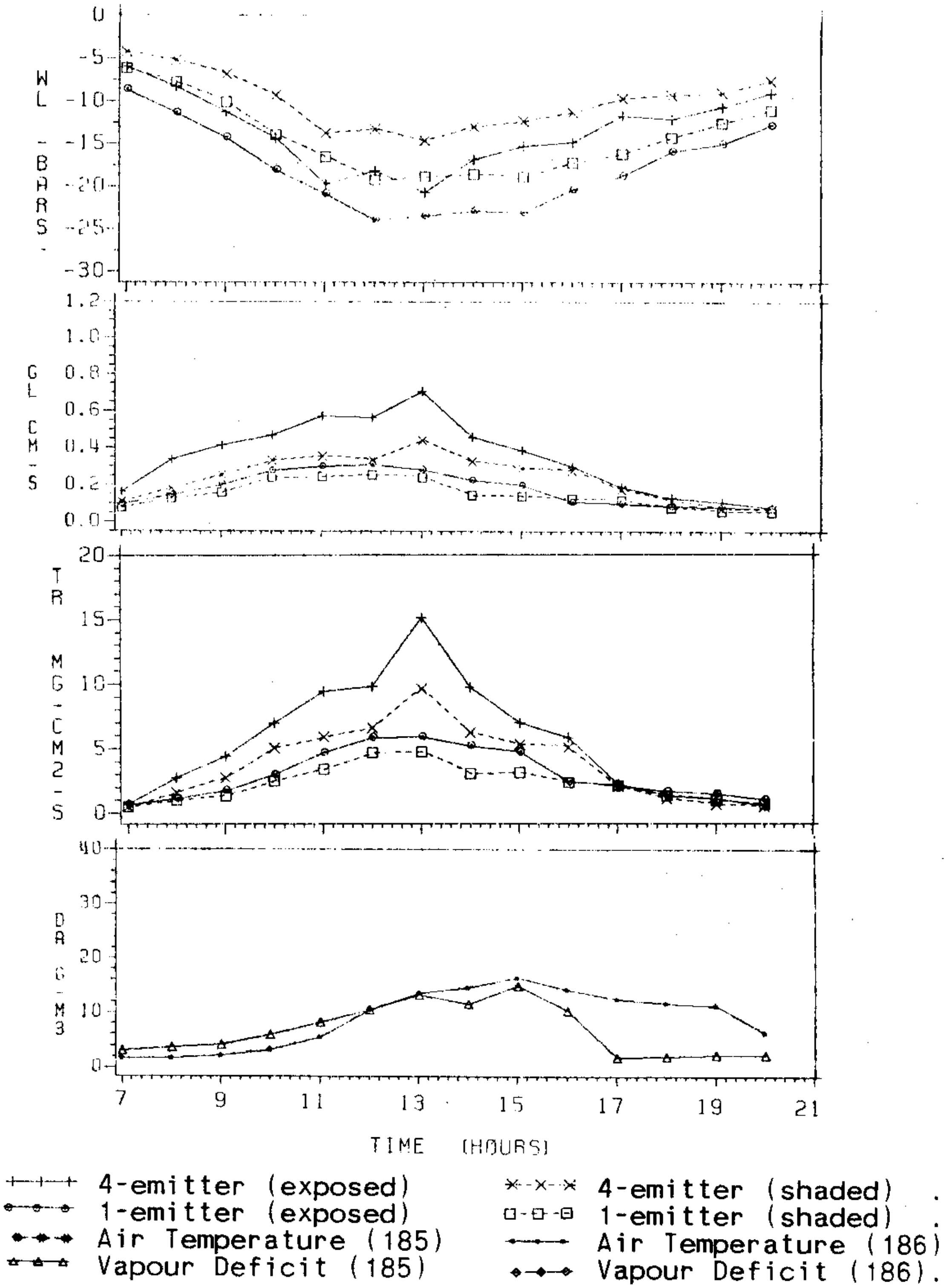

Figure 7: Diurnal Trends in Plant Responses and Selected Environmental Variables for 4- and 1-emitter Trees on Day 185 and 186 After Irrigation Treatment.

4-emitter tree. This indicated that the 1-emitter tree was under considerable stress and remained that way beyond 1300 hours. An increase of 3 to 4 bars in early morning wl measured at 0700 hours indicated that irrigation had decreased stress in the 4-emitter tree. The 1-emitter tree which was being irrigated at one-quarter the rate of the 4-emitter tree, had lower wl indicating it had not fully recovered by 0700 hours and that it was under greater stress than the 4-emitter tree.

Figure 5 showed rapid decrease in rl occurred between 0700 and 0800 hours for the 4- and 3-emitter trees and began to increase after 1700 hours. Leaf resistance of the shaded leaves for the 4- and 3-emitter trees were considerably higher before 0900 and after 1800 hours. Figure 6 shows rl of the 2- and 1-emitter tree decreased rapidly up to 1000 hours and began increasing after 1700 hours. This would indicate that stomata are responding slowly in the 2- and 1-emitter trees.

Comparisons of rl for the 4- and 1-emitter trees in Figure 7 indicate that rl of exposed leaves of the 1-emitter tree was higher than the shaded leaves of the 4-emitter tree throughout most of the day. Only after 1800 hours does rl of shaded leaves of the 4-emitter tree become higher than the exposed leaves of the 1-emitter tree, due to very low values of radiation that cause stomates of the shaded leaves to close before those of exposed leaves. Comparing the effects of both wl and rl it may be concluded that lowered wl and increased rl for the 1-emitter tree indicates that it is under stress throughout most of the day.

The increased rl results in partial stomatal closure and therefore a decrease in productivity. The 1-emitter tree was being water stressed since each tree was being subjected to the same environmental stress, therefore differences in wl and rl in the test trees may be attributed to different irrigation rates. If the tree were adequately supplied with water rl of an exposed leaf would be lower than for a fully shaded leaf. The high rl in the 1-emitter tree is thus an indication that it is not being adequately supplied with water.

The peaks in gl and Tr of the 4- and 3-emitter trees in Figure 5 occurred at 1300 hours, whereas for the 2 and 1-emitter trees in Figure 6, the peaks occurred earlier at 1200 hours. The peaks in Tr for the 2- and 1-emitter trees were identical and were less than half of that measured for the 4- and 3-emitter trees.

In Figure 7, gl and Tr for the shaded leaf of the 4-emitter tree was higher than both the exposed and shaded leaves of the 1-emitter tree for most of the day. This is a further indication that the 1-emitter tree is under stress, and is due to the very low irrigation rate. After 1600 hours on 4 July, rapid decrease in radiation and air temperature caused a similar decrease in leaf temperatures of the 4- and 3-emitter trees, this in turn decreased Tr of the 4-emitter tree. Comparing Tr rates for the 4- and 1-emitter trees in Figure 7, indicated that after 1700 hours Tr for the 4-emitter tree was lower than the 1-emitter tree, and may be atttributed to a rapid lowering of leaf

Before Harvest

Measurements on 24 and 25 July are plotted in Figure 8, 9, and 10. These measurements represent the water status of the trees before harvest and indicate the effect of a heavy fruit load on tree responses.

Leaf water potentials for all trees did not show much change and followed a similar diurnal trend as stated previously. However, there were two noticeable differences. First there was a considerable downward shift in wl curves for both the exposed and shaded leaves for all trees indicating considerable stress. Second, there was a sharp decline in early morning values of wl for all trees. Leaf water potentials remained consistently lower for the 1-emitter tree. In Figure 10 wl for the shaded leaves of the 4-emitter tree were between 3 to 4 bars higher than shaded leaves of the 1-emitter tree from 1300 to 1800 hours.

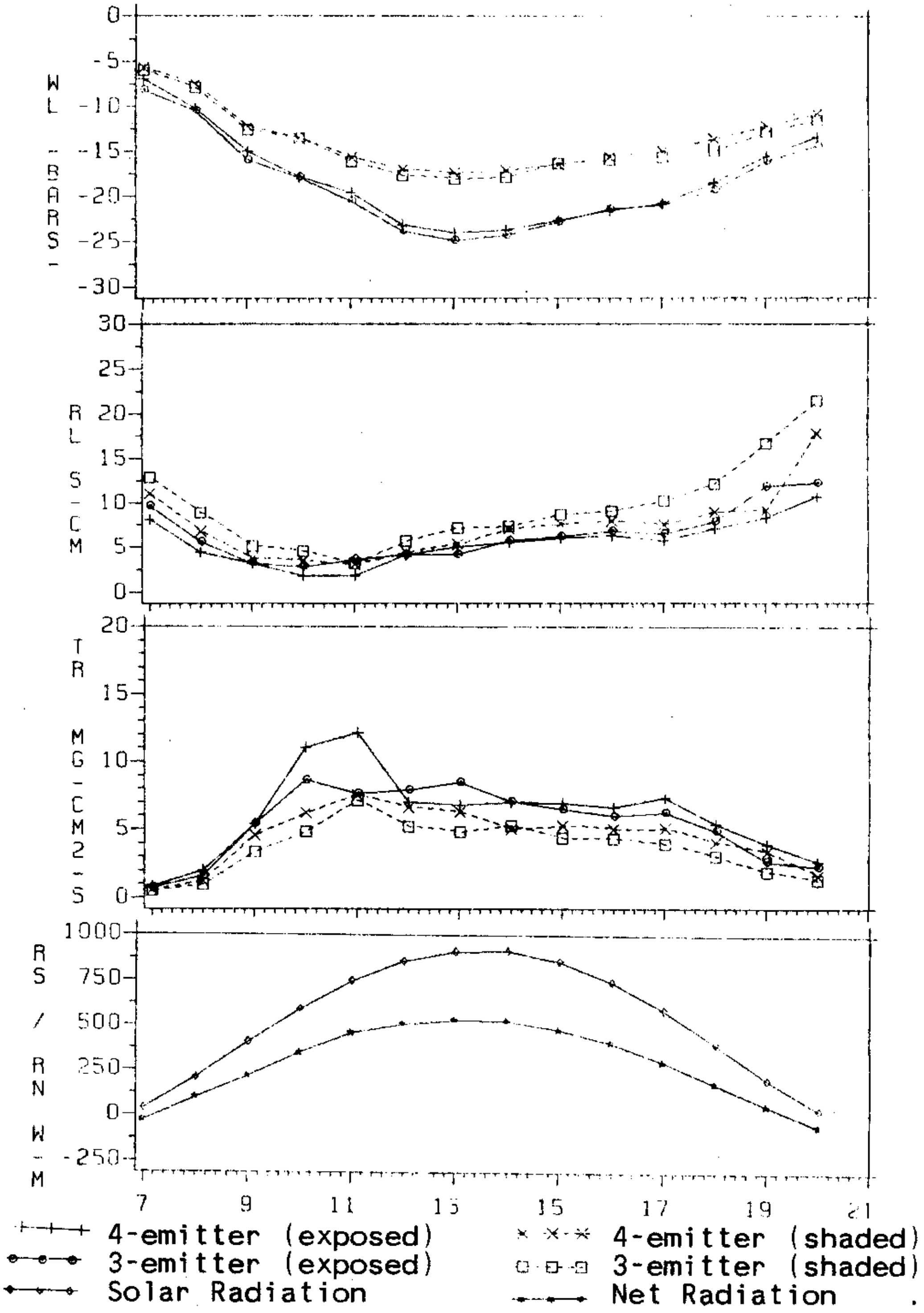

Figure 8: Diurnal Trends in Plant Responses and Selected Environmental Variables for 4- and 3-emitter Trees on Day 205 Before Harvest.

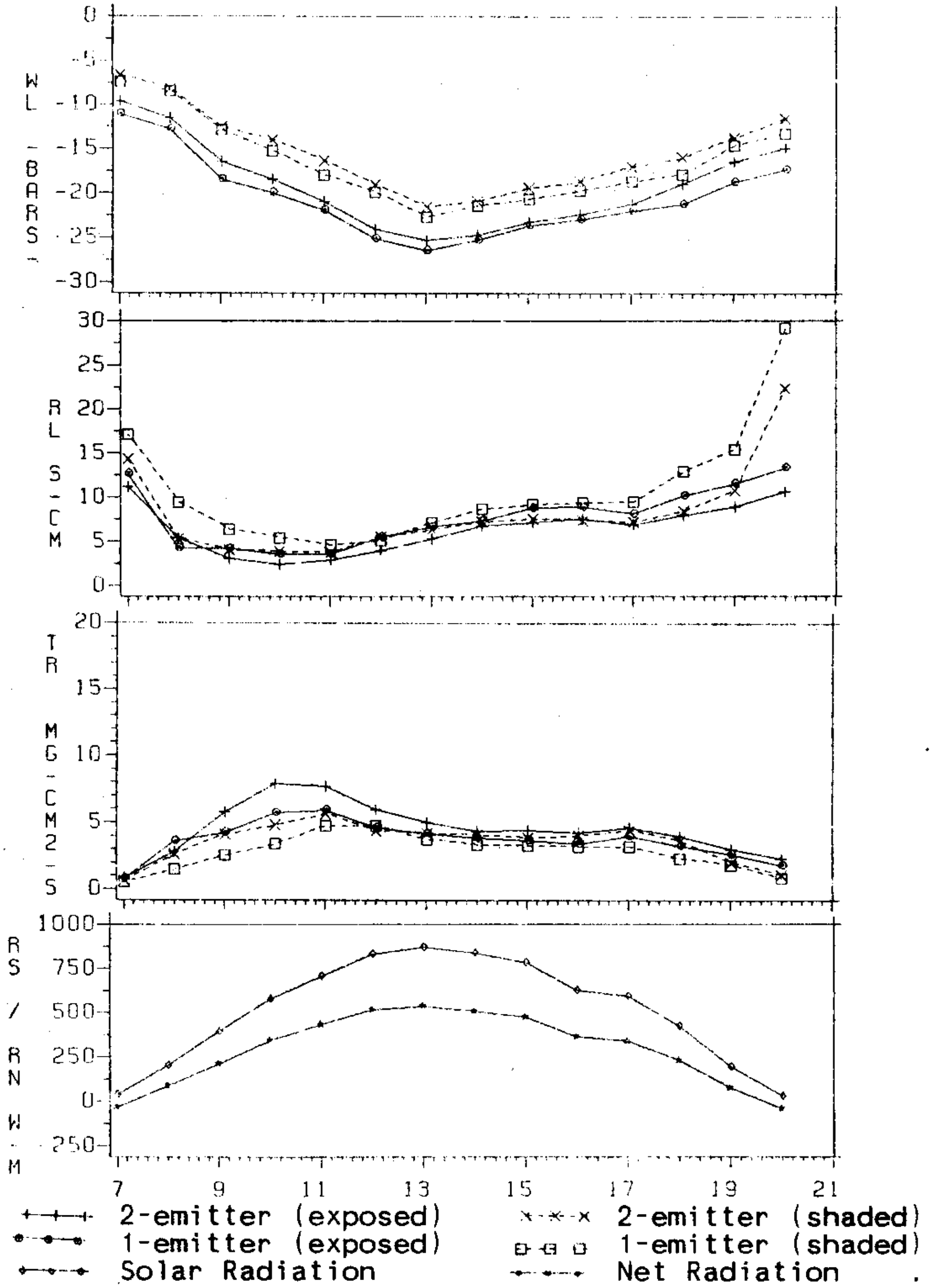

Figure 9: Diurnal Trends in Plant Responses and Selected Enviromental Variables for 2- and 1-emitter Trees on Day 206 Before Harvest.

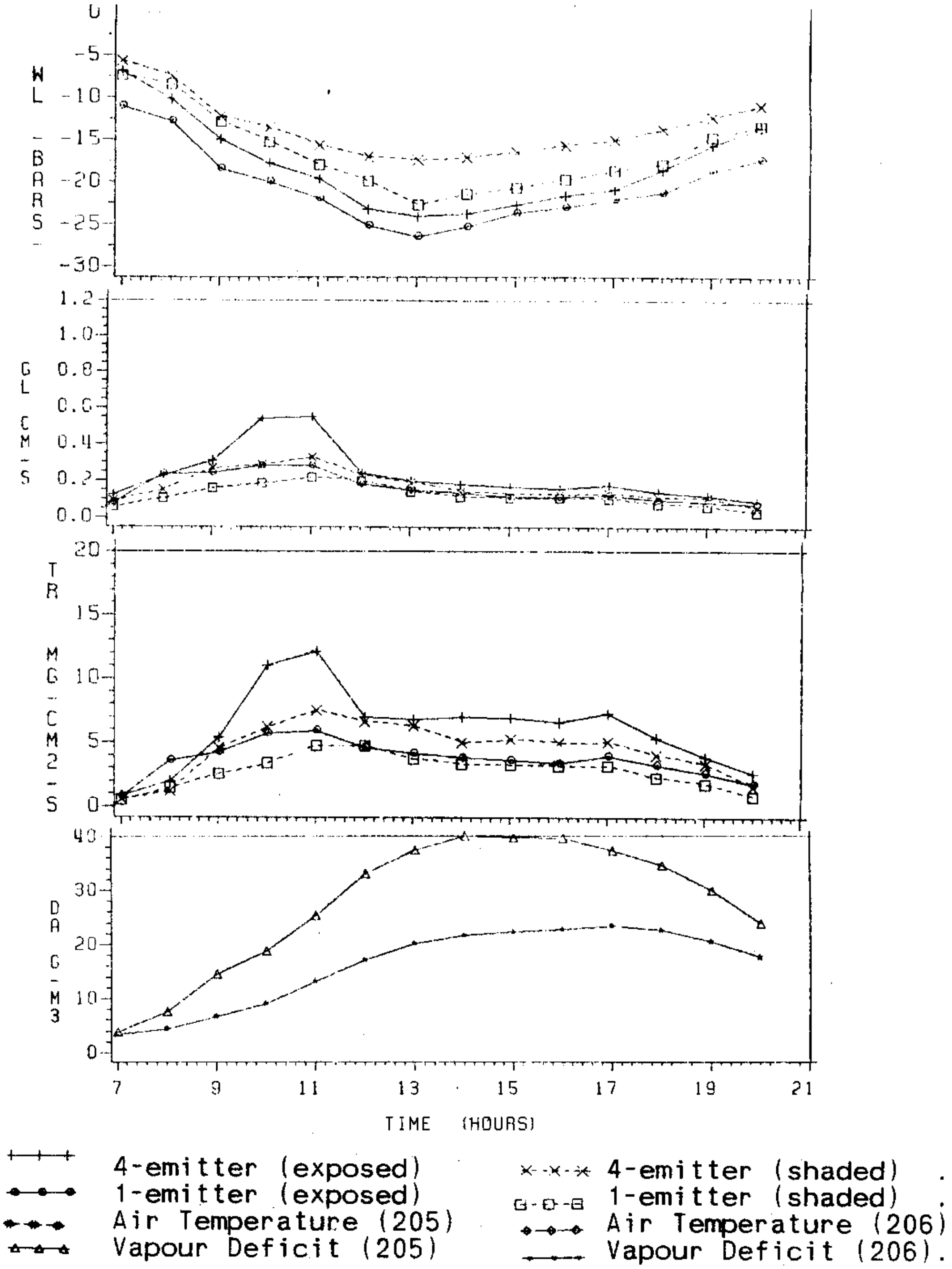

Figure 10: Diurnal Trends in Plant Responses and Selected Environmental Variables for 4- and 1-emitter Trees on Day 205 and 206 Before Harvest.

Leaf resistance curves for all trees in Figure 8, 9 and 10 indicated higher rl throughout the day. In general rl decreased from 0700 to 1000 hours and began to increase slowly after 1100 hours, and increased rapidily after 1700 hours. Higher rl would indicate that the stomates are partially closed during most of the day indicating the trees are under greater stress prior to harvest. Partial closure of stomates during the day also acts as a control mechanism that prevents wl from decreasing to a critical level that may injure the plant. Therefore some of the effects of stress on wl would be compensated by changes in rl, this is a further indication of the importance of concurrent measurements of wl and rl. Leaf resistance of shaded leaves of the 1-emitter tree was higher than the exposed leaves of the 4-emitter tree from 1100 hours onwards. This would indicate that the 1-emitter tree was being stressed due to the fruit load on the trees and also due to inadequate supply of water to the 1-emitter tree.

All trees showed a pronounced peak in Tr between 1000 and 1100 hours. A smaller less pronounced peak in Tr occurred about 1700 hours for all trees. This effect may be attributed to the irrigation system which was started each day at 1400 hours. The highest Tr rate was observed for the exposed leaves of the 4-emitter tree. Transpiration values for the other trees were low due to high values of rl.

Transpiration for the exposed leaves of the 1-emitter tree was higher than the 4-emitter tree during early morning upto 0800 hours. After this Tr rates for the exposed leaves of the 1-emitter tree remained lower than the shaded leaves of the 4-emitter tree for the remainder of the day. This is a further indication that the 1-emitter tree is under greater stress than the 4-emitter tree, since an exposed leaf would transpire more than a shaded leaf unless it were under water stress.

After Harvest

Measurements taken on 12 and 13 August are plotted in Figure 11, 12, and 13. These measurements were taken after all the fruit had been removed from the trees.

Diurnal changes in wl on 12 August for indicated 4- and 3-emitter trees remained considerably higher during the day as compared to measurements that were taken before the trees had been harvested on 24 July. In the 4- and 3-emitter trees which are well watered, the decrease in stress may be attributed to the removal of the fruit load from these trees. This would suggest that heavily cropped peach trees are more sensitive to stress and develop stress faster. The wl curves in Figure 11 show a significant upward shift for both exposed 4- and 3-emitter trees, such that there is only a small difference between wl values of the shaded and

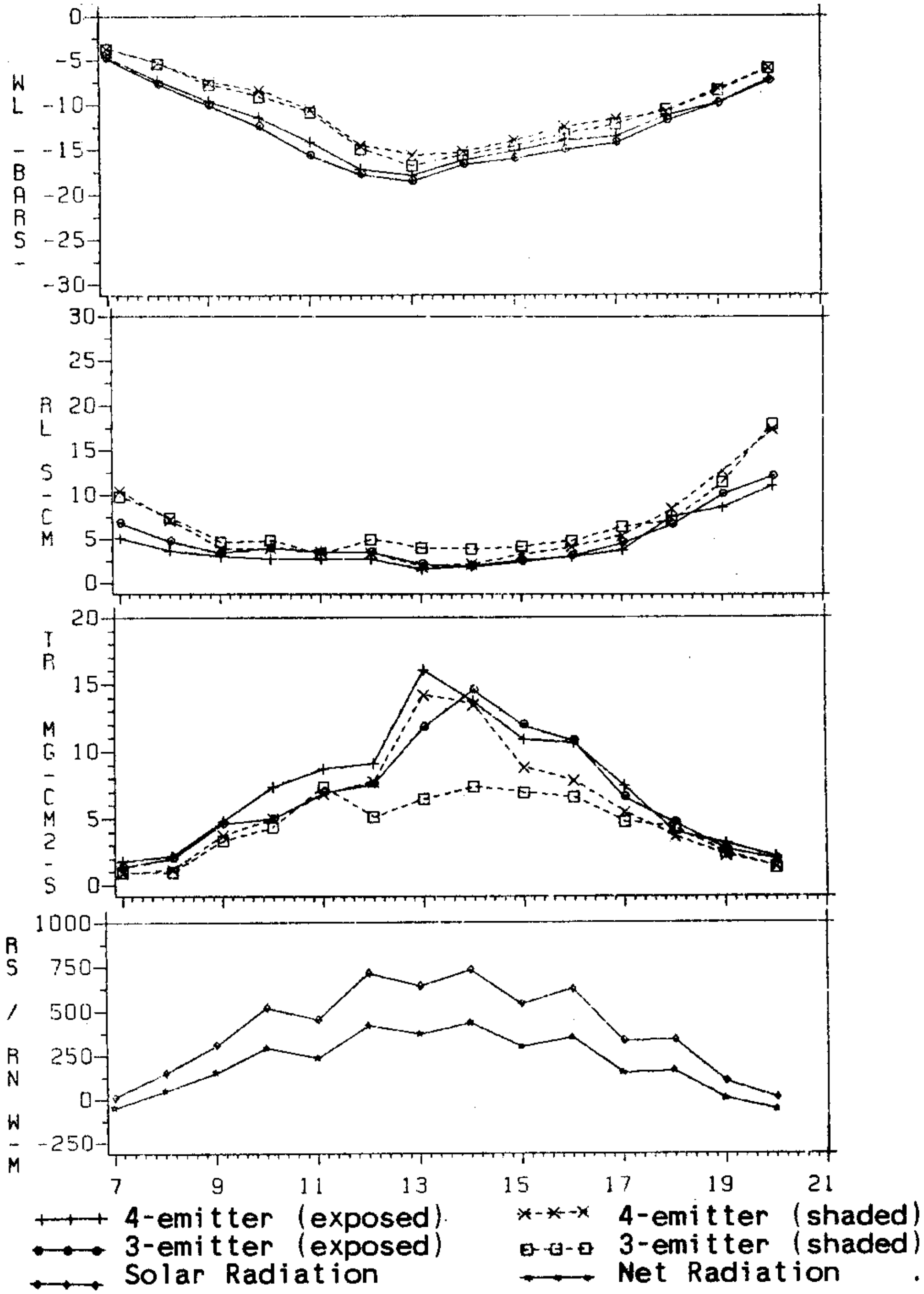

Figure 11: Diurnal Trends in Plant Responses and Selected Environmental Variables for 4- and 3-emitter Trees on Day 224 After Harvest.

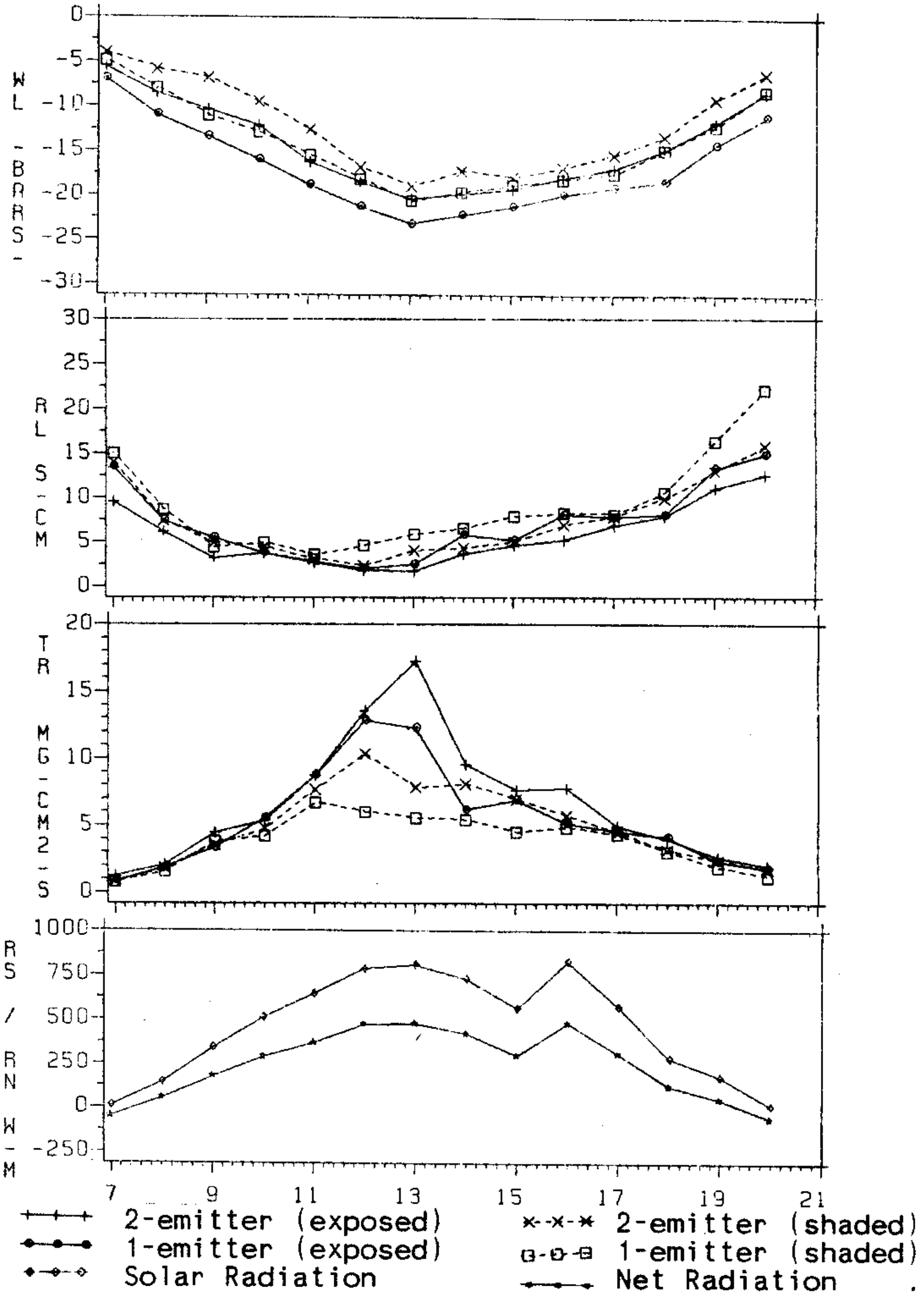

Figure 12: Diurnal Trends in Plant Responses and Selected Environmental Variables for 2- and 1-emitter Trees on Day 225 After Harvest.

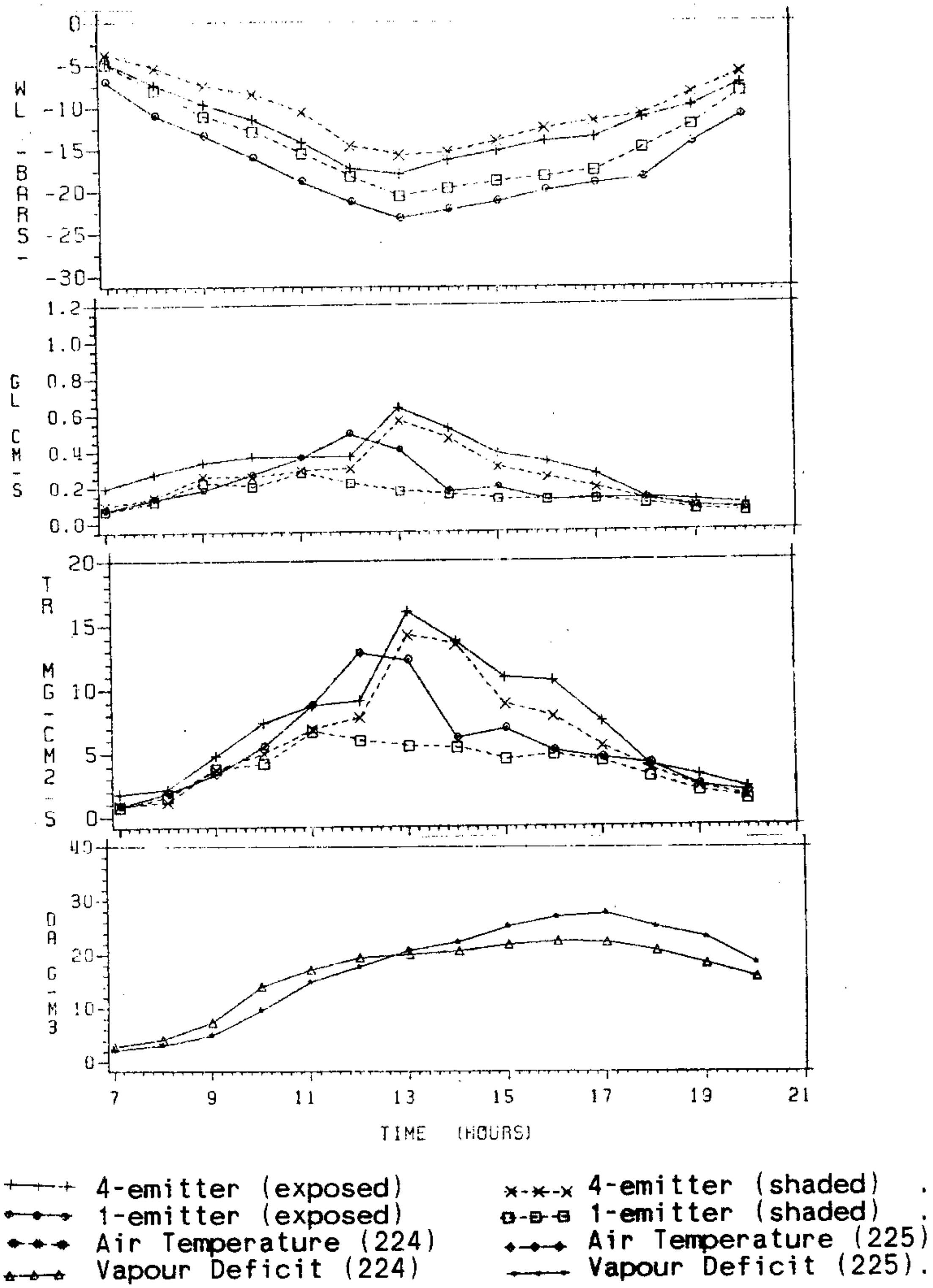

Figure 13: Diurnal Trends in Plant Responses and Selected Environmental Variables for 4- 1-emitter Trees on Days 224 and 225 after Harvest.

exposed leaves for both trees. A similar upward shift in wl was shown in Figure 12 for the 2- and 1-emitter trees. The increase in wl on 12 August is further evident when comparisons are made with measurements taken on 24 July. These indicate that the minimum wl measured on 24 July for the exposed leaves of the 4- emitter tree was -24.1 bars, whereas on 12 August the minimum wl measured was -17.9 bars or an increase of 6.2 bars. Similarly on 25 July the minimum wl measured for the exposed leaves of the 1-emitter tree was -26.4 bars, whereas on 13 August the minimum wl measured was -23.2 bars or an increase of 3.2 bars. Similar but smaller increase in wl also occurred for the shaded leaves. The diurnal course of wl for the shaded leaves of the 1-emitter tree was similar to the exposed leaves of the 2-emitter tree signifying more stress. This should indicate that although some stress has been alleviated by removal of the fruit load, the 1-emitter tree has not fully recovered. The probable reason is that the 1-emitter tree has consistently been supplied with less water than was required to meet its' needs. More conclusive proof of this is indicated in Figure 13 which shows a comparison between measurements made on the 4- and 1-emitter trees. The wl curve for the exposed leaves of the 4-emitter tree was higher than the shaded leaves of the 1-emitter tree for the entire day. The largest difference between the two curves occurred between 1300 and 1800 hours.

Comparisons of the rl curves in Figure 11 for the 4- and 3- emitter trees show a considerable decrease in rl during the course of the day, indicating a decrease in stress. Leaf resistance for the 4- and 3-emitter trees decreased rapidily on 12 August between 0700 and 0800 hours, and began to increase rapidly after 1700 hours. Leaf resistances remained low between 0800 and 1700 hours. Similar trends were observed on 13 August for the 2-emitter tree in Figure 12 which indicate an overall decrease in rl when compared to measurements made on 25 July before the fruit was harvested. Leaf resistance for the leaves of the 1-emitter tree showed some recovery during the morning, however, after 1100 hours rl began increasing. After 1300 hours rl of the exposed leaves of the 1-emitter tree exhibited a somewhat cyclic pattern in rl as the stomates began to close gradually.

When measurements of rl and wl are compared for the 4- and 1-emitter trees in Figure 13 it is observed that the rl of exposed leaves of the 1-emitter tree was higher than rl of shaded leaves of the 4-emitter tree between 0700 and 0900, and between 1300 and 1900 hours. Leaf water potentials of the shaded leaves of the 1-emitter tree were lower than the exposed leaves of the 4-emitter tree throughout the day, indicating the 1-emitter had not recovered completely even though the fruit load had been removed. In contrast there was rapid recovery in wl for the 4-emitter tree.

Peaks in gl correspond with peaks in Tr for all trees. Figures 11 and 12 illustrate that Tr for 4- and 2-emitter trees peaked at 1300 hours, the 3-emitter tree peaked at 1400 hours, and the 1-emitter tree peaked at 1200 hours. The largest value of Tr occurred on 13 August for the 2-emitter tree with a value of 17.2 $ug.cm^{-2}.s^{-1}$, the 4-emittter tree had a value of 16.0 $ug.cm^{-2}.s^{-1}$, the 3-emitter tree was 14.5 $ug.cm^{-2}.s^{-1}$, and the 1-emitter tree was 12.8 $ug.cm^{-2}.s^{-1}$. The shaded leaves of the 4-emitter tree had a higher value of Tr at 1300 hours than the exposed leaves of the 3-emitter tree. Similarly the shaded leaves of the 2-emitter tree had a higher Tr rate between 1400 and 1600 hours than the exposed leaves of the 1-emitter tree.

In Figure 13 Tl of the 1-emitter tree was much higher than the 4-emitter tree between 1300 and 1800 hours, for both exposed and shaded leaves. Decrease in Tr and higher rl due to partial stomatal closure resulted in an increase in Tl of the 1-emitter tree. This is another indication that the 1-emitter tree was under greater stress.

Analysis of Leaf Water Potential

The mean wl values of each tree measured on day 170 and 171, before the trees were placed on selected drip irrigation treatments are presented in Table 1. Waller-Duncan K-ratio t test on the means showed no significant difference in wl for the 4-, 3-, 2- and 1-emitter trees. The mean wl of shaded leaves of the 1-emitter tree alone was significantly different from wl of exposed leaves of the 3-emitter tree.

Waller-Duncan K-ratio t test indicated that after the drip irrigation system had been started for the season, seasonal averages of leaf water potential (wlsa) showed significant differences as indicated in Table 2. For both exposed and shaded leaves there were no significant differences in wlsa values between the 4- and 3-emitter trees. However, for both exposed and shaded leaves there were significant differences in wlsa of the 2- and 1-emitter trees, and each was also significantly different from the 4- and 3-emitter trees. Analysis on wlsa indicated that plant water stress did decrease significantly for the 3-emitter tree as compared to the 2-emitter tree. Increasing the number of emitters to 4 resulted in no significant difference between the 4- and 3-emitter trees. These results suggest that 3-emitters per tree would be the best recommendation for the peach orchard in Stephenville.

TABLE 1

LEAF WATER POTENTIALS BEFORE IRRIGATION TREATMENT.

(WALLER-DUNCAN K-RATIO T TEST, Alpha level = 0.05)

Number of emitters	Shaded leaves	Number of emitters	Exposed leaves
1	-14.72 a*	2	-18.53 a*
2	-15.05 a	1	-18.85 a
4	-15.22 a	4	-18.91 a
3	-15.40 a	3	-19.22 a

*Means followed by the same letter are not significantly different.

TABLE 2

LEAF WATER POTENTIALS AFTER IRRIGATION TREATMENT.

(WALLER-DUNCAN K-RATIO T TEST, Alpha level = 0.05)

Number of emitters	Shaded leaves	Exposed leaves
4	-11.77 a*	-14.96 a*
3	-12.57 a	-15.87 a
2	-13.97 a	-17.12 b
1	-15.75 c	-19.01 c

*Means followed by the same letter are not significantly different.

Ranking the means in Table 1 before irrigation was started indicated that wl of the shaded leaves of the 1-emitter tree was highest and that wl of exposed leaves of the 3-emitter tree was lowest. However, in Table 2 after irrigation was started, the increase in plant water stress was related to the number of emitters per tree. The highest wlsa occurred in the shaded leaves of the 4-emitter tree and the lowest wlsa occurred in the exposed leaves of the 1-emitter tree. This suggests the different irrigation treatments determined the level of stress in the trees.

The wlsa of the shaded leaves of the 1-emitter tree was lower than the exposed leaves of the 4-emitter tree. Under conditions of adequate soil moisture wlsa of exposed leaves are generally lower than shaded leaves. Although these two means were not significantly different it is a definite indication that the 1-emitter tree was under much higher stress.

Comparisons of Mean Daily Leaf Water Potential

Figure 14 a and b shows the seasonal variation in mean daily leaf water potential (wlmd) of exposed and shaded leaves for all treatments. The means of all wl measured on exposed leaves are plotted in Figure 14a, and for the shaded leaves in Figure 14b. The differences between wlmd of exposed and shaded leaves for each treatment ranged from 2

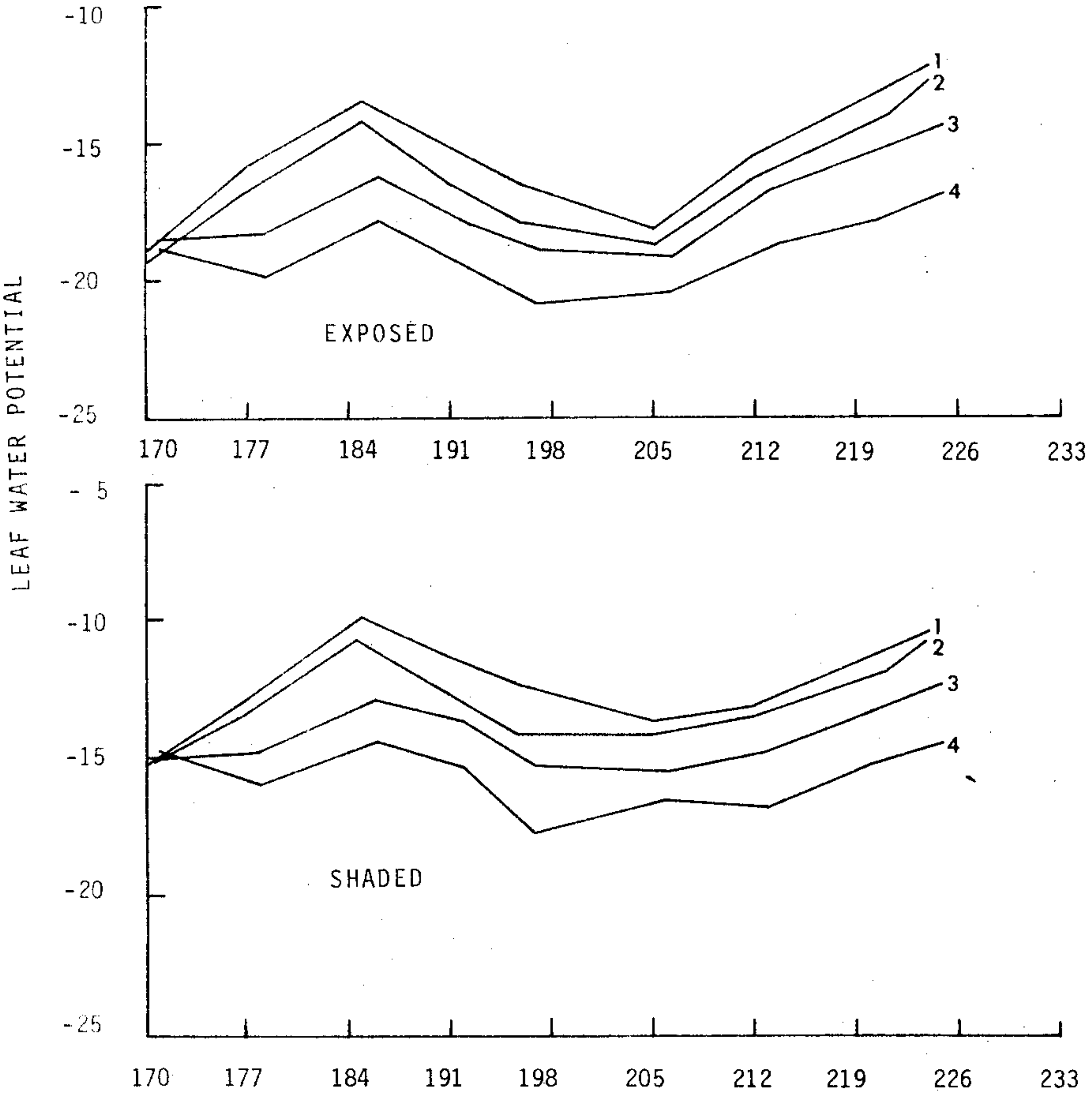

Figure 14: Seasonal Variations in Mean Daily Leaf Water Potentials of (a) exposed and (b) shaded leaves for each Treatment.

to 5 bars. Exposed leaves had lower wlmd values than shaded leaves at all times. The greatest differences between wlmd ofexposed and shaded leaves occurred on day 205 and 206 with smallest differences occurring at the end of the growing season on day 224 and 225. The large difference in wlmd on day 205 and 206 were due to low wl for the exposed leaves indicating the trees were under considerable stress prior to harvest. The smaller difference in wlmd between exposed and shaded leaves on day 224 and 225 were due to higher wl for both exposed and shaded leaves indicating the trees had recovered considerably after harvest.

Figure 14 a and b showed that measurements on day 170 and 171 before the start of the irrigation season showed that wlmd of exposed leaves for all trees ranged from -18.5 to -19.2 bars. Similar results were observed for wlmd of the shaded leaves which ranged from -14.7 to -15.4 bars. This indicated little difference in wlmd for all trees before the start of the irrigation season. After the trees were placed on selected irrigation treatments there was considerable difference in wlmd. During the irrigation season the wlmd of the 4-emitter tree was highest. The 3-, 2- and 1- emitter trees followed the pattern of the 4-emitter tree, and wlmd was lowest in the 1-emitter tree.

Trends in wlmd indicated that after irrigation was started on day 175 the 4- and 3-emitter trees showed rapid recovery by day 177, the 2-emitter tree increased only slightly, and the 1-emitter tree showed a decrease in wlmd on day 178. The trees showed a general increase in wlmd from day 177 and 178 to day 185 and 186. Waller-Duncan K-ratio t test showed that wlmd for day 170 was significantly different from day 185 for both 4- and 3-emitter trees. Results for the 2- and 1-emitter trees indicated wlmd for day 171 were not significantly different from day 186. These results suggest that irrigation decreased stress in the 4- and 3-emitter trees but had little effect for the 2- and 1-emitter trees.

Mean daily leaf water potentials for all trees decreased from day 186 to day 206. The 1-emitter tree decreased only upto day 197 and increased slightly by day 206. Leaf resistances for the 1-emitter tree were considerably higher on day 206, this would cause partial stomatal closure and would account for the slight increase in wlmd for day 206. Waller-Duncan K-ratio t test showed that wlmd for day 185 was significantly different from day 196 and 205 for both 4- and 3-emitter trees. Mean daily leaf water potential of the exposed leaves of the 2-emitter tree for day 186 was significantly different from day 206, but not significantly different for the shaded leaves of the 2-emitter tree. For the 1-emitter tree wlmd for day 186 were significantly different for day 197 but not for day

206. These results suggest that stress occurred earlier in trees that were subjected to severe water deficits, and that trees with a heavy fruit load showed signs of being water stressed.

After day 205 and 206 the fruit on the trees were picked at four intervals and wlmd showed a general increase until day 225. Waller-Duncan K-ratio t test showed that wlmd for day 205 was significantly different from day 221 and 224 for both 4- and 3-emitter trees. For the exposed leaf of the 2-emitter tree wlmd for day 206 was significantly different from day 220 and 225, whereas for the shaded leaf of the 2-emitter tree wlmd for day 206 was significantly different from day 225. For day 197 and 206 wlmd of exposed leaves of the 1-emitter tree were significantly different from day 225, whereas for the shaded leaves of the 1-emitter tree wlmd for day 206 was significantly different from day 225. These results indicate rapid recovery in wlmd for the trees after the fruit load had been removed. Leaf resistance measurements indicated that for the 4- and 3- emitter trees there was a decrease in rl after harvest and that increase in wlmd was due to the rate at which water was being supplied to the trees. For the 2- and 1- emitter trees part of the recovery in wlmd after day 206 was due to higher rl indicating a much slower recovery in rl for trees that are severly stressed.

Comparisons of Mean Hourly Leaf Water Potential for Diurnal Differences

In Table 3 a and b exposed and shaded leaves of all trees indicated that mean hourly leaf water potentials (wlmh) measured at 0700, 0800, 0900, 1000, 1100 and 1200 hours were significantly different. Table 4 a and b shows no significant differences were observed between wlmh measured at 1300, 1400 and 1500 hours for exposed and shaded leaves of both the 4- and 3-emitter trees, and for the exposed leaves of the 2-emitter tree. For the shaded leaves of the 2-emitter tree and the exposed and shaded leaves of the 1-emitter tree no significant differences were observed between wlmh measured at 1300 and 1400 hours, however the 1500 hour mean was significantly different from the 1300 hour mean. For the 2- and 1-emitter trees wlmh were consistently lower than the 4- and 3-emitter trees. All treated trees showed significant differences in wlmh measured at 1400, 1600, 1800 and 2000 hours. Significant differences in wlmh also occurred at 1500, 1700 and 1900 hours for all trees.

For the exposed leaves of the 4- and 3-emitter trees no significant differences were observed between consecutive hourly readings such as between 1600 and 1700, or between 1700 and 1800 hours. Similar results were observed for shaded leaves of the 4- and 3-emitter trees, however, wlmh measured at 1900 hours was significantly different from

TABLE 3

COMPARISONS OF MEAN HOURLY LEAF WATER POTENTIALS FROM 0700 TO 1300 HOURS.

a. EXPOSED LEAVES

WALLER-DUNCAN K-RATIO T TEST
ALPHA LEVEL = 0.05

	Emitters				
Time	1	2	3	4	
7	-6.35	-6.73	-7.96	-0.94	A
8	-9.01	-9.34	-10.12	-11.81	B
9	-11.76	-12.57	-13.35	-15.47	C
10	-14.94	-15.75	-16.71	-18.72	D
11	-18.28	-19.51	-20.04	-21.29	E
12	-20.43	-21.38	-21.95	-24.00	F
13	-21.58	-22.40	-23.23	-24.86	F

b. SHADED LEAVES

WALLER-DUNCAN K-RATIO T TEST
ALPHA LEVEL = 0.05

	Emitters					
Time	4	3	2		1	
7	-5.06	-5.31	-6.08	A*	-6.80	A*
8	-6.64	-7.08	-7.81	B	-8.73	B
9	-8.80	-9.40	-9.84	C	-11.35	C
10	-11.15	-11.89	-13.23	D	-14.59	D
11	-13.99	-14.95	-15.76	E	-17.58	E
12	-15.83	-16.75	-18.45	F	-20.07	F
13	-17.10	-17.98	-19.56	F	-21.22	G

*Means followed by the same letter are not significantly different.

TABLE 4

COMPARISONS OF MEAN HOURLY LEAF WATER POTENTIALS FROM 1300 TO 2000 HOURS.

a. EXPOSED LEAVES

WALLER-DUNCAN K-RATIO T TEST
ALPHA LEVEL = 0.05

	Emitters			Emitters		
Time	4	3		2	1	
20	-10.82	-11.60	A*	-12.68	-14.73	A*
19	-12.68	-13.62	B	-14.95	-16.95	B
18	-14.72	-15.68	C	-17.37	-19.27	C
17	-16.57	-17.65	D	-19.03	-20.67	D
16	-17.95	-18.86	D	-20.22	-21.88	E
15	-19.57	-20.57	E	-21.76	-23.20	F
14	-20.89	-21.75	EF	-22.55	-24.05	FG
13	-21.58	-22.40	F	-23.23	-24.86	G

b. SHADED LEAVES

WALLER-DUNCAN K-RATIO TEST
ALPHA LEVEL = 0.05

	Emitters				Emitters		
Time	4		3		2	1	
20	-8.68	A*	-9.26	A*	-10.16	-11.79	A*
19	-10.47	B	-11.08	B	-12.34	-13.92	B
18	-12.15	C	-12.89	C	-14.29	-16.09	C
17	-13.38	D	-14.30	D	-15.76	-17.74	D
16	-14.54	E	-15.41	DE	-17.00	-18.82	E
15	-15.83	F	-16.53	F	-18.20	-19.77	F
14	-16.55	FG	-17.55	FG	-18.73	-20.45	FG
13	-17.10	G	-17.98	G	-19.56	-21.22	G

*Means followed by the same letter are not significantly different.

those at 2000. The shaded wlmh of the 3-emitter tree at 1900 hours was also significantly different from those at 1800 hours.

For the 2- and 1-emitter trees for both exposed and shaded leaves, wlmh measured at 1700, 1800, 1900 and 2000 hours were significantly different. Leaf resistances indicated that the rapid recovery after 1600 hours for the 2- and 1-emitter tree could be attributed to stomates closing rapidly beyond 1600 hours. No significant differences in wlmh occurred for consecutive hourly measurements between 1300 and 1600 hours.

Comparisons of Mean Hourly Leaf Water Potential for Treatment Differences

Ranking wlmh for all trees measured at 0700 hours indicated that the exposed leaf of the 1-emitter tree had lower wlmh than all other trees. The wlmh of shaded leaves of the 1-emitter tree was lower than that of other shaded leaves and was also lower than wlmh for the exposed leaves of the 4- and 3- emitter trees. This indicated that the severest stress was occurring in the 1-emitter tree. From 0800 to 1400 hours wlmh of shaded leaves of the 1-emitter tree was higher than the exposed leaves but it was still lower than all shaded leaves. The lowest wlmh were measured in trees receiving the lowest amount of water. At 1500 and 1600 hours the shaded leaves of the 1-emitter tree was lower than the exposed leaves of the 4-emitter tree, suggesting that while the other treated trees were recovering the 1-emitter tree was not recovering fast enough. This is further evident from wlmh between 1700 and 2000 hours where the shaded leaves of the 1-emitter were lower than both the exposed leaves of the 4- and 3-emitter trees, again suggesting the 1-emitter tree does not recover rapidly. The 4- and 3-emitter trees that are well supplied with water demonstrate a faster rate of recovery in alleviating stress caused by the diurnal cycle of wl.

Waller-Duncan K-ratio t test showed no significant differences were found between the shaded leaves of the 4-, 3-, and 2-emitter trees and also no differences were found between the 2- and 1-emitter trees at 0700, 1100 and 2000 hours. Thus the shaded leaves of the 4- and 3-emitter trees had wlmh that were significantly different from the shaded leaf of the 1-emitter tree. For the exposed leaves at 0700 hours the 4- and 3-emitter trees showed no significant differences in wlmh. Similar results were shown for the exposed leaves of the 2- and 1-emitter trees. However, wlmh for the 4- and 3-emitter trees were significantly different when compared to the 2- and 1- emitter trees. The lower wlmh for the 2- and 1-emitter trees at 0700 hours indicated they were under greater stress. These results are in agreement with Ferreres et al. (1980), that severely stressed trees had lower wl during early morning.

At 1300 and 1400 hours the exposed wlmh for the 4-, 3- and 2- emitter trees showed no significant differences. Similarly the 2- and 1-emitter trees were not significantly different. However, the 4- and 3-emitter trees were significantly different from the 1-emitter tree. Lower wl and higher rl for the 1-emitter tree during midday suggested the 1-emitter tree was being severely stressed. This is further evident from results on exposed leaves at 2000 hours, indicating no significant difference for the 4-, 3- and 2-emitter trees, all of which were significantly different from the 1-emitter tree. This would suggest that although stomates closed earlier in the 1-emitter tree, wlmh had still not recovered fully by 2000 hours and were significantly lower.

Analysis of Leaf Resistance

Waller-Duncan K-ratio t test indicated that after the drip irrigation system had been started for the season, seasonal averages of leaf resistance (rlsa) showed significant differences as indicated in Table 5. The shaded leaves of the 1-emitter tree had significantly higher rlsa than the other trees indicating an increase in resistance was due to limiting soil moisture conditions. Seasonal averages of leaf resistance for the shaded leaves of the 2- and 3-emitter trees were not significantly different.

TABLE 5

<u>AFTER IRRIGATION TREATMENT</u>

WALLER-DUNCAN K-RATIO T TEST FOR LEAF RESISTANCE

Alpha level = 0.05

Number of emitters	Shaded LWP	Number of emitters	Exposed LWP
1	9.68 A*	2	7.44 A*
2	7.73 B	1	5.97 B
3	6.96 B	3	4.91 C
4	4.29 C	4	4.29 C

*Means followed by the same letter are not significantly different.

Similarly the 3- and 4-emitter trees were not significantly different. However, rlsa of the shaded leaves of the 2-emitter tree was significantly higher than the 4-emitter tree. This would indicate that severity of stress for the trees increased with decreasing number of emitters per tree.

For the exposed leaves the differences in treatment were more pronounced, as would be expected since sunlit leaves are under greater environmental stress. The exposed leaves of the 1-emitter tree had significantly higher rlsa than the other trees, this was also true for the exposed leaves of the 2-emitter. For the 3- and 4-emitter trees no significant reduction in rlsa occurred by increasing the number of emitters from 3 to 4.

Ranking of the means also indicated that the 1-emitter tree was under severe climate and water stress. The exposed leaves of the 1-emitter tree had higher resistance than the shaded leaves of the 3- and 4-emitter trees, and furthermore was significantly higher than the shaded leaves of the 4-emitter tree. This is a definite indication of water stress since higher resistances would be expected in the shaded leaves due to lower radiation reaching them.

Comparisons of Mean Daily Leaf Resistances

Figure 15 shows the seasonal variation in mean daily leaf resistance (rlmd) for all treatments. The differences between rlmd of exposed and shaded leaves for each treatment ranged from 0.5 to 5 $s.cm^{-1}$. Shaded leaves had higher rlmd than exposed leaves at all times. The greatest differences between rlmd of exposed and shaded leaves occurred on day 205 and 212 for the 4- and 3-emitter trees, and on day 206, 213, and 220 for the 2- and 1-emitter trees. Smallest differences occurred at the beginning of the growing season, whereas for wlmd smallest differences occurred at the end of the growing season on day 224 and 225 indicating that wl had recovered rapidly soon after harvest whereas rl had not.

Figure 15 showed that rlmd on day 170 and 171 before the start of the irrigation season remained in a very narrow range from 5 to 6 $s.cm^{-1}$ for exposed and shaded leaves of all trees. Differences in the 4- and 3-emitter tree remained in a relatively narrow range for the entire season. However, stress in the 2- and 1-emitter trees resulted in progressively higher rlmd during the growing season. There was some recovery after day 220 and indicated recovery in rl was much slower than for wl. During the irrigation season rlmd for the 1 emitter tree was highest in both exposed and shaded leaves, with greatest differences occurring on days

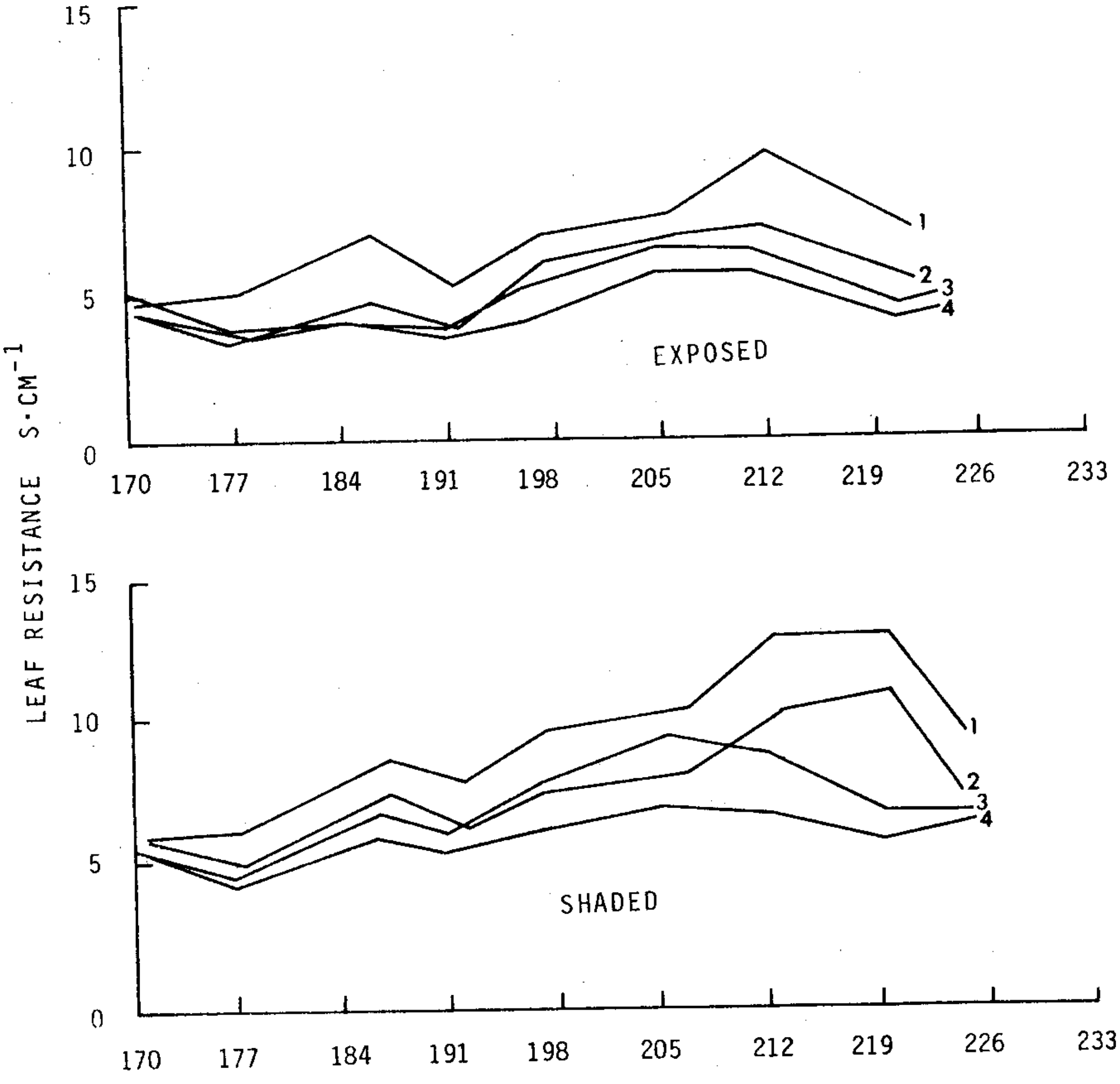

Figure 15: Seasonal Variations in Mean Daily Leaf Resistance for all Treatments.

212 and 213, one week after the trees had been harvested. This indicated that rl in the 4-emitter tree had lowered substantially whereas in the 1-emitter tree it had not been lowered.

Analysis of Transpiration Rate

Table 6 showed that after the drip system had been started for the season there were significant differences in the seasonal averages of transpiration rate (Trsa) of the trees.

Waller-Duncan K-ratio t test indicated that for the exposed leaves Trsa was significantly different for each tree that was treated. The analysis on wlsa and rlsa indicated there were no significant differences between the exposed leaves of the 4- and 3-emitter tree. This would indicate that although wlsa and rlsa of the 4-emitter tree was not significantly lower than the 3-emitter tree, the effect on Trsa resulted in significantly higher water loss from the 4-emitter tree.

For the shaded leaves no significant differences occurred between the 3 and 2-emitter trees, and between the 2- and 1-emitter trees. However, significant differences did occur between the shaded leaves of the 4-emitter tree and the other trees. The 3-emitter tree was also significantly different from the 1-emitter tree.

TABLE 6

AFTER IRRIGATION TREATMENT

WALLER-DUNCAN K-RATIO T TEST FOR TRANSPIRATION

Alpha level = 0.05

Number of emitters	Shaded wl		Number of emitters	Exposed wl	
1	5.11	A*	1	7.33	A*
2	4.27	B	2	6.30	B
3	3.77	BC	3	5.25	C
4	3.02	C	4	4.20	D

*Means followed by the same letter are not significantly different.

Ranking of the means revealed that Trsa for the exposed leaves of the 1-emitter tree was lower than the shaded leaves of the 4- and 3-emitter trees. Although Trsa of shaded leaves of the 3-emitter tree was not significantly different from the exposed leaves of the 1-emitter tree, the shaded leaves of the 4-emitter tree was significantly higher than the exposed leaves of the 1-emitter tree. This indicated that the low water application rate for the 1-emitter tree caused stomatal closure which decreased Tr severely.

Relationship Between Leaf Water Potential and Solar Radiation

Leaf water potentials of treated trees showed similiar diurnal patterns as solar radiation (Rs). Leaf water potentials decreased from 0700 to 1300 hours as Rs increased, and increased beyond 1400 hours as Rs decreased. Leaf water potentials plotted against Rs in Figures 16 to 19 showed considerable scatter in the range from 0 to 600 $W.m^{-2}$, for both exposed and shaded leaves in each treatment. Jarvis (1976) and Landsberg et al., (1975) showed from wl plotted against net radiation (Rn) or vapour pressure deficit, that considerable diurnal hysteresis occurred which results in a scatter diagram if many values are plotted. They explained that hysteresis resulted from the simultaneous dependance of wl on both Rn and vapour deficit.

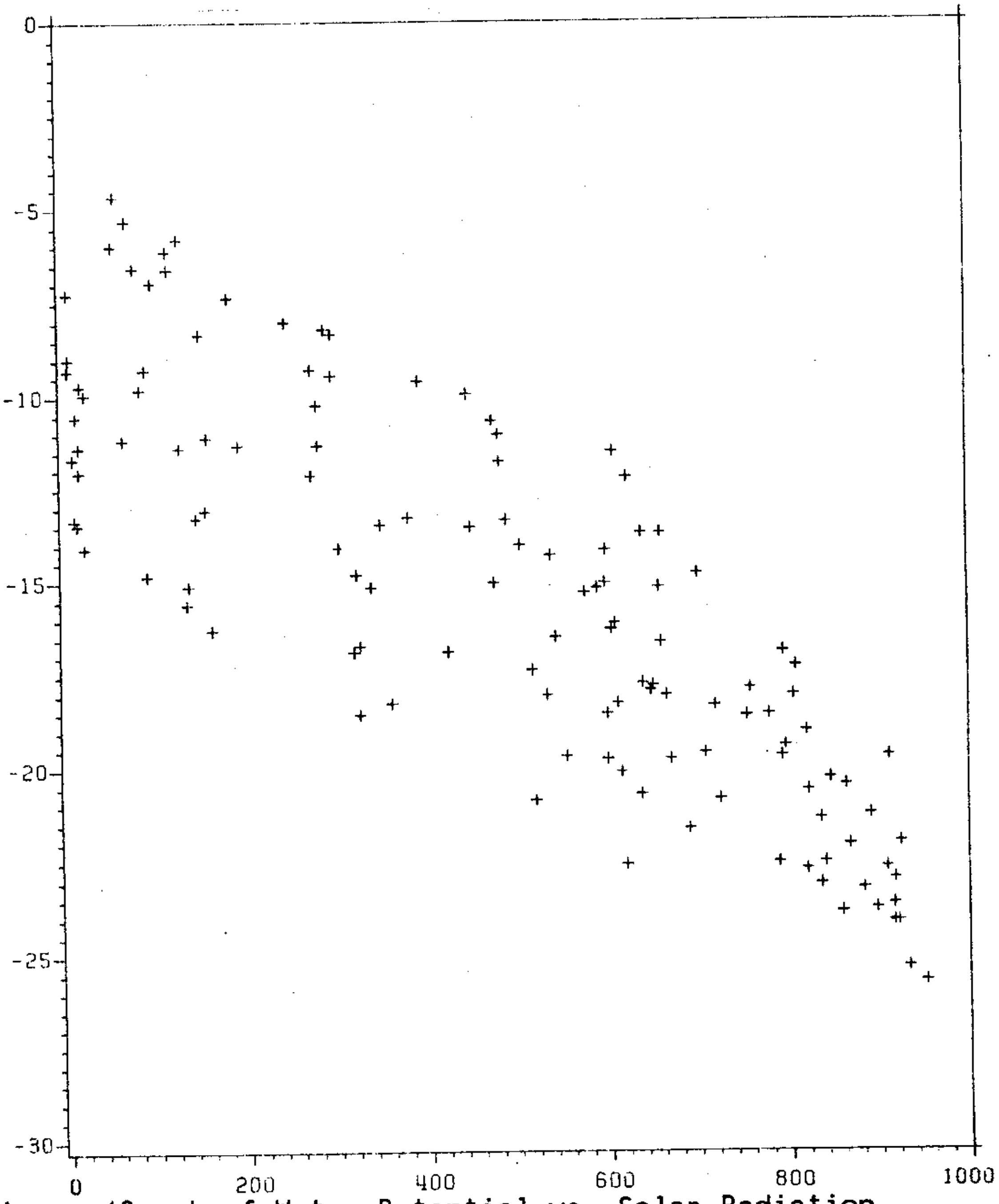

Figure 16: Leaf Water Potential vs. Solar Radiation for the Exposed 4-emitter tree from 0700 to 2000 hours.

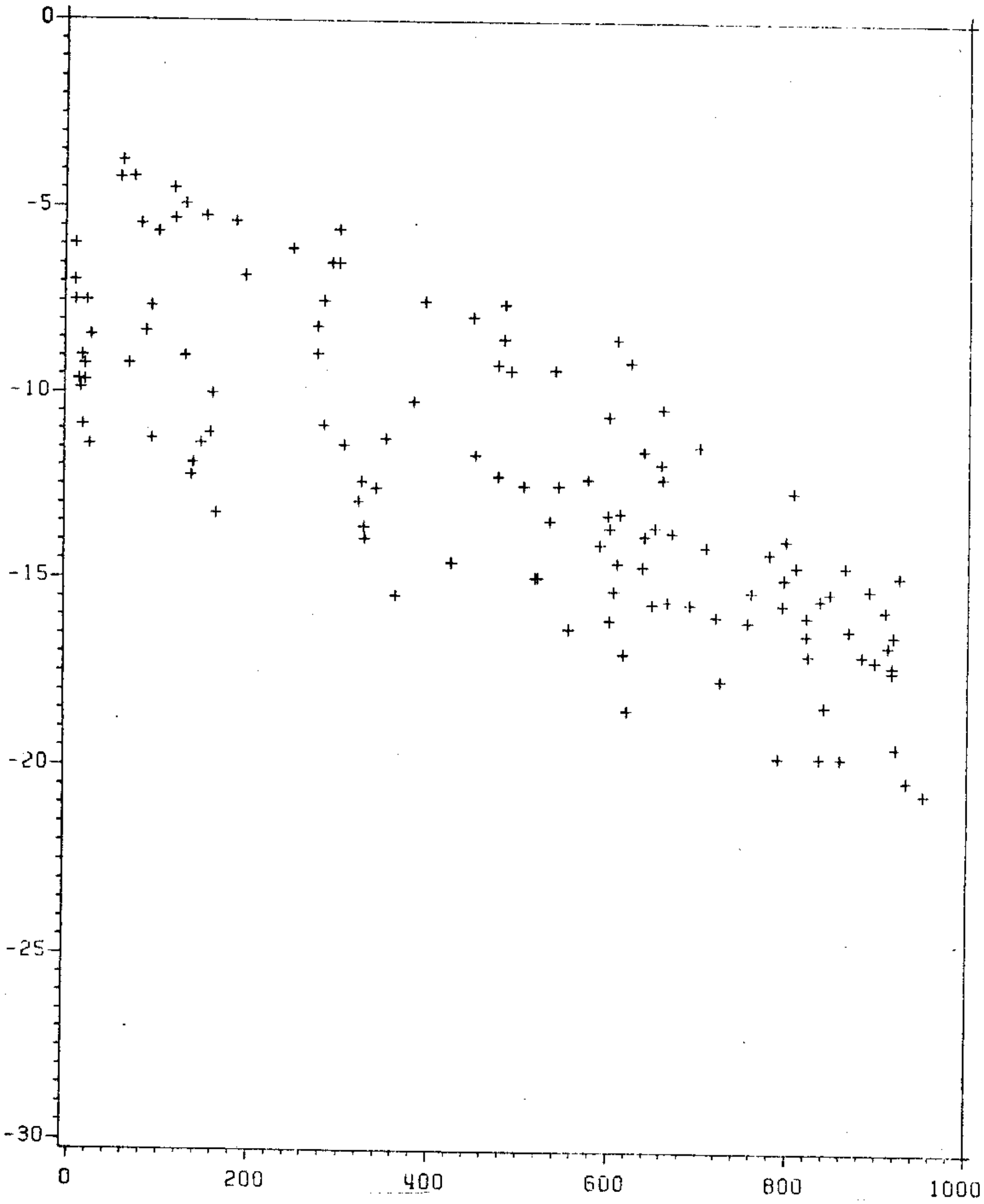

Figure 17: Leaf Water Potential vs. Solar Radiation for the Shaded 4-emitter tree from 0700 to 2000 hours.

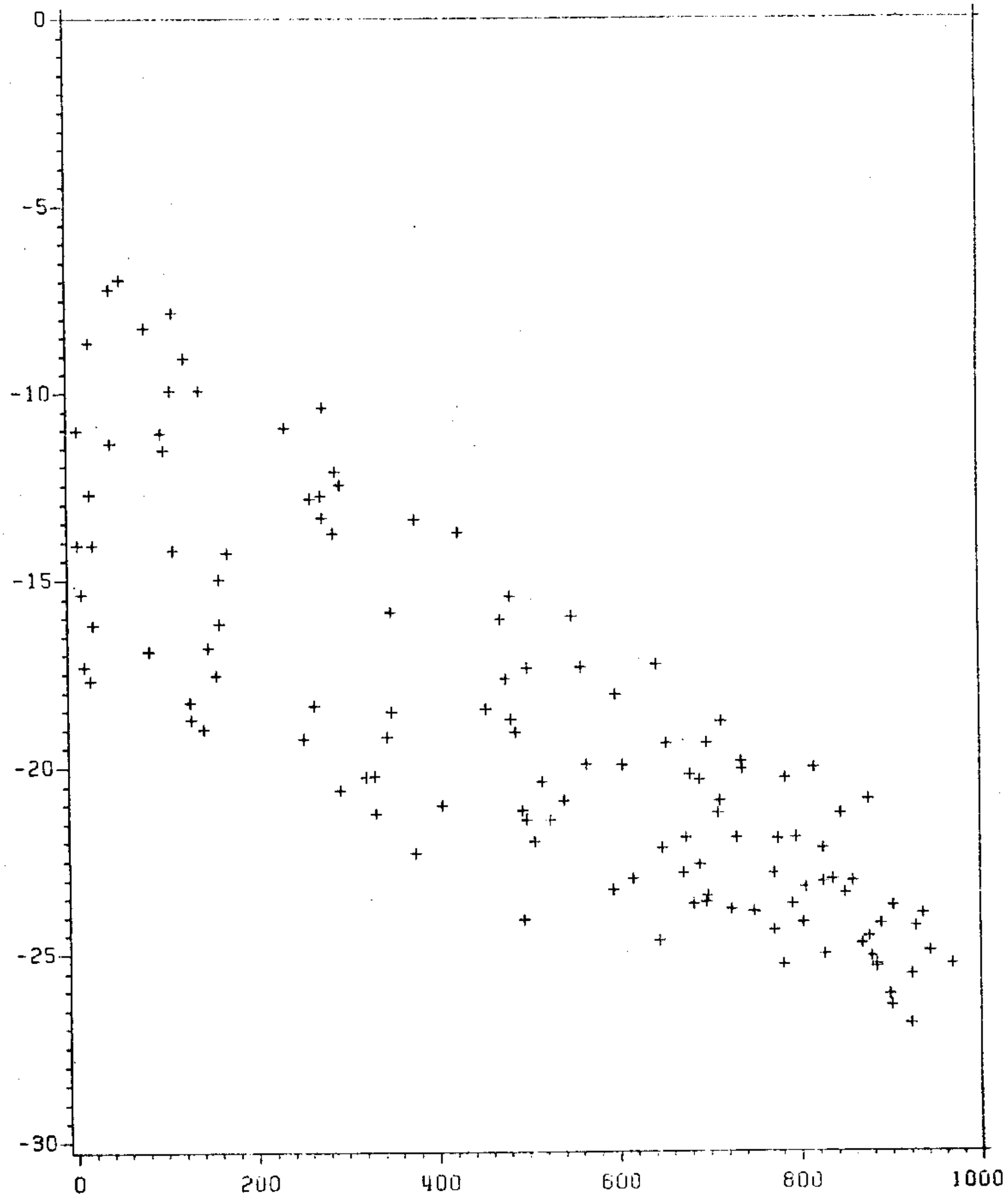

Figure 18: Leaf Water Potential vs. Solar Radiation for the Exposed 1-emitter tree from 0700 to 2000 hours

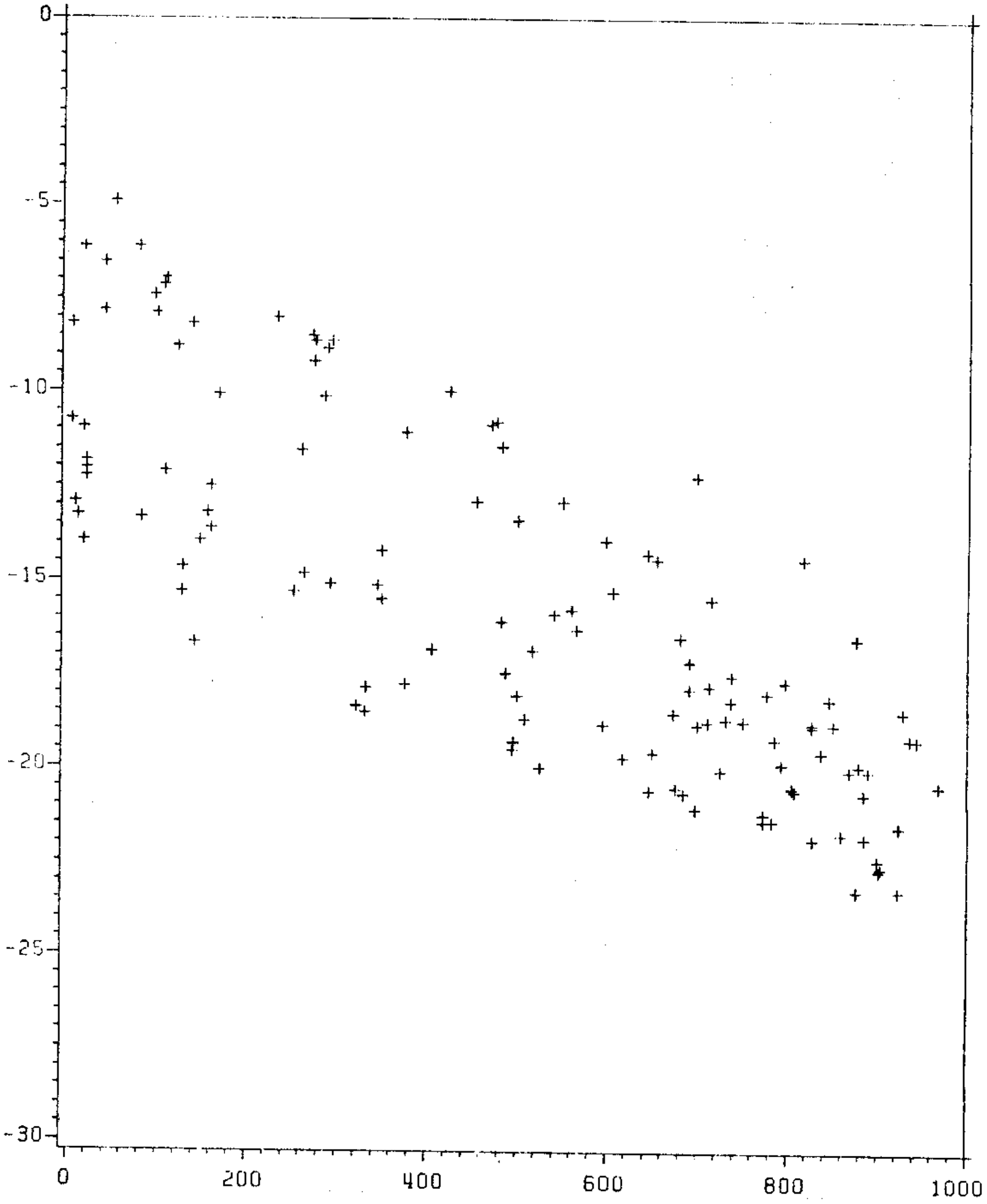

Figure 19: Leaf Water Potential vs. Solar Radiation for the Shaded 1-emitter tree from 0700 to 2000 hours

Changes in vapour deficit lag behind changes in Rn and this results in hysteresis.

Much of the scatter in wl at low radiation values due to diurnal hysteresis may be removed by separating the measurements into two time periods from 0700 to 1200 and from 1300 to 2000 hours. The relationship between wl and Rs in both time periods was essentially linear and are shown in Figures 20 to 23, R^2 for the morning period (0700 to 1200 hours) for all trees for both exposed and shaded leaves ranged from 0.85 to 0.90. This would indicate that Rs was the single most important factor governing wl and therefore most of the morning decline in wl can be explained as a function of solar radiation. During the afternoon period (1300 to 2000 hours), R^2 for all trees in both sunlit and shaded leaves ranged from 0.79 to 0.83. The lower R^2 for the afternoon period is due to higher temperatures and vapour deficits that would have a greater effect on wl during this time. Smart and Barrs (1973), used multiple regression analysis to show that the variation in temperature, vapour deficit and net radiation may account for up to 96 percent of the variation in wl.

The range of wl values for a given range of solar radiation was much higher in the 4-emitter tree than in the 1-emitter tree. During the morning period for Rs values between 400 and 500 $W.m^{-2}$, wl for exposed leaves of the

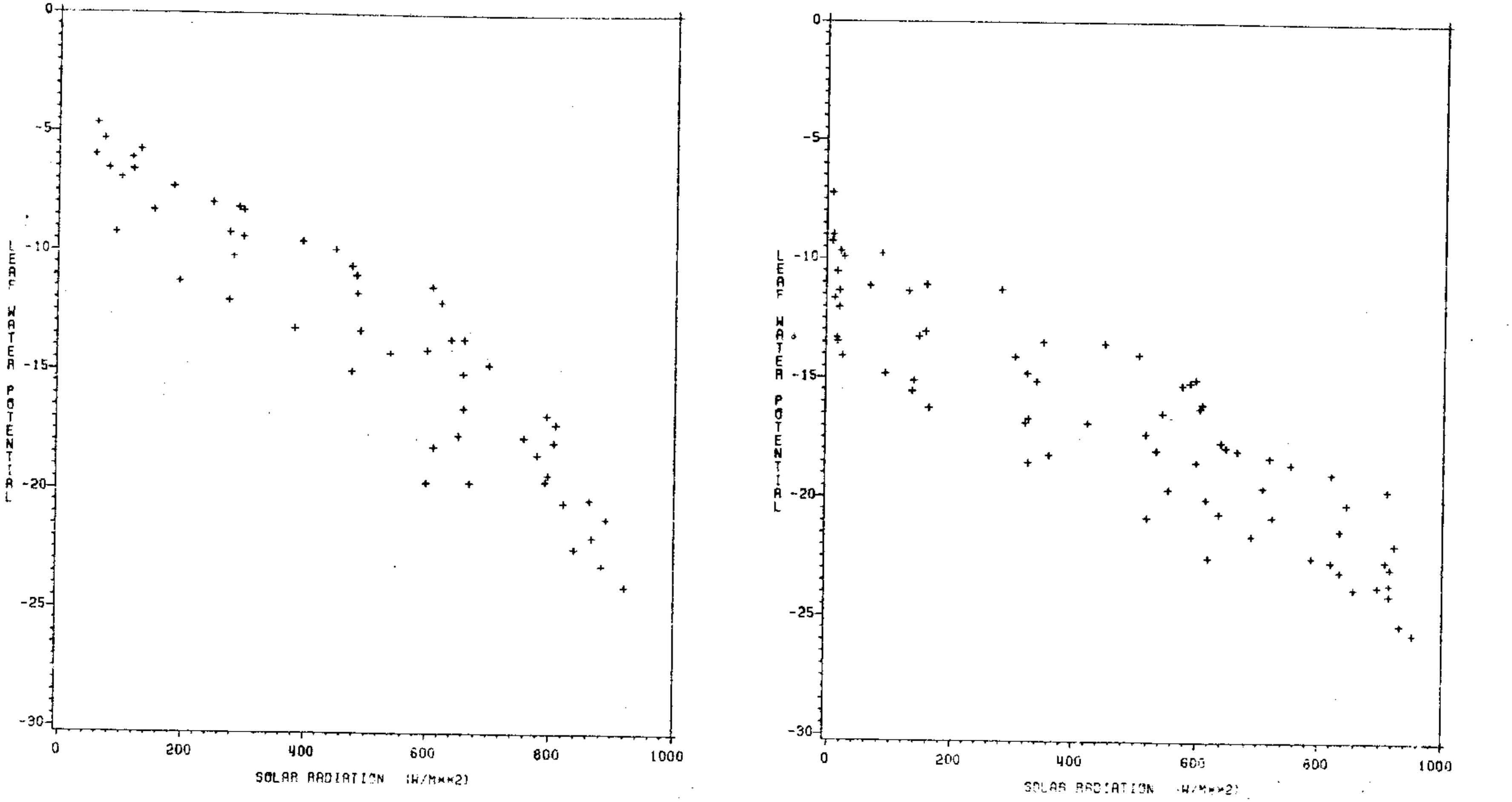

Figure 20: Leaf water potential vs. Solar Radiation for the Exposed 4-emitter tree from 0700 to 1200 hours and from 1300 to 2000 hours.

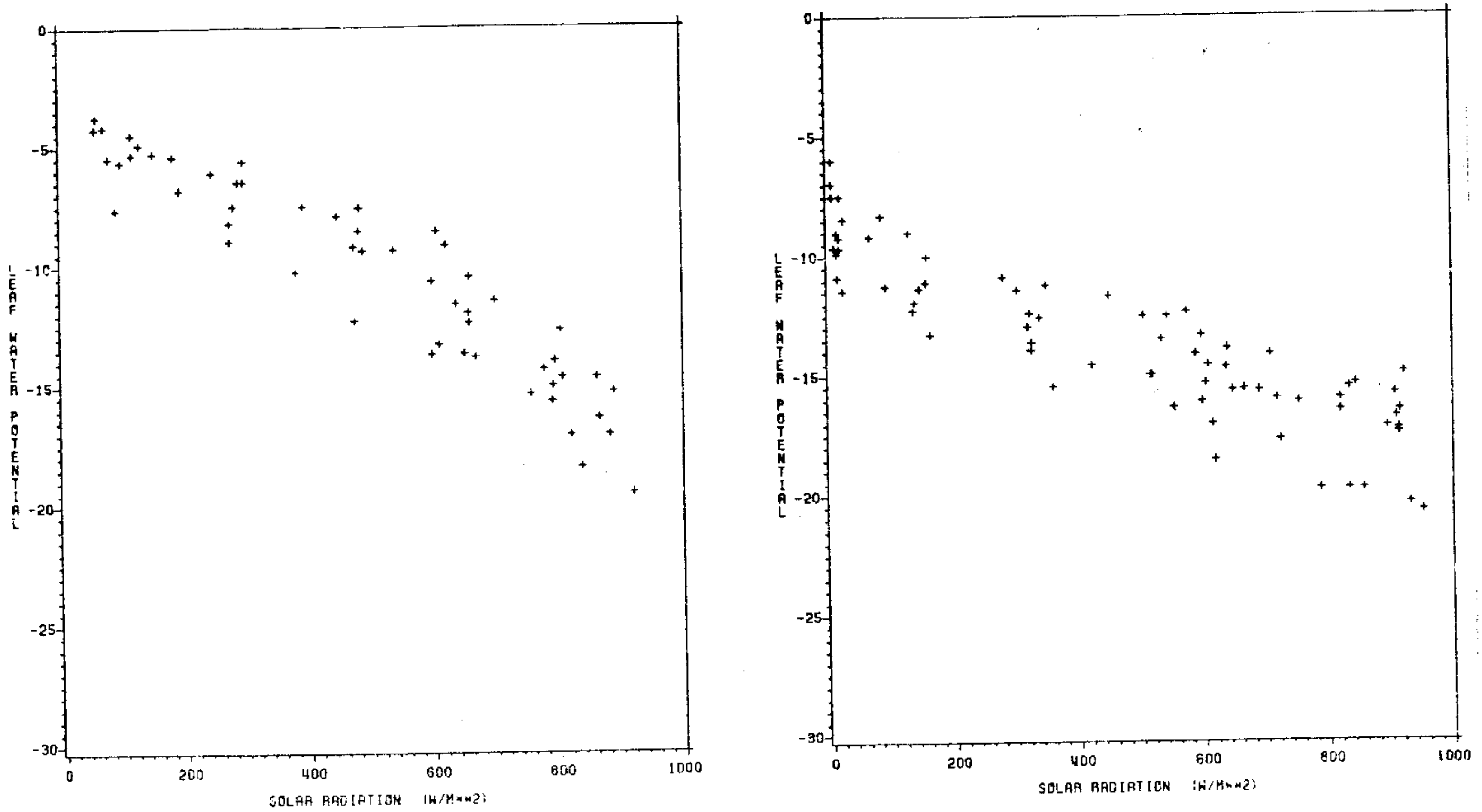

Figure 21: Leaf Water Potential vs. Solar Radiation for the Shaded 4-emitter tree from 0700 to 1200 hours and from 1300 to 2000 hours.

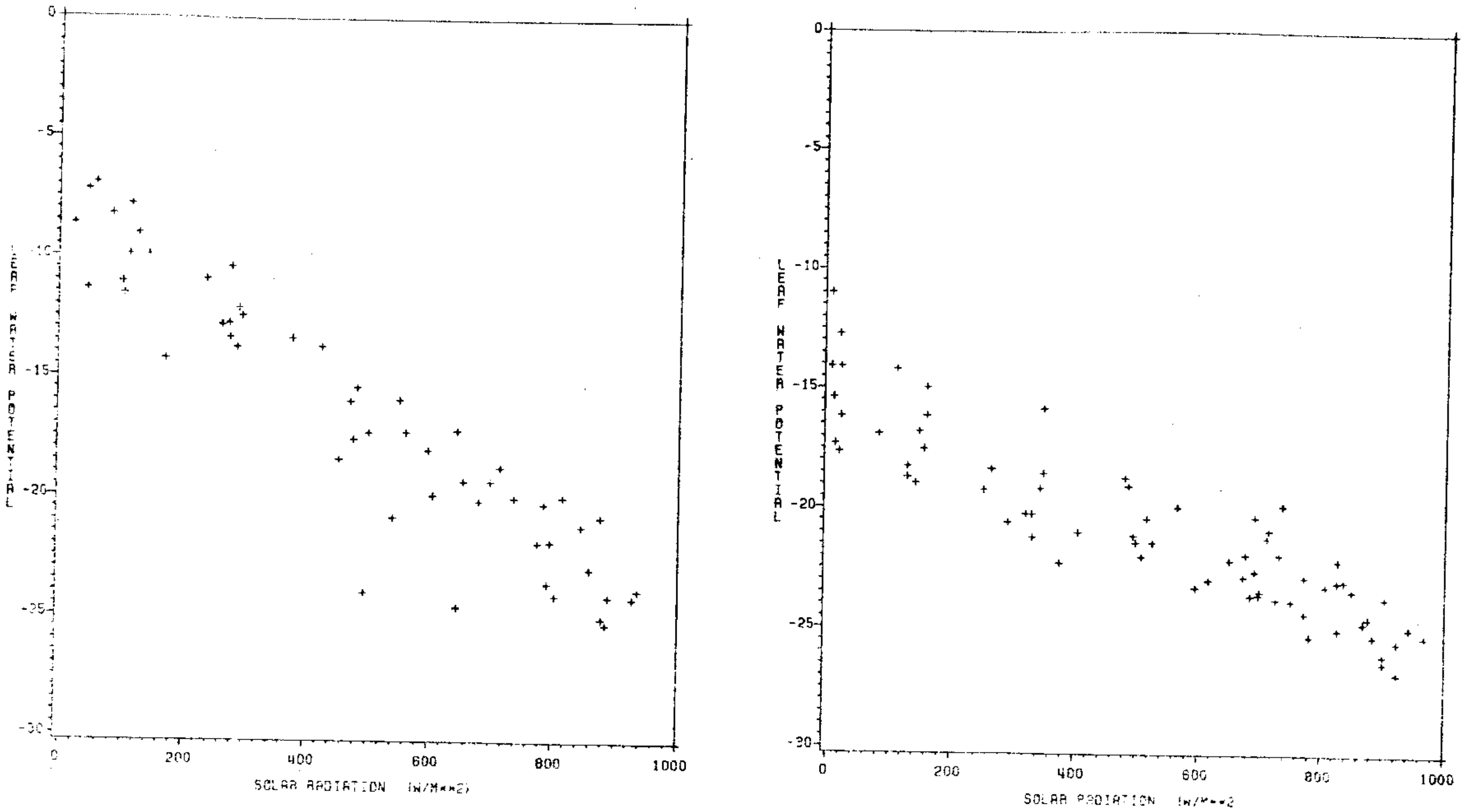

Figure 22: Leaf Water Potential vs. Solar Radiation for the Exposed 1-emitter tree from 0700 to 1200 hours and from 1300 to 2000 hours.

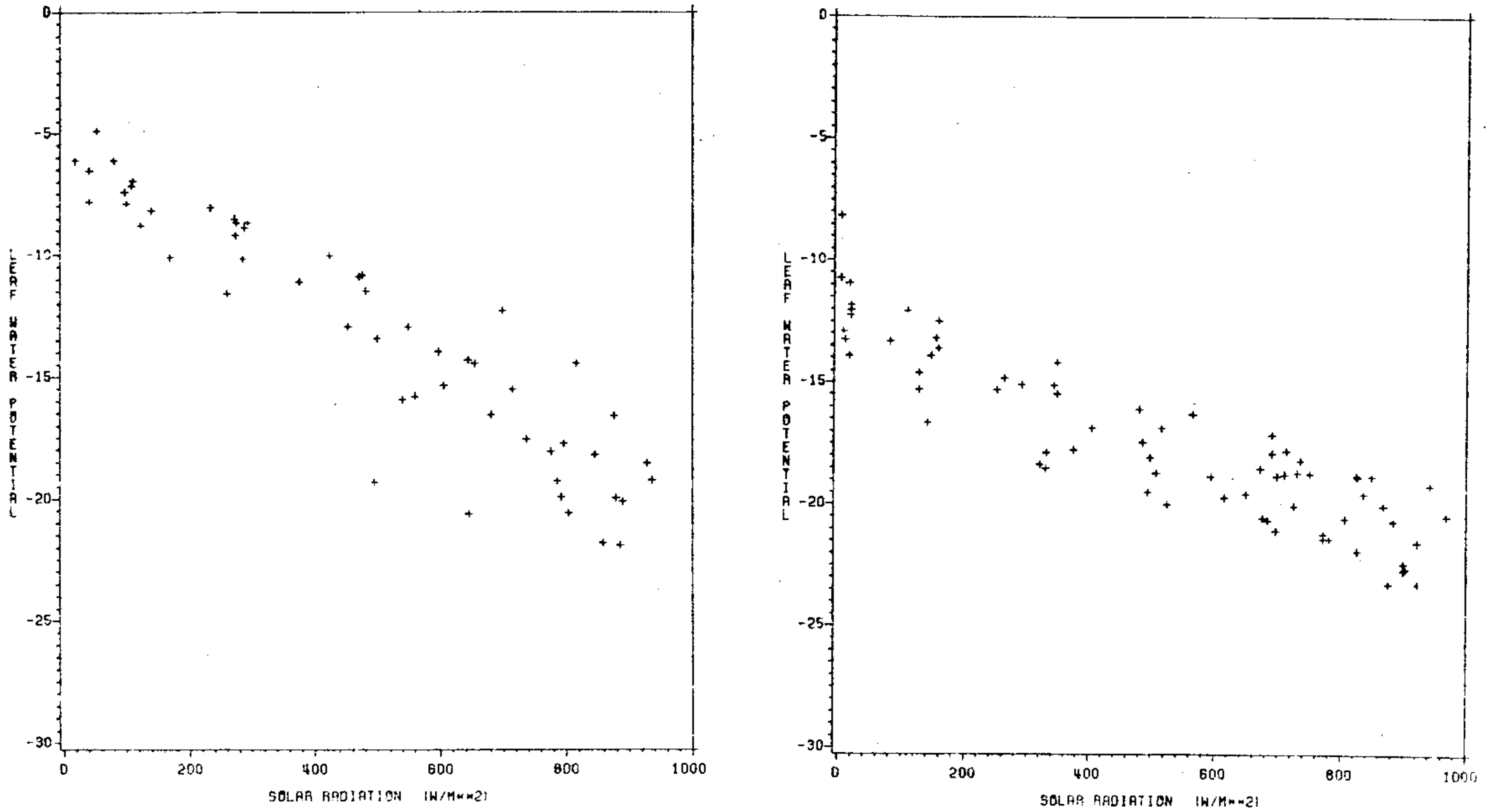

Figure 23: Leaf Water Potential vs. Solar Radiation for the Shaded 1-emitter tree from 0700 to 1200 hours and from 1300 to 2000 hours.

4-emitter tree were between -8 and -14 bars whereas for exposed leaves of the 1-emitter tree wl ranged from -15 to -22 bars. This indicated the 1-emitter tree although exposed to similar environmental stress was additionally being water stressed. The effect of stress was also reflected in the intercept values (value of wl when Rs equals zero) which was -4.4 and -3.2 bars in exposed and shaded leaves respectively, of the 4-emitter tree during the morning period. Intercept values for the 1-emitter tree during the same time period were -8.1 and -5.6 bars in exposed and shaded leaves respectively. Similar differences occurred between 4- and 1-emitter trees for the afternoon period, and suggested that the 1-emitter tree was subjected to greater stress throughout the day.

These results indicate a linear fit may be used to describe the relationship between wl and Rs for non-stressed and stressed trees. Differences in slopes occurred for the morning and afternoon periods and for exposed and shaded leaves. However, within a given time period and degree of exposure there was very little difference in the slopes for the trees. Therefore, early morning and late evening measurements of wl from non-stressed and stressed trees would establish the value of the intercept and could then be used to calculate reasonable estimates of wl from measurements of Rs.

Relationship Between Leaf Resistance and Solar Radiation

Leaf resistances of all treated trees on each measurement day showed diurnal trends. In general rl was lowest between 0900 and 1500 hours, and highest before 0900 and after 1700 hours. Depending on the level of stress in the tree, rl decreased from 0700 to between 1100 and 1300 hours after which it increased. Leaf resistances for each tree are plotted against Rs in Figure 24 to 27. For all treatments rl decreased exponentially with increasing Rs. Jarvis (1976) and Landsberg et al. (1975) have reported similar results for peach trees.

Considerable diurnal hysteresis occurred in rl as in the case of wl. Distinctive opening and closing patterns in rl were noted in both exposed and shaded leaves. Similar results were reported for rl in oak leaves by Hinckley et al. (1975). Leaf resistances were higher in the closing phase than in the opening phase for a given level of solar radiation. In order to reduce the scatter due to hysteresis, measurements taken on each day were divided into two periods consistent with those selected for wl measurements. The opening phase was represented by measurements made from 0700 to 1200 hours whereas the closing phase was represented by measurements made from and from 1300 to 2000 hours.

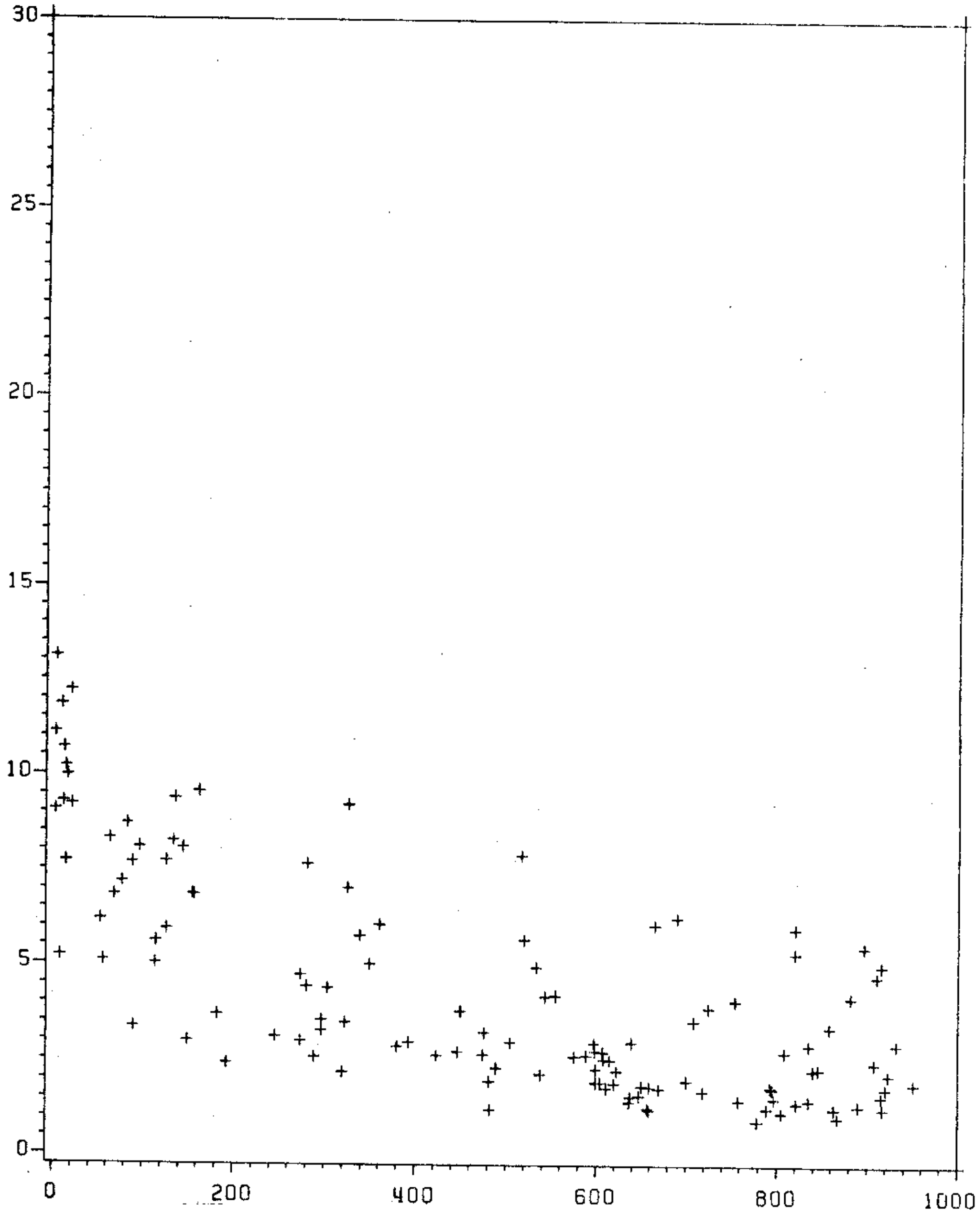

Figure 24: Leaf Resistance vs. Solar Radiation for the Exposed 4-emitter tree from 0700 to 2000 hours.

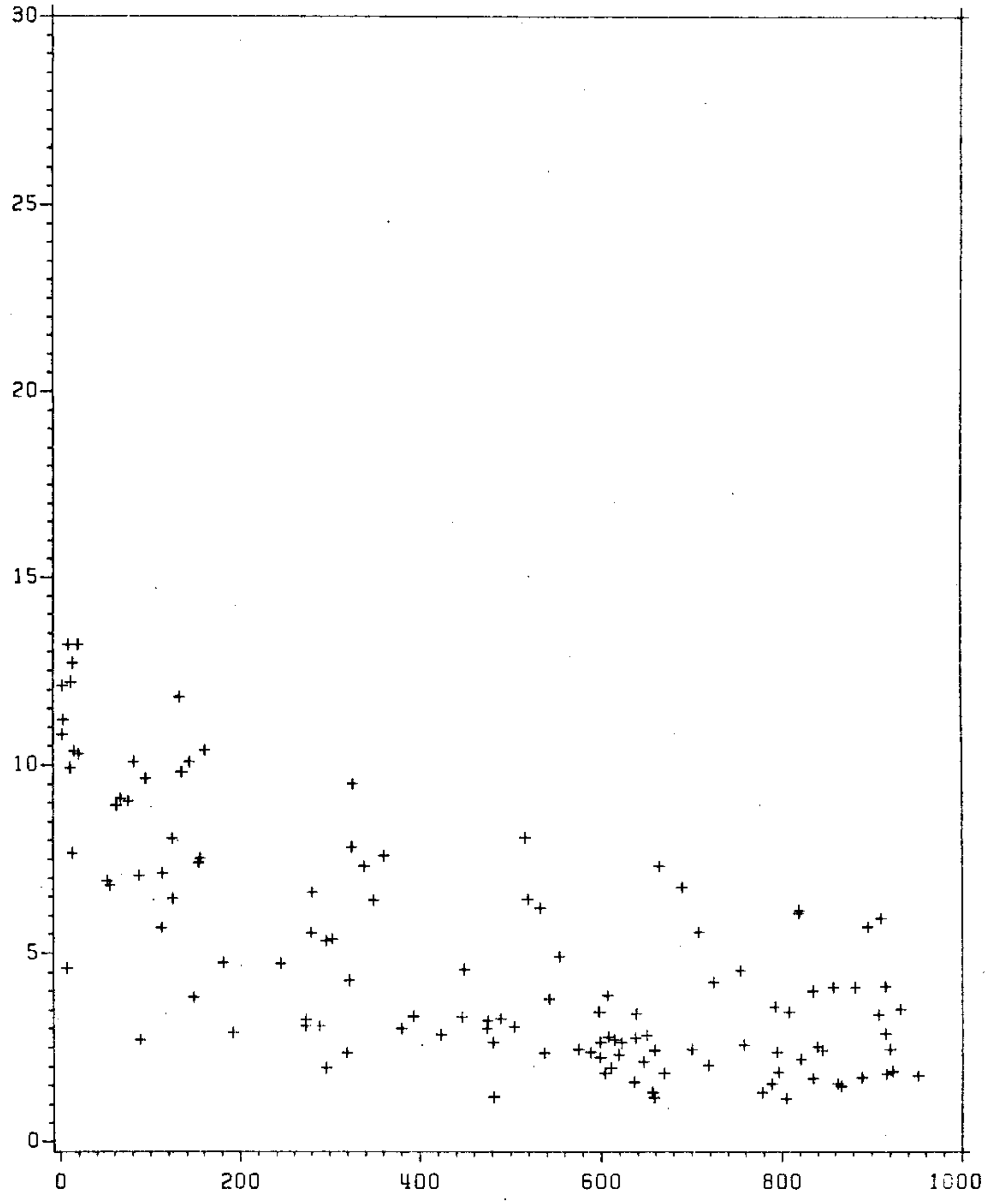

Figure 25: Leaf Resistance vs. Solar Radiation for the Shaded 4-emitter tree from 0700 to 2000 hours.

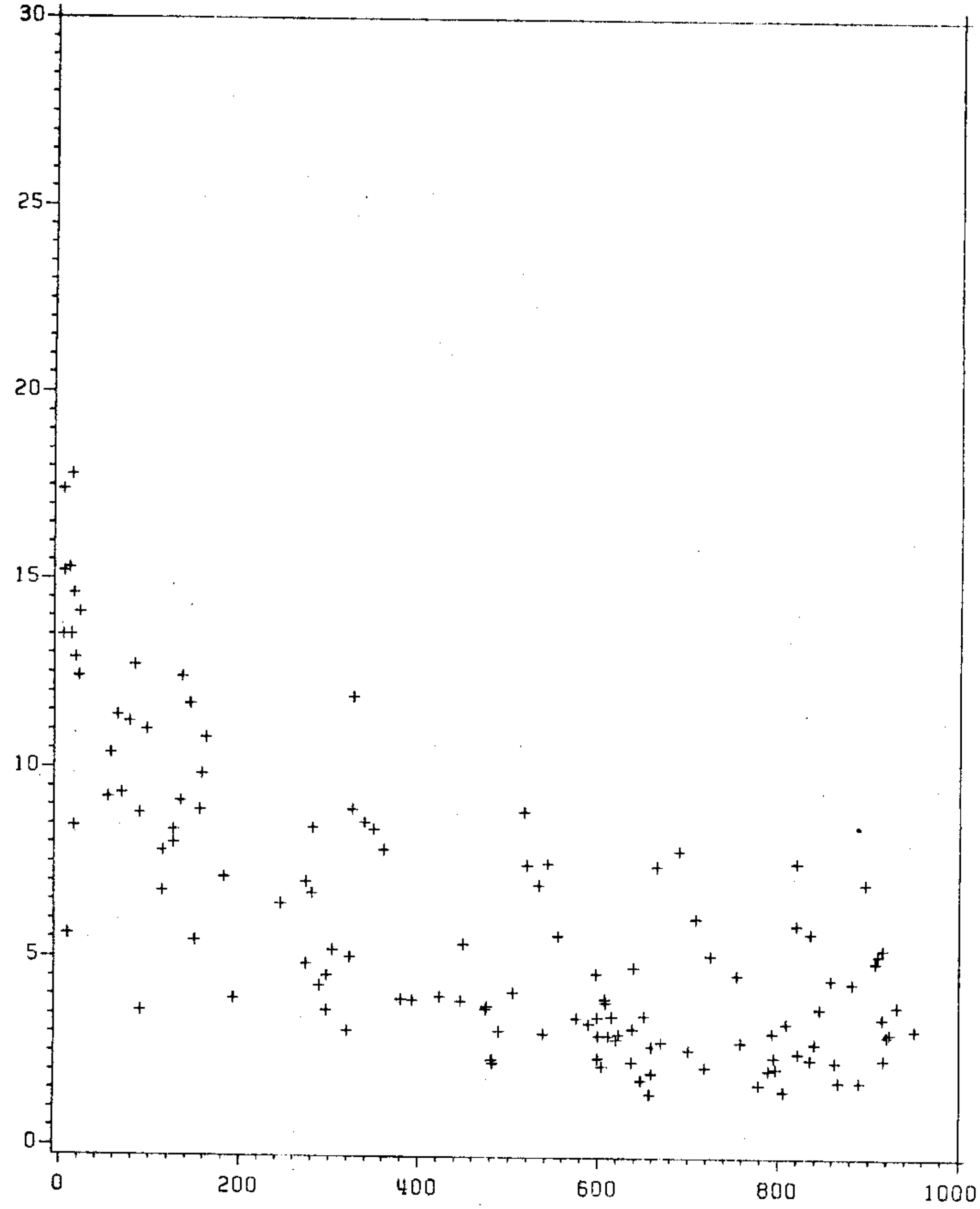

Figure 26: Leaf Resistance vs. Solar Radiation for the Exposed 3-emitter tree from 0700 to 2000 hours.

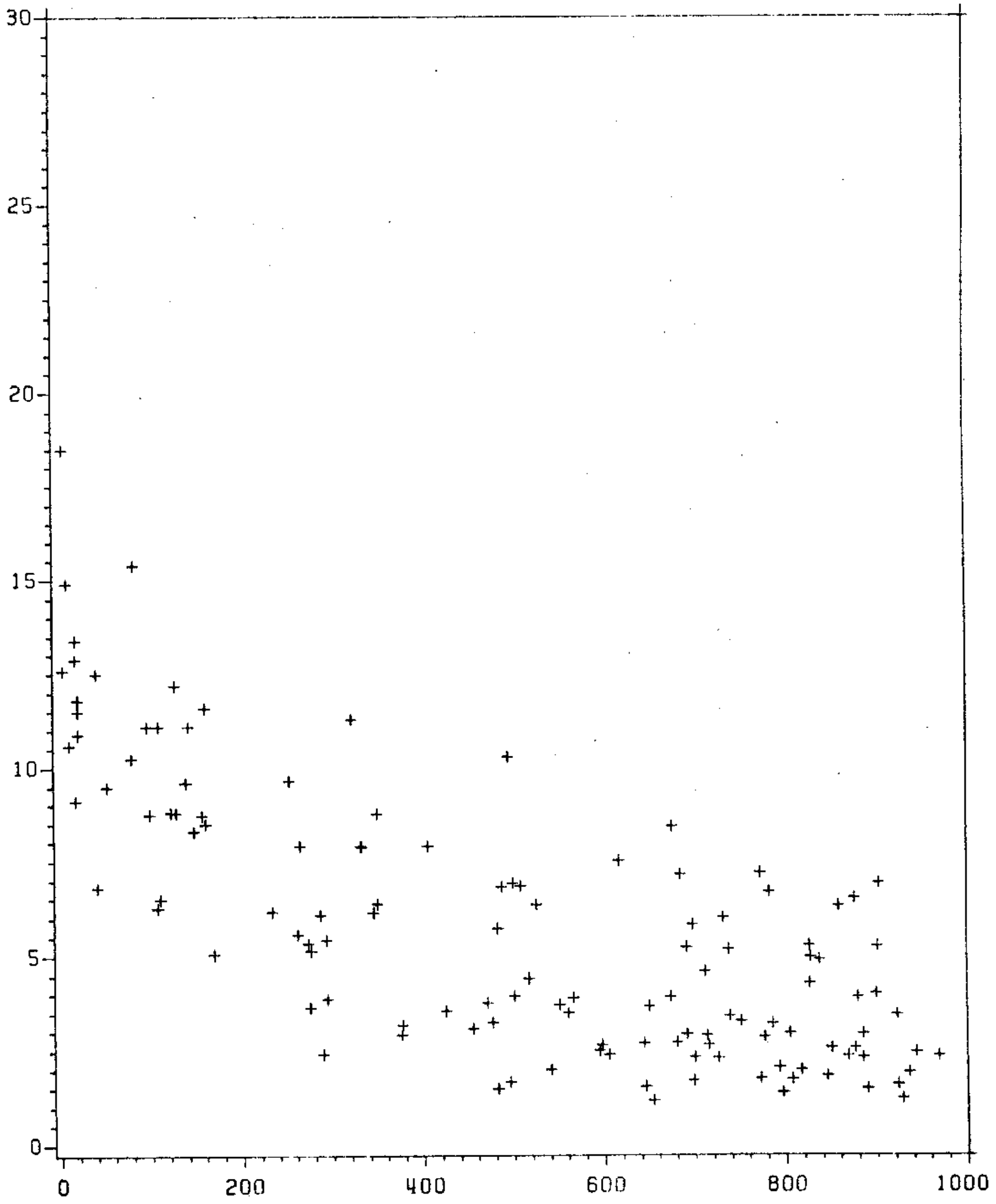

Figure 27: Leaf Resistance vs. Solar Radiation for the Exposed 2-emitter tree from 0700 to 2000 hours.

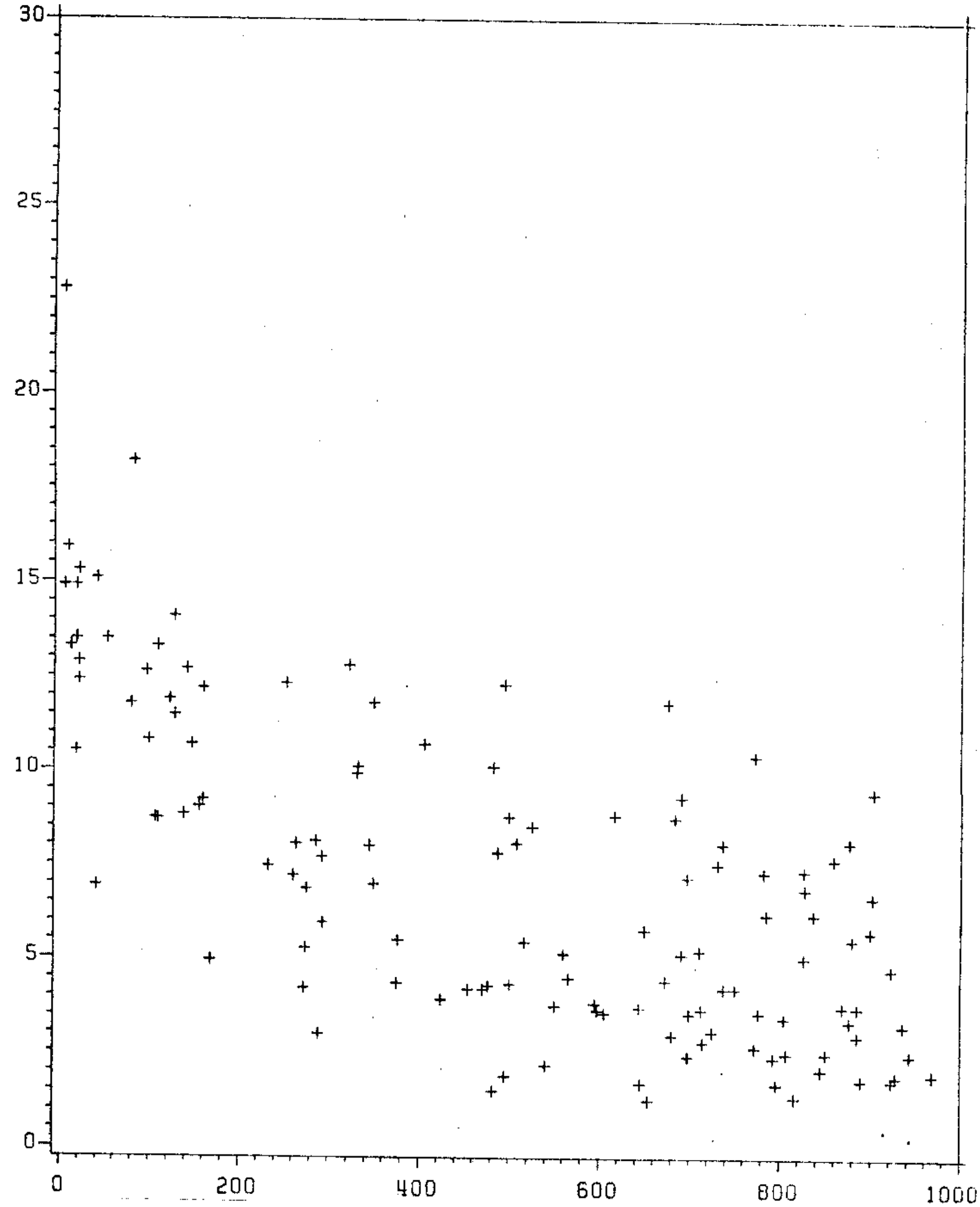

Figure 28: Leaf Resistance vs. Solar Radiation for the Exposed 1-emitter tree from 0700 to 2000 hours.

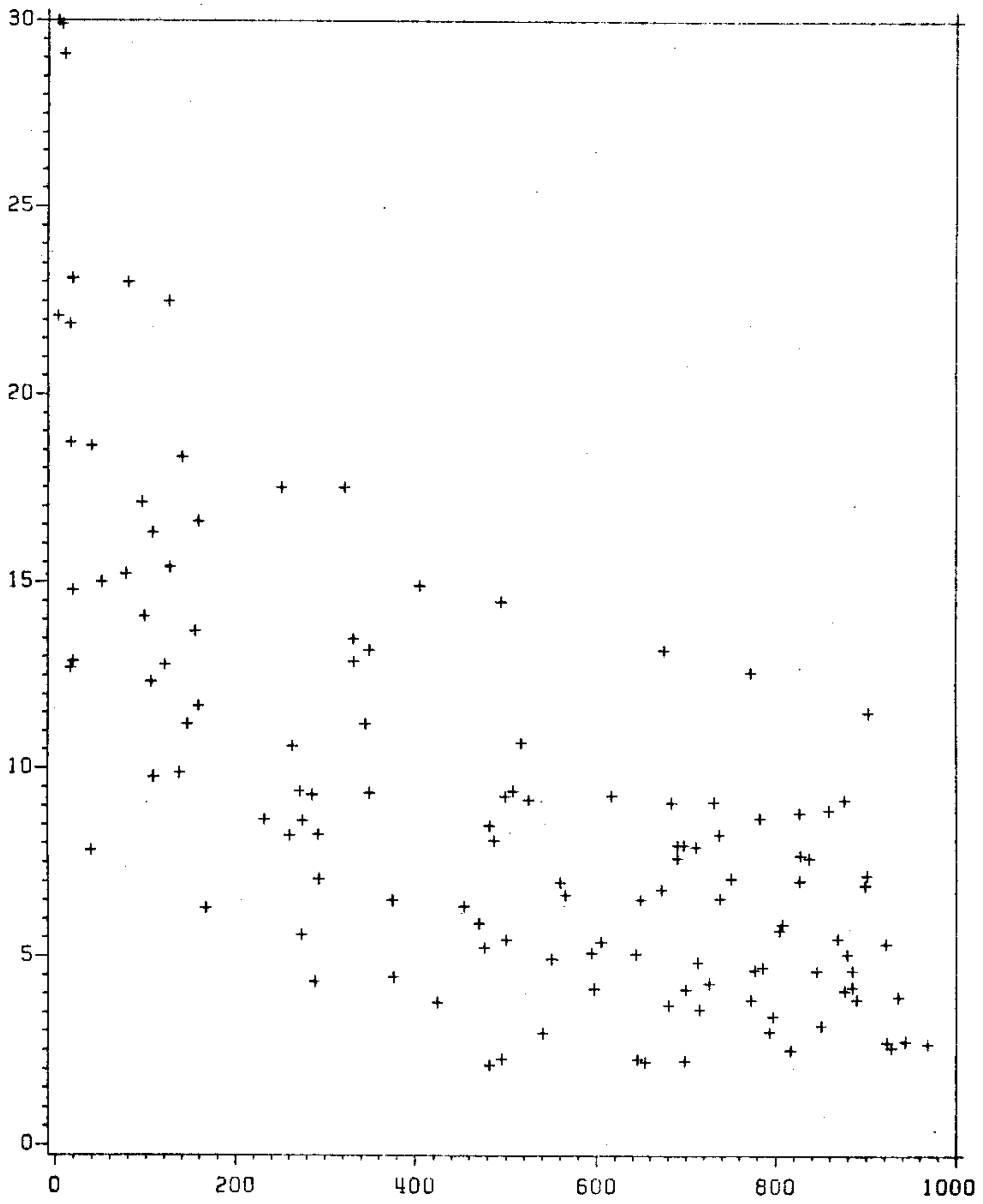

Figure 29: Leaf Resistance vs. Solar Radiation for the Shaded 1-emitter tree from 0700 to 2000 hours.

The closing phase of rl for all trees in both exposed and shaded leaves showed greater scatter in rl as solar radiation decreased beyond 1300 hours. Jarvis (1976), indicated that rl is a function of radiation, ambient CO2 concentration, vapour deficit, leaf temperature and leaf water potential. Since peaks in vapour deficit and leaf temperature lag behind Rs, it may be concluded that they would have a more pronounced effect on rl during the closing phase. Thus higher values of rl were found in the evening closing phase than in the opening phase for a similar level of solar radiation. Similar results were reported by Hinckley et al. (1975) for stomata of white oak leaves. They indicated that the differential response between opening and closing was the result of higher leaf temperatures and vapour deficits, and lower wl during the closing phase.

Stomata of trees with non-limiting soil moisture conditions began to respond at lower levels of Rs than in trees with limiting soil moisture. Figure 24 and 26 showed that stomata were almost fully opened between 250 and 275 $W.m^{-2}$ in exposed leaves of the 4- and 3-emitter trees. Figure 28 and 29 for exposed and shaded leaves of the 1-emitter tree indicated that stomates responded at a slower rate to increasing radiation levels and also required higher light saturation levels. Figure 27 for exposed leaves of the 2-emitter tree indicated stomata were fully opened between 325 and 350 $W.m^{-2}$, and in Figure 28 for exposed leaves of the 1-emitter tree stomata were fully opened between 400 and 425 $W.m^{-2}$.

The principal factors that regulate stomatal behaviour are solar radiation and soil moisture content (Singh and Szeicz, 1980). They found the amount of radiation initiating stomatal opening in both maple and beech leaves was about 7 to 14 $W.m^{-2}$, and as high as 105 $W.m^{-2}$ when leaves were senescing. Stomata were fully opened at 210 $W.m^{-2}$ when soil moisture was not limiting. Hinckley et al. (1975), found stomata of white oak appeared to be light saturated at 112 to 125 $W.m^{-2}$ in exposed leaves and 139 to 153 $W.m^{-2}$ in shaded leaves. Comparisons of these results suggests that saturation light intensities differ from species to species.

Singh and Szeicz (1980), also reported the value of minimum rl depends on soil moisture conditions, and were twice as high during the dry season. Stomata of peach leaves for the treated trees opened only slightly with increasing solar radiation, once the stomates were light saturated. Minimum rl in exposed leaves of 4- and 3-emitter trees during the opening phase was about 1.5 $s.cm^{-1}$, and increased to 3 $s.cm^{-1}$ in the 1-emitter tree. Similarly for shaded leaves the 4-emitter tree had a minimum rl of 2.0

$s.cm^{-1}$ which increased to 3.5 $s.cm^{-1}$ in the 1-emitter tree. Therefore, as soil moisture becomes limiting there is an upward shift in the entire diurnal trend of rl (Dougherty, 1973).

Relationship Between Leaf Water Potential and Leaf Resistance

The relationship between wl and rl showed pronounced diurnal hysteresis. Differences in the relationship was subject to different irrigation regimes and between exposed and shaded leaves.

Figures 30 to 33 for the well-watered 4- and 3-emitter trees showed decreasing rl was associated with decreasing wl until a minimum rl and a corresponding minimum wl had been reached, after which both rl and wl increased. Figure 34 and 36 showed exposed leaves of the 4- and 3- emitter tree had lower rl values from 0700 to 1200 hours. Highest values of rl between 5 and 10 $s.cm^{-1}$ occurred at 0700 and decreased to between 2 and 3 $s.cm^{-1}$ as wl decreased from -5 to -12 bars. There was little change in rl as wl decreased from -12 to -21 bars, and started to increase in rl as wl decreased below -21 bars.

The closing phase of rl for exposed leaves of both 4- and 3- emitter trees showed greater scatter than the opening phase. In general rl increased as wl increased from -25 to -15 bars and increased rapidly as wl increased beyond -15

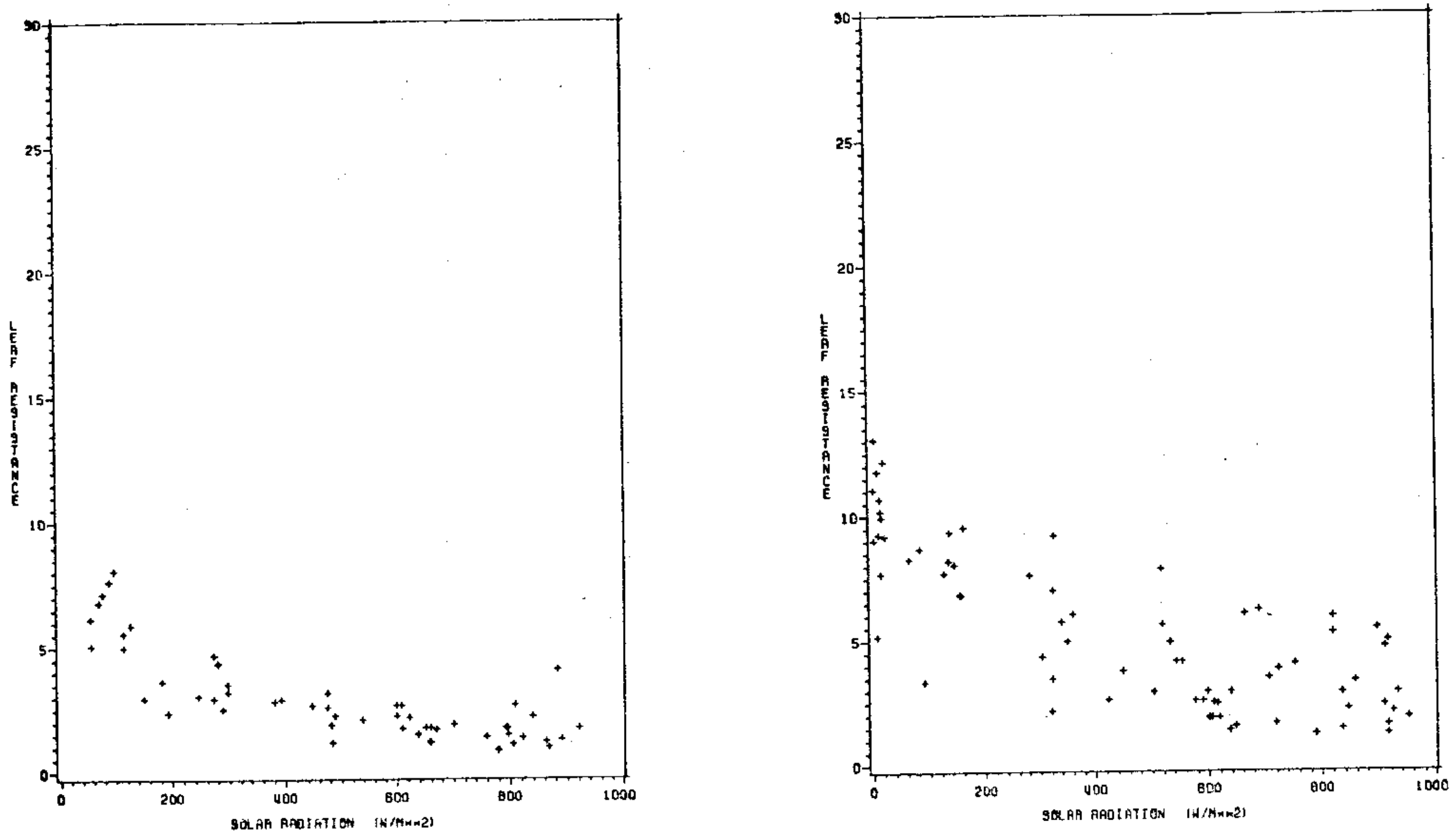

Figure 30: Leaf Resistance vs. Solar Radiation for the Exposed 4-emitter tree from 0700 to 1200 hours and from 1300 to 2000 hours.

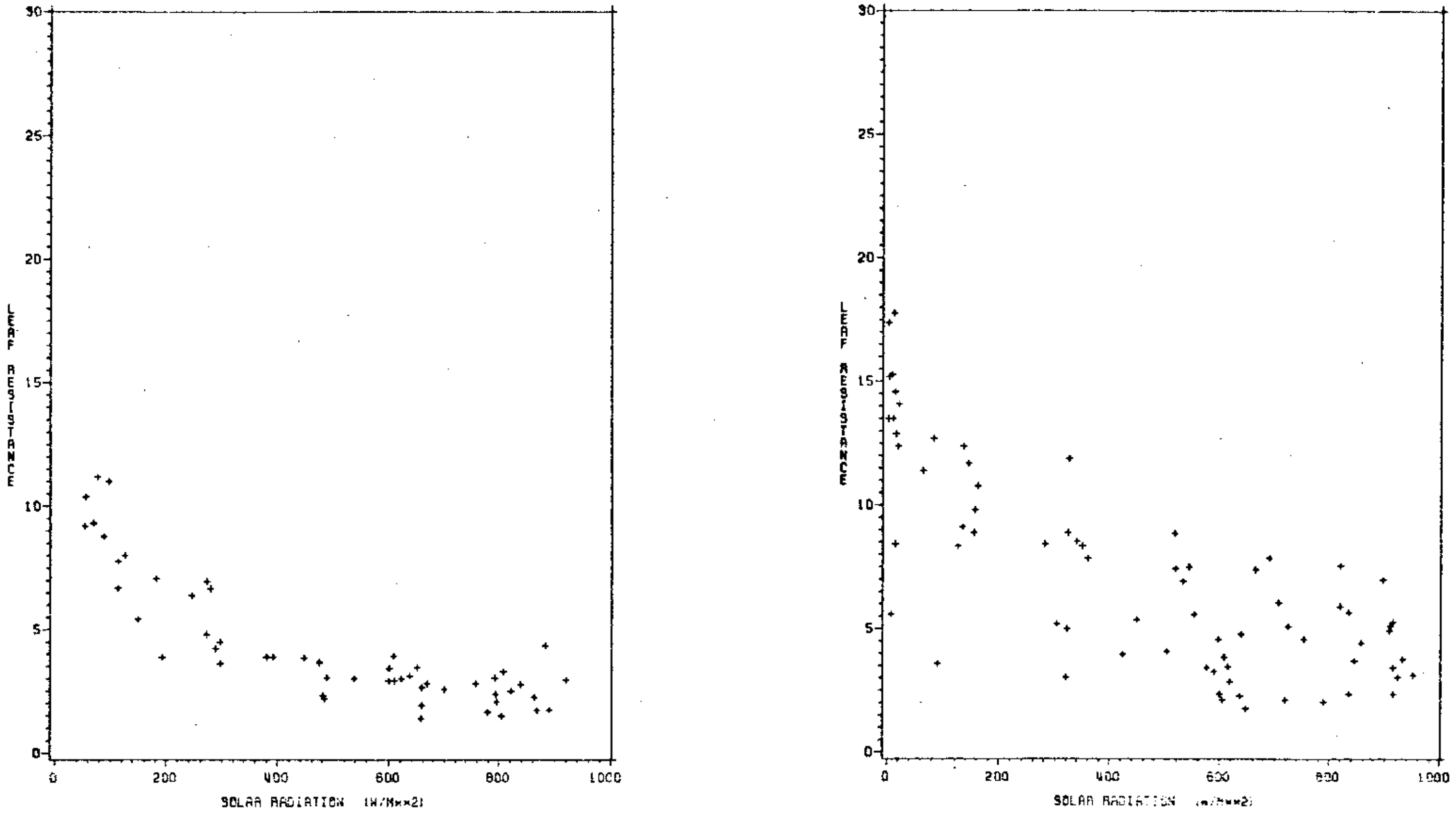

Figure 31: Leaf Resistance vs. Solar Radiation for the Shaded 4-emitter tree from 0700 to 1200 hours and from 1300 to 2000 hours.

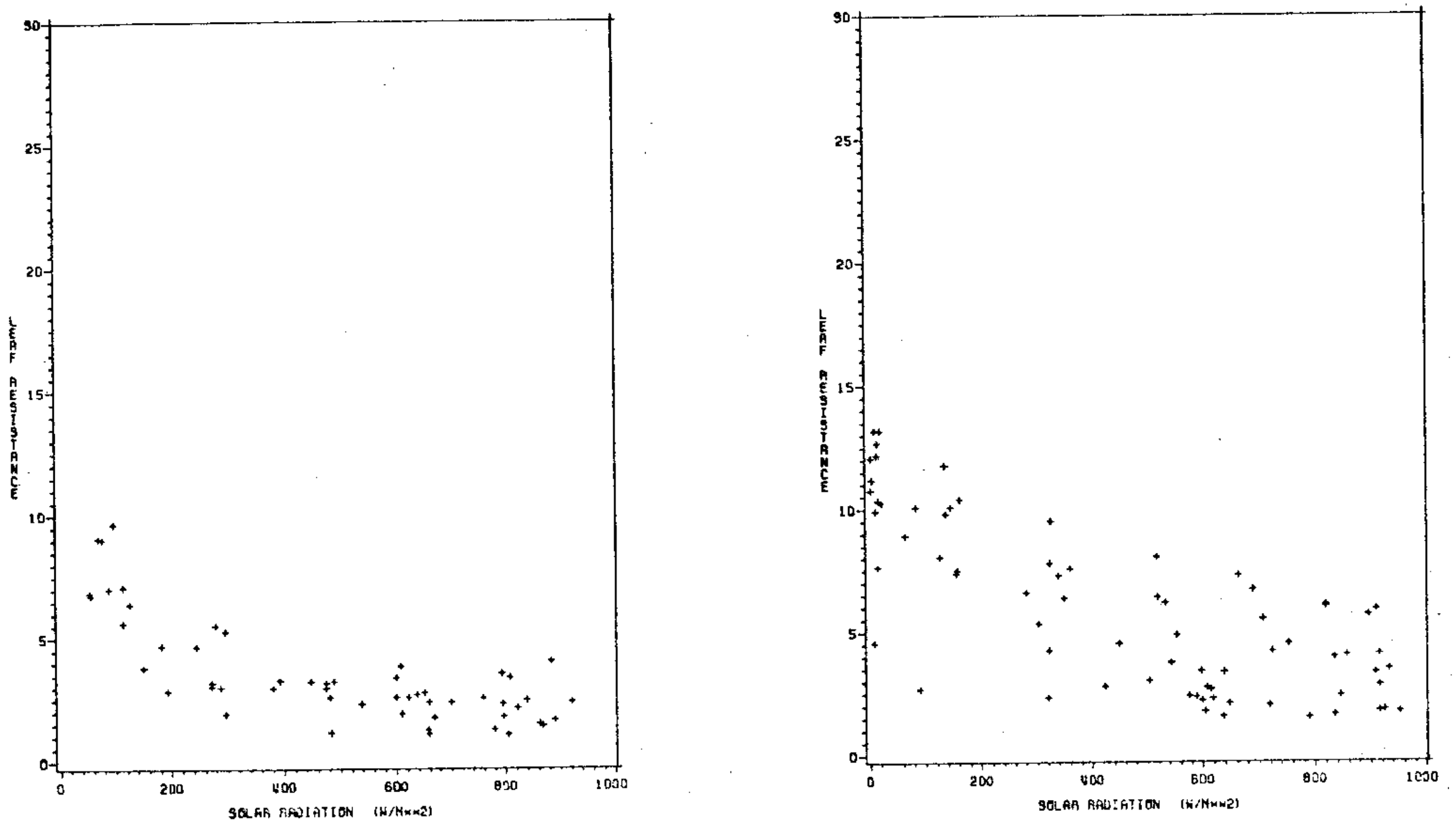

Figure 32: Leaf Resistance vs. Solar Radiation for the Exposed 3-emitter tree from 0700 to 1200 hours and from 1300 to 2000 hours.

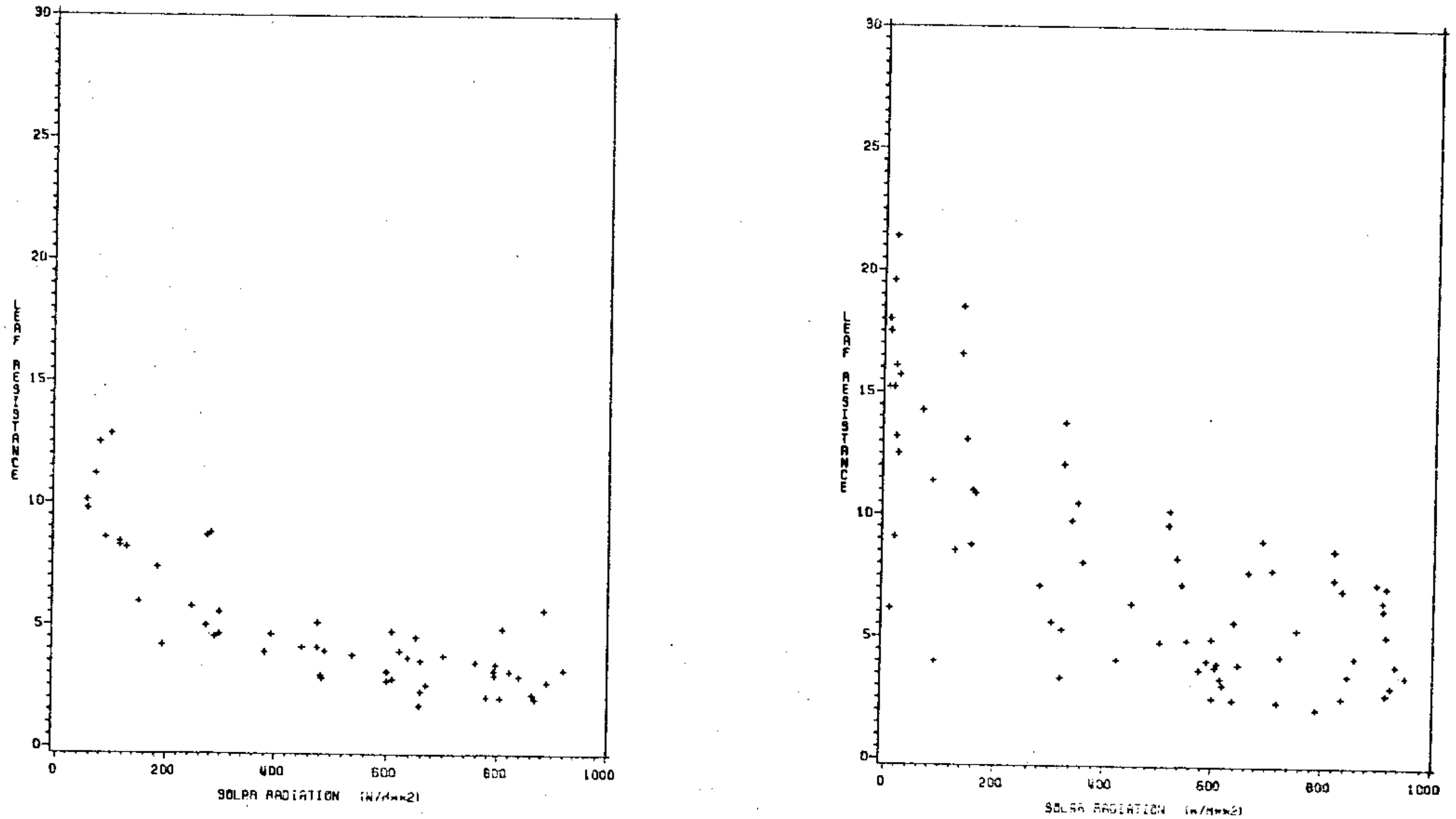

Figure 33: Leaf Resistance vs. Solar Radiation for the Shaded 3-emitter tree from 0700 to 1200 hours and from 1300 to 2000 hours.

bars. Leaf resistance measured during late evening were considerably higher than those measured during early morning.

Shaded leaves of the 4- and 3-emitter trees in Figure 31 and 33 for the opening phase showed rl was between 5 and 10 s.cm^{-1} at 0700 and wl was between -3 and -6 bars. From 0800 to 1200 wl dropped to -20 bars whereas rl decreased little and remained in a relatively narrow range of 2 to 5 s.cm^{-1}. Slight increase in rl occurred as wl dropped below -18 bars. This would suggest the critical wl of shaded leaves for well-watered trees was -18 bars and for exposed leaves was -21 bars. In the closing phase rl increased as wl increased, gradually at first and later more rapidly. Late evening values of rl were considerably higher, 12 to 18 s.cm^{-1} as opposed to early morning measurements of rl that ranged from 5 to 10 s.cm^{-1}.

Exposed leaves of the 2- and 1-emitter trees in Figure 34 and 36 showed similar trends as the 4- and 3- emitter trees. However, wl were much lower early in the day for the 2- and 1-emitter trees. There was also a shift in the curve to the right between -10 to -20 bars indicating higher values of rl in the 2- and 1-emitter trees. A combination of lower wl and higher rl would suggest the 2- and 1-emitter trees were under greater stress during the day. It should also be noted that stomata of exposed leaves of the 2- and

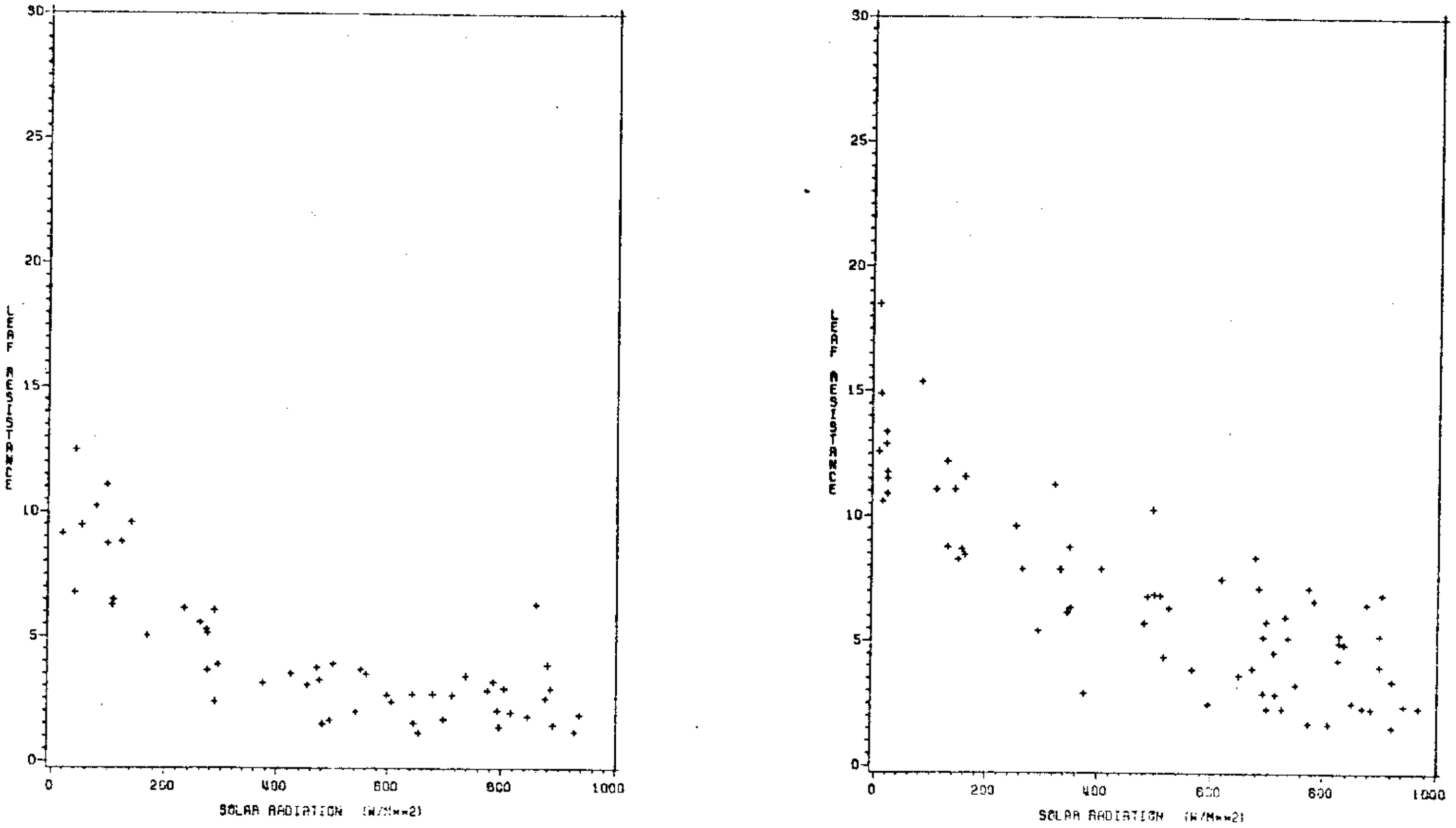

Figure 34: Leaf Resistance vs. Solar Radiation for the Exposed 2-emitter tree from 0700 to 1200 hours and from 1300 to 2000 hours.

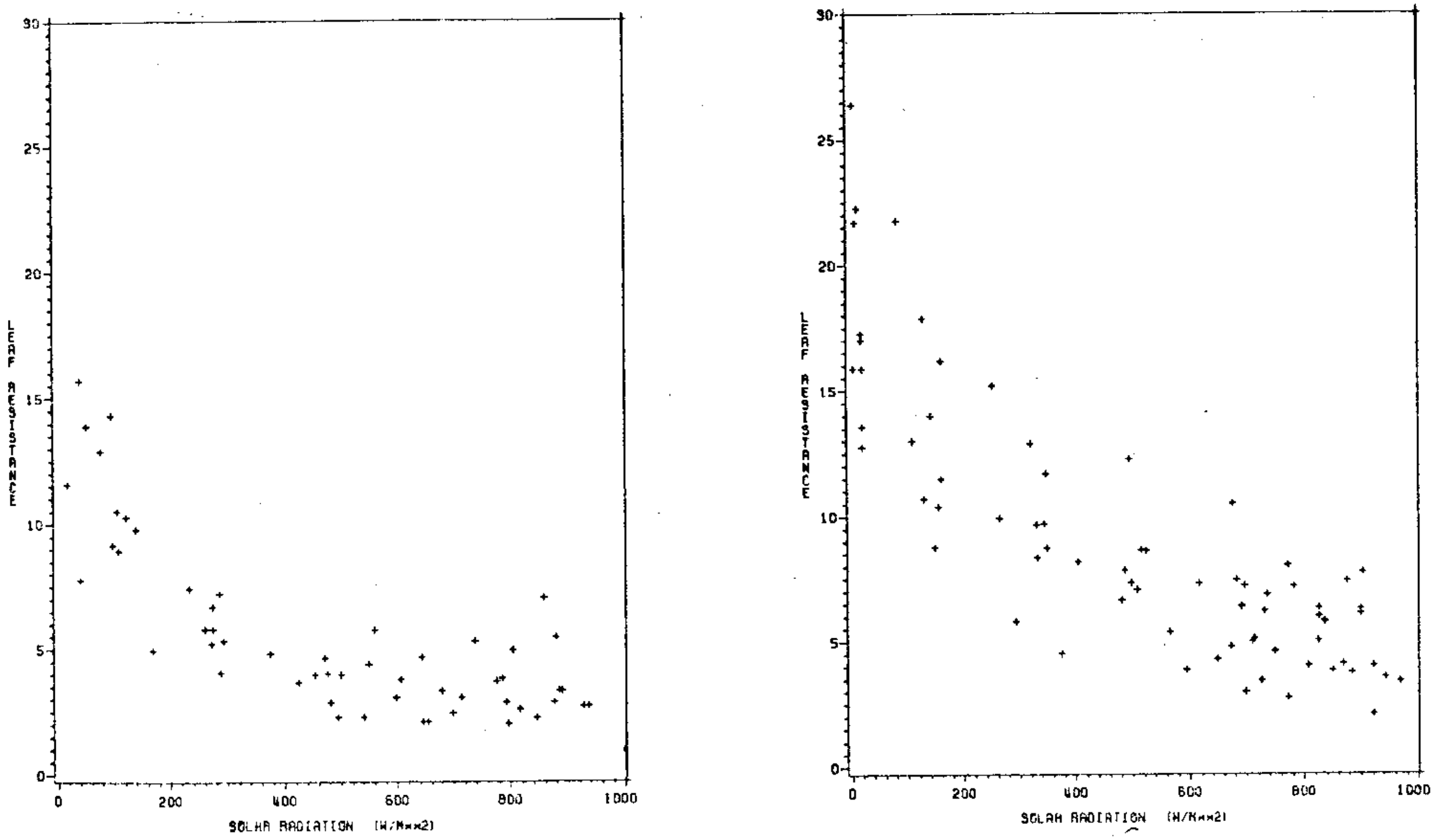

Figure 35: Leaf Resistance vs. Solar Radiation for the Shaded 2-emitter tree from 0700 to 1200 hours and from 1300 to 2000 hours.

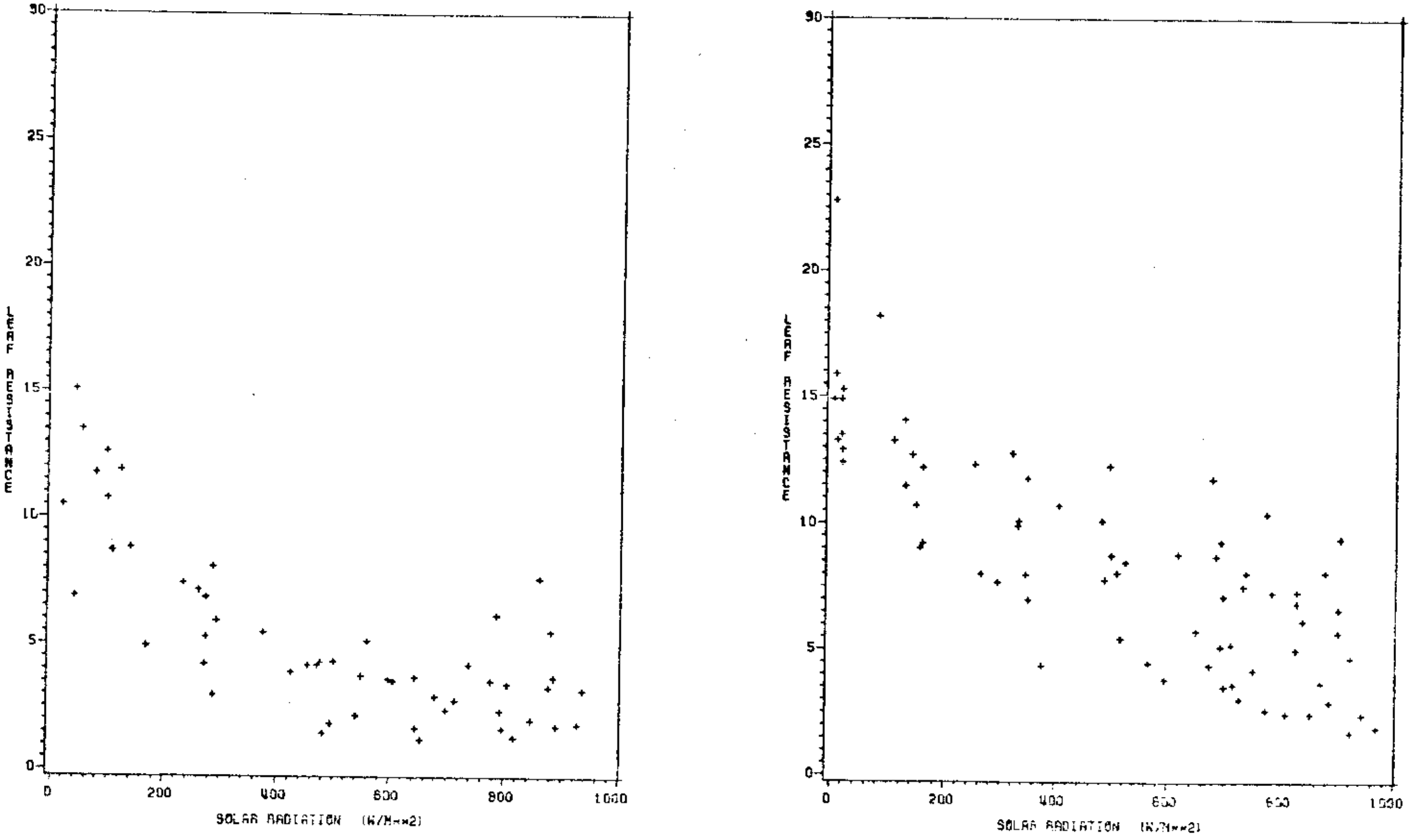

Figure 36: Leaf Resistance vs. Solar Radiation for the Exposed 1-emitter tree from 0700 to 1200 hours and from 1300 to 2000 hours.

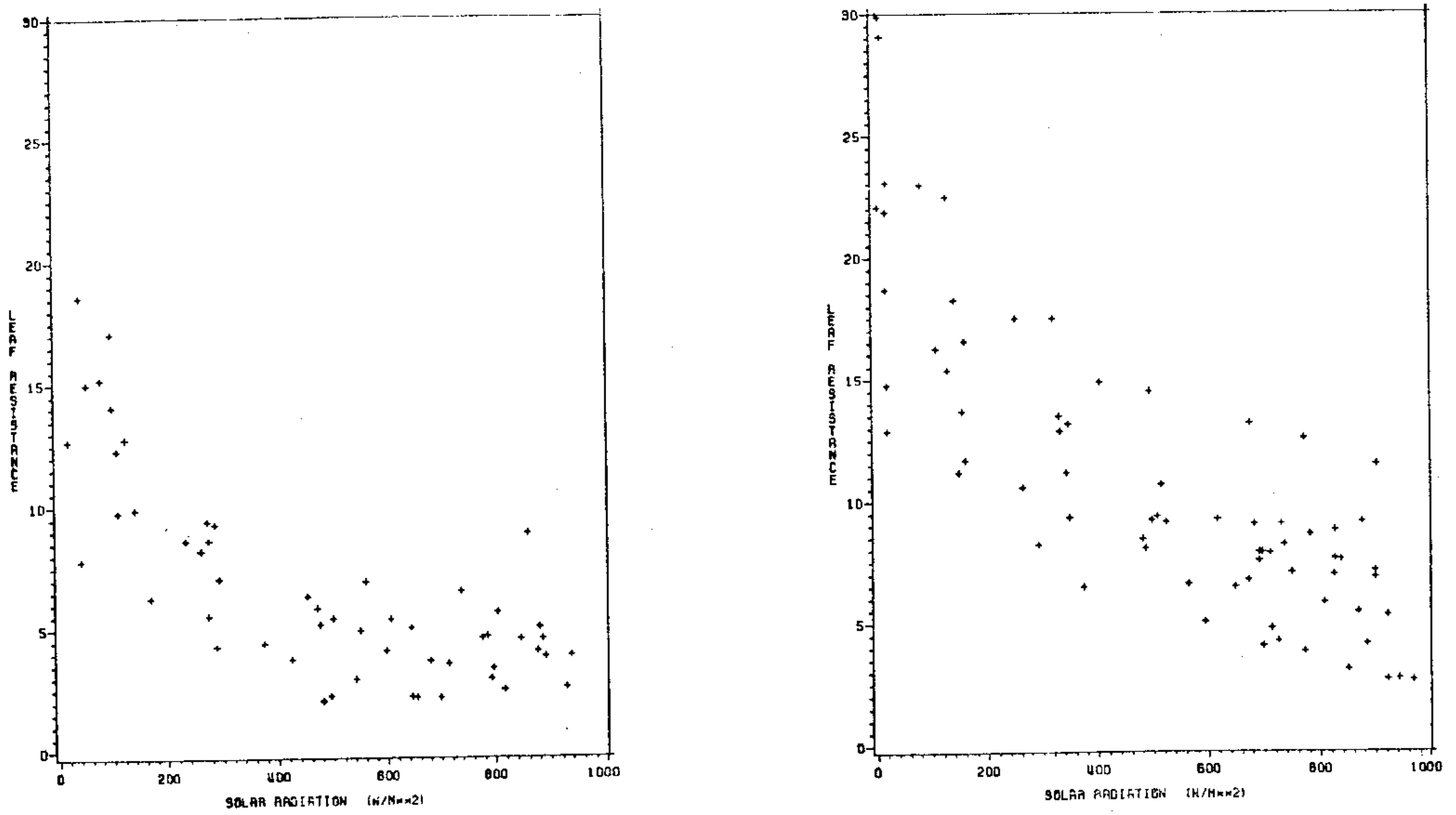

Figure 37: Leaf Resistance vs. Solar Radiation for the Shaded 1-emitter tree from 0700 to 1200 hours and from 1300 to 2000 hours.

1-emitter trees remained open (rl 5 s.cm^{-1}) even at low wl of -25 bars suggesting there may have been some degree of adaptation to stress in these trees. During the closing phase, exposed leaves of the 2- and 1-emitter trees showed rapid increase in rl whereas wl increased at a slower rate. In the range of wl from -15 to -20 bars, the 2- and 1-emitter tree rl was considerably higher than for the 4- and 3-emitter tree in the same range of wl. Lower wl and higher rl values indicated the trees had not fully recovered even though environmental stress had considerabley lessened.

Shaded leaves of 2- and 1-emitter trees in Figure 35 and 37 during the opening phase showed a hyperbolic relationship between wl and rl. Rapid decrease in rl from 15 to 5 s.cm^{-1} occurred as wl decreased from -5 to -10 bars, after which there was little change in rl as wl dropped further to -20 bars. The closing phase in Figure 35 and 37 showed rl increased rapidly as wl increased. Leaf resistances were between 15 and 25 s.cm^{-1} during late evening and were much higher than those measured for the 4- and 3-emitter trees at the same time.

These results suggest that the relationship between wl and rl would vary according to the degree of stress the plant was being subjected to. Limiting soil moisture conditions and, or physiological stress caused by a heavy fruit load would also affect this relationship. Thus the value of rl and wl in plants subjected to similar environmental conditions would depend on the water status of the plant and thus indirectly on the soil water potential.

Relationship Between Leaf Water Potential and Transpiration

Up to the present a great many studies have been done in order to understand the relationship between wl and Tr. However, most of these have been carried out in laboratory environments where it has been difficult to simulate field conditions. Landsberg et al. (1975, 1976) carried out an extensive field, laboratory and theoretical study of water movement in apple trees. More recently Jones et al. (1982) and Zur et al. (1982) carried out a comprehensive field study of plant resistance to water flow in field soyabeans under non-limiting and limiting soil moisture.

Hansen (1974a), indicated stomatal resistance, photosynthesis, and growth are strongly related to water status. It is therefore desirable to be able to predict water status of plants subjected to varying soil moisture conditions and atmospheric demands. The rate of water flow through the plant and the soil depends upon the difference in water potential between the leaves and the source of water in the bulk soil (ws), and on the sum of resistances (rs + rp) to liquid flow between the source of water in the soil and the leaves (Landsberg et al., 1975; Rose et al., 1976). Therefore by taking Tr to be an estimate of rate of flow, and ignoring the capacitance of the plants,

$$Tr = (ws - wl) / (rs + rp) \qquad \text{---------------[25]}$$

Rearranging this equation gives:

$$wl = ws - Tr(rs + rp) \qquad \text{---------------[26]}$$

Where: rs = soil resistance to flow ($bar.m^2.s.ug^{-1}$)

rp = plant resistance to flow ($bar.m^2.s.ug^{-1}$)

Hailey (1971), indicated rp is constant if the relationship between transpiration rate versus leaf water potential is linear. The absolute value of the slope represents an effective internal plant resistance.

Hansen (1974a, 1974b) has suggested that wl might influence rp. It was explained that the relationship between wl and rp is due to change in Tr with change in wl rather than to direct influence of rp by water stress. Total resistance (rs + rp) was shown to increase curvilinearly with decreasing wl.

Jones et al. (1982) and Zur et al. (1982) found rp was not constant and decreased as Tr increased from morning hours to midday. During the afternoon hours a decrease in Tr was accompanied by an increase in rp. Lowest values of rp occurred during midday. They found a curvilinear relationship between rp and Tr. This is in contrast with the results found by Lascano (1977) that rp is constant for soyabeans. Their results agree with Hailey (1973) showing an increase in rp with age.

Four sets of consecutive days during the growing season were selected in order to examine the relationship between wl and Tr of peach leaves in the field. The days selected were consistent with those selected for earlier discussion and represent periods in the growing season when most pronounced changes occurred. Concurrent measurements of Tr and wl on exposed and shaded leaves of each treated tree for each day were plotted together. Measurements were taken hourly from 0700 to 2000 hours and under a wide range of existing field conditions, and are shown in Figure 38 and 39. A reasonably good linear fit was obtained only on days when the trees were not being stressed. R^2 were much lower for the 1-emitter tree than the 4-emitter tree.

Figure 40, shows the relationship between wl and Tr for the 4- and 3-emitter trees on day 170. For both trees wl decreased linearly with increasing Tr rate. R^2 were 0.88 and 0.78 for the 4- and 3-emitter trees respectively. The 2 and 1 emitter trees on day 171 are shown in Figure 41. These also show a reasonable linear fit with R^2 of 0.75 and 0.73 for the 2- and 1-emitter tree respectively. Similar

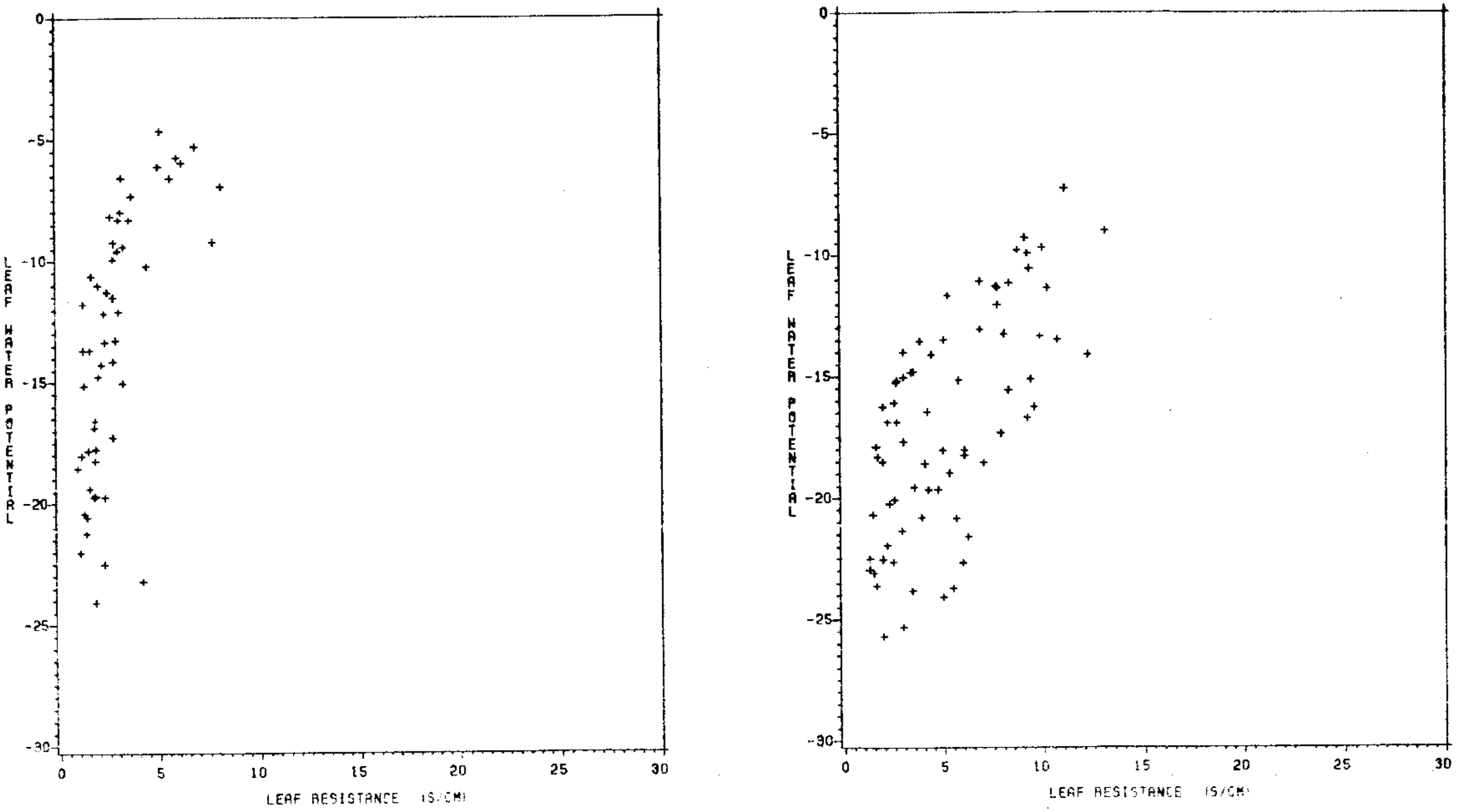

Figure 38: Leaf Water Potential vs. Leaf Resistance for the Exposed 4-emitter tree from 0700 to 1200 hours and from 1300 to 2000 hours.

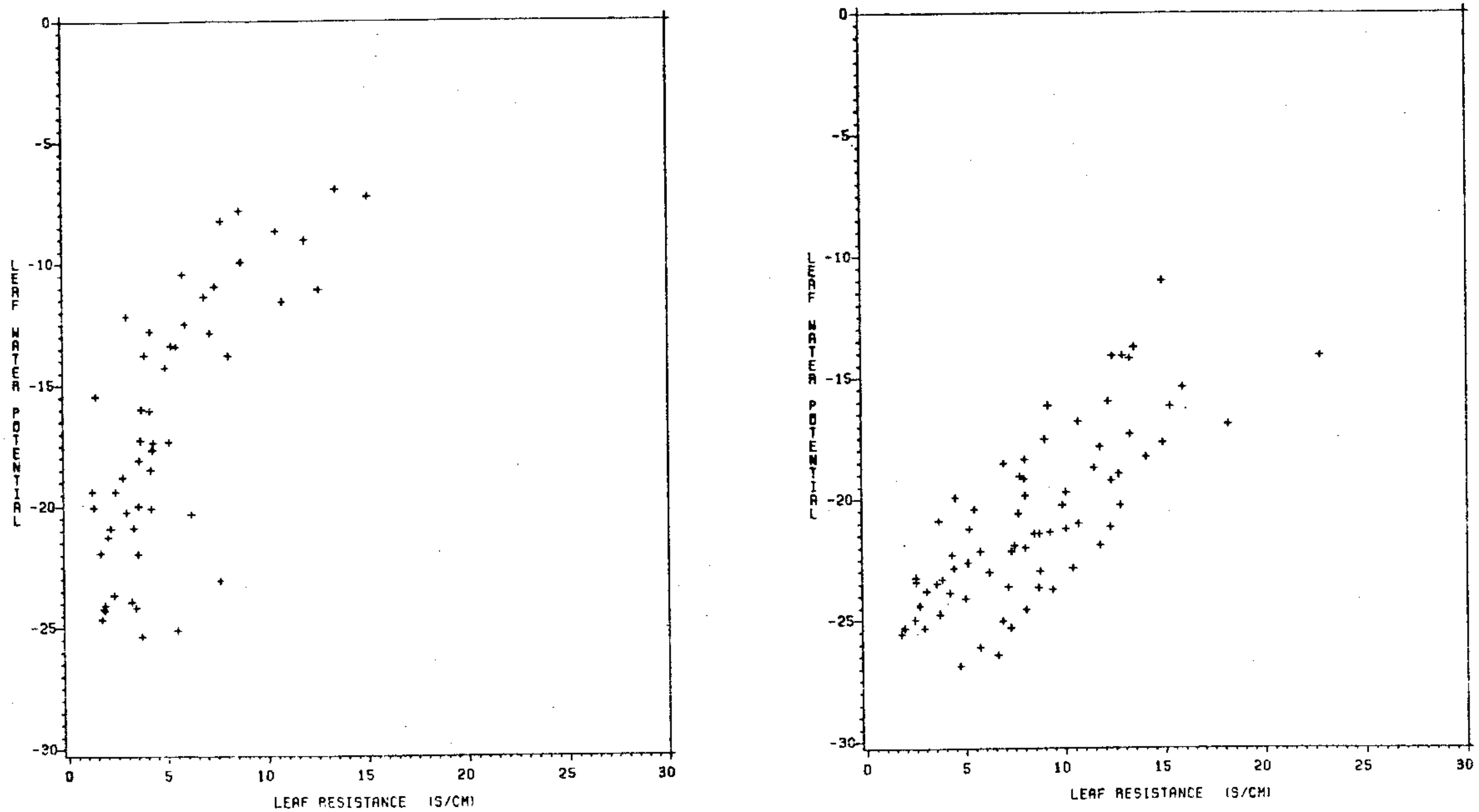

Figure 39: Leaf Water Potential vs. Leaf Resistance for the Exposed 1-emitter tree from 0700 to 1200 hours and from 1300 to 2000 hours.

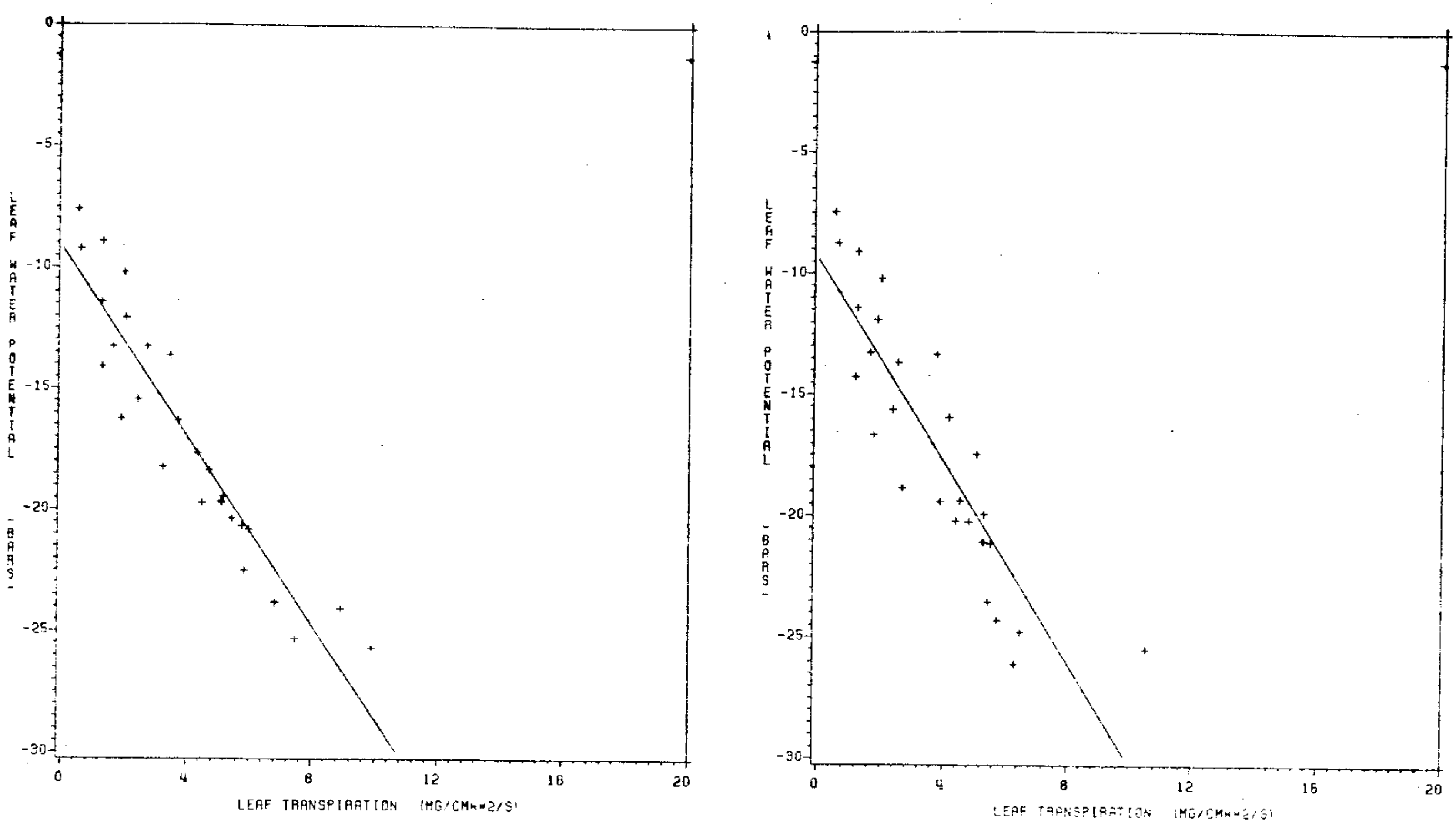

Figure 40: Leaf Water Potential vs. Transpiration for 4- and 3-emitter tree (exposed and shaded) on Day 170 from 0700 to 2000 hours.

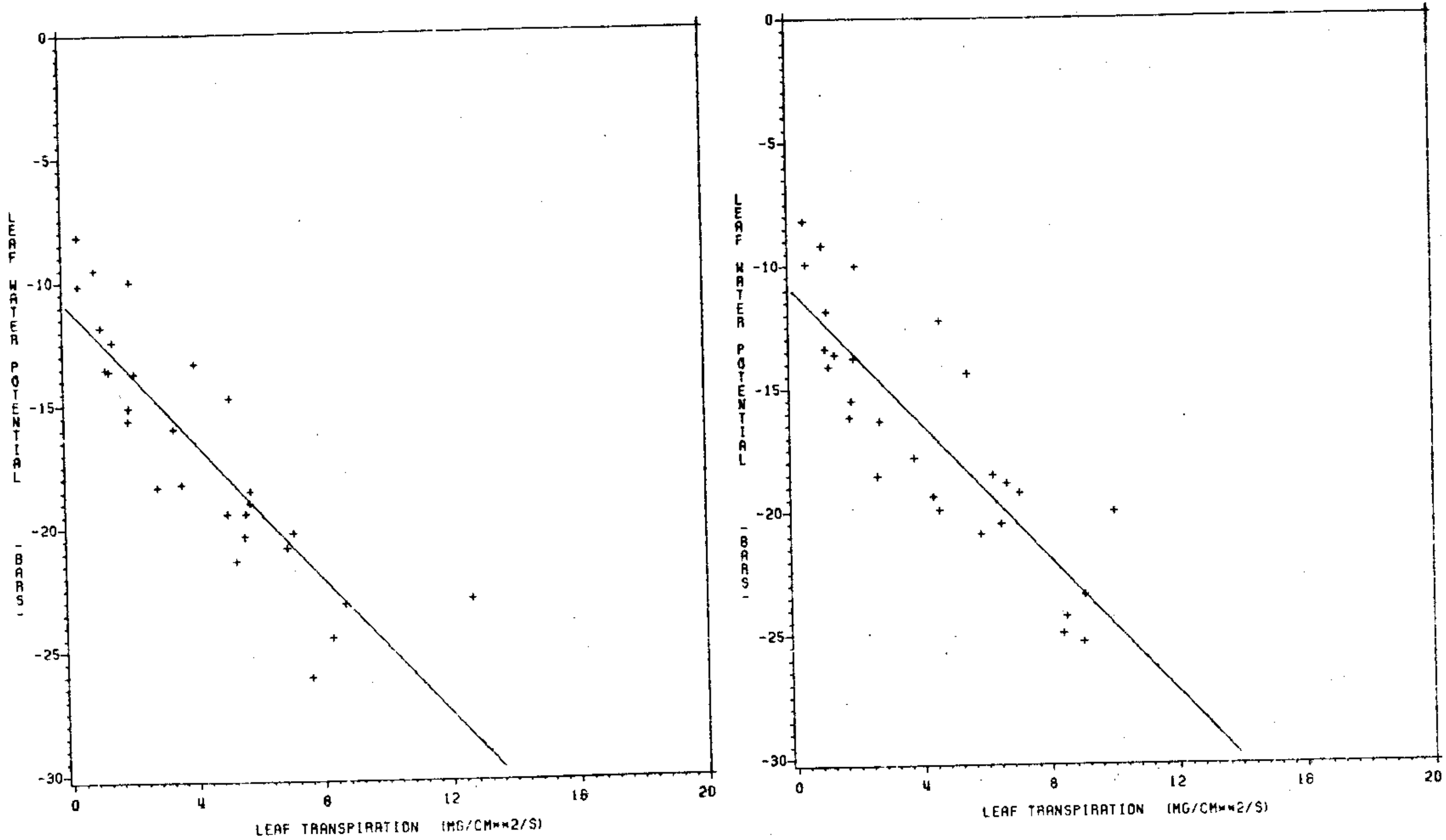

Figure 41: Leaf Water Potential vs. Transpiration for 2- and 1-emitter tree (exposed and shaded) on Day 171 from 0700 to 2000 hours.

results were shown for all treated trees on day 185 and 186 in Figure 42 and 43. However, there were notable differences in slopes for the different treatments, and these will be discussed later. The lowest R^2 for the 4-, 2- and 1-emitter trees occurred on day 205 and 206 when the severest stress occurred immediately before harvest. R^2 for the 3-emitter tree was highest about 0.77 as compared to the other trees, however, it was lower than that measured earlier and later in the season. All treated trees on day 224 and 225, after the trees had been harvested showed significant improvement in the relationship between wl and Tr.

Table 7 shows means of the total resistance (sum of plant and soil resistance) for the 4- and 3-emitter trees were 1.09 $bar.cm^2.s.ug^{-1}$ ($1.09X10^9$ s) and 1.35 $bar.cm^2.s.ug^{-1}$ ($1.35X10^9$ s) respectively. Total resistance seemed to increase with increasing severity of stress in the trees. Means of rp for the 2- and 1-emitter trees were 1.55 $bar.cm^2.s.ug^{-1}$ ($1.55X10^9$ s) and 1.99 $bar.cm^2.s.ug^{-1}$ ($1.99X10^9$ s). Total resistance was twice as high in the 1-emitter tree than in the 4-emitter tree. Without an independent calculation of rs it cannot be conclusively stated that the increase in rt for the 1-emitter tree was due to an increase in rs. It can however, be hypothesized that rs does increase as soil moisture becomes limiting, but

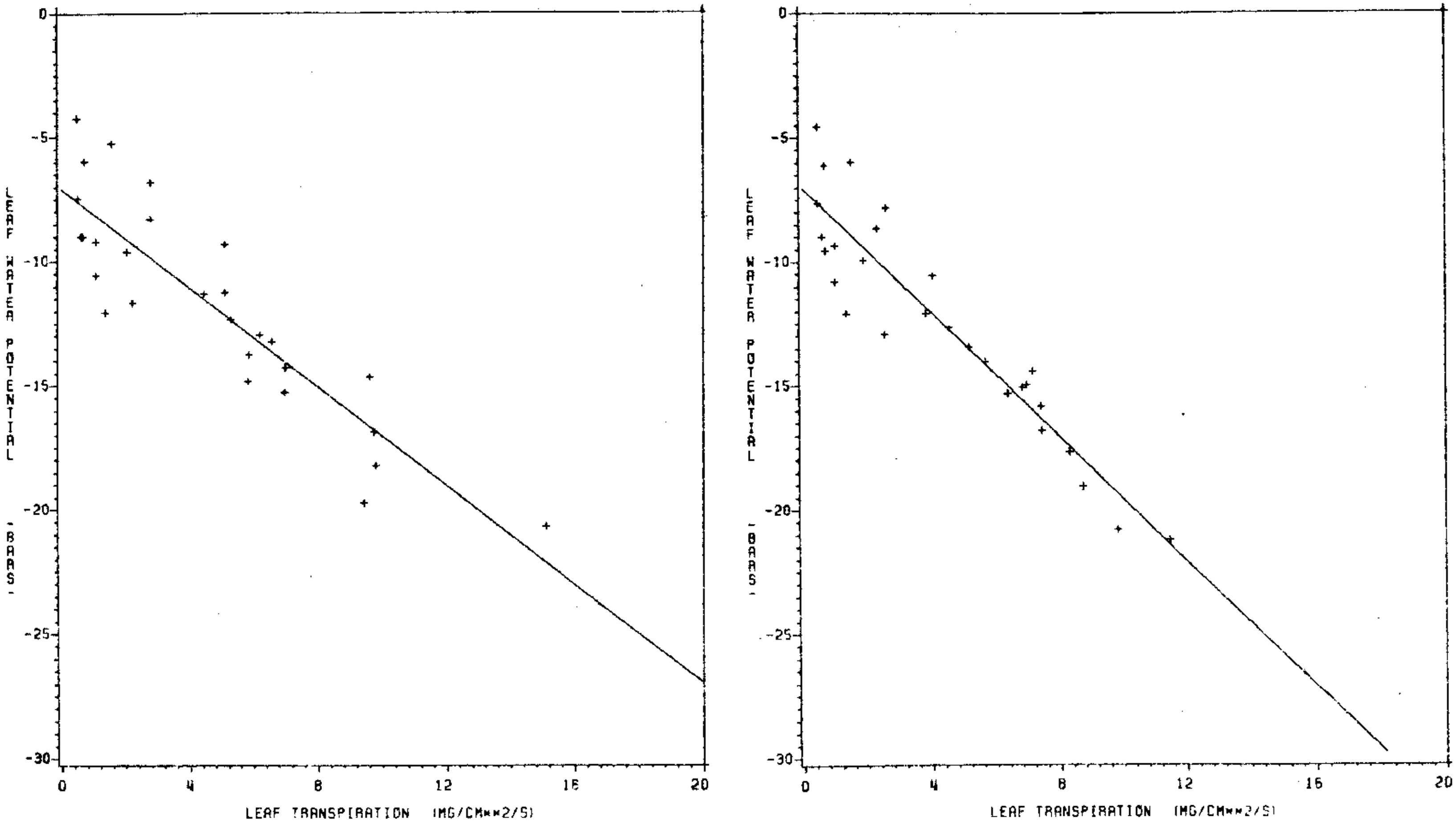

Figure 42: Leaf Water Potential vs. Transpiration for
4- and 3-emitter tree (exposed and shaded)
on Day 185 from 0700 to 2000 hours.

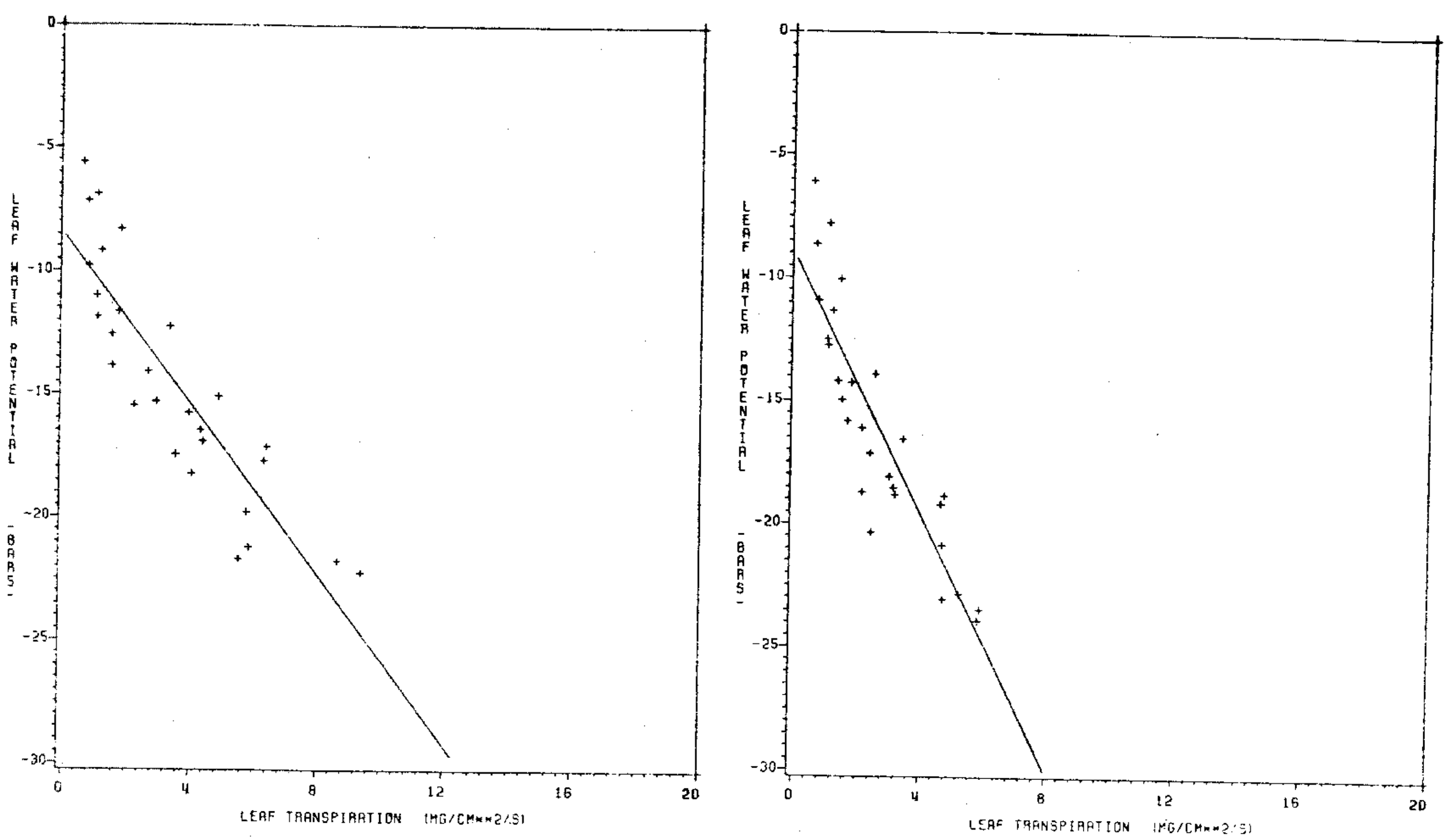

Figure 43: Leaf Water Potential vs. Transpiration for 2- and 1-emitter tree (exposed and shaded) on Day 186 from 0700 to 2000 hours.

TABLE 7

DAILY VALUES OF TOTAL RESISTANCE FOR EACH TREATMENT

	Emitters			Emitters	
Day	4	3	Day	2	1
170	1.94	2.08	171	1.39	1.36
177	1.21	1.55	178	2.05	2.26
185	1.00	1.25	186	1.72	2.59
191	1.18	1.24	192	1.02	0.97
196	0.72	0.91	197	1.25	1.43
205	1.39	1.79	206	1.86	2.52
212	0.68	1.23	213	1.69	2.97
221	0.83	1.08	220	1.92	2.44
224	0.83	1.02	225	1.05	1.33
Mean	1.09	1.35		1.55	1.99
Std. Dev.	0.14	0.13		0.13	0.45

NOTE: Values in this table represent slopes obtained from assuming a linear relationship between wl and transpiration from 0700 to 2000 hours.

it may not be large enough to cause rt to increase by a factor of two. Newman (1969a, 1969b) demonstrated that there is an increase in rt in the stressed trees due to decreased wl and Tr, and that lowered ws may also contribute to an increase in rt.

It was demonstrated earlier that there was considerable diurnal hystereses occuring in wl and rl. On the basis of this the measurements were divided into two time periods corresponding closely with the opening and closing phase of the stomates, from 0700 to 1200 and 1300 to 2000 hours. Figures 44 to 45 show the relationship of wl to Tr for both the opening and closing phase for each treated tree. Days selected to demonstrate these relationships were consistent with those selected earlier. In each case there was a considerable increase in R^2, suggesting rp may be assumed constant for quasi steady state conditions. Also in each case the average rp were very similar for the opening and closing phase for each tree. However, on any given day there may be considerable difference between rp of the opening phase and rp of the closing phase. Table 8 shows means of the total resistance from 0700 to 1200 hours (opening phase) and 1300 to 2000 hours (closing phase) for each treatment. For each treatment rt for the opening phase was very close to that of the closing phase. For the 4-emitter tree rt was 1.23 bar $cm^2.s.ug^{-1}$ (1.23×10^9 s) for

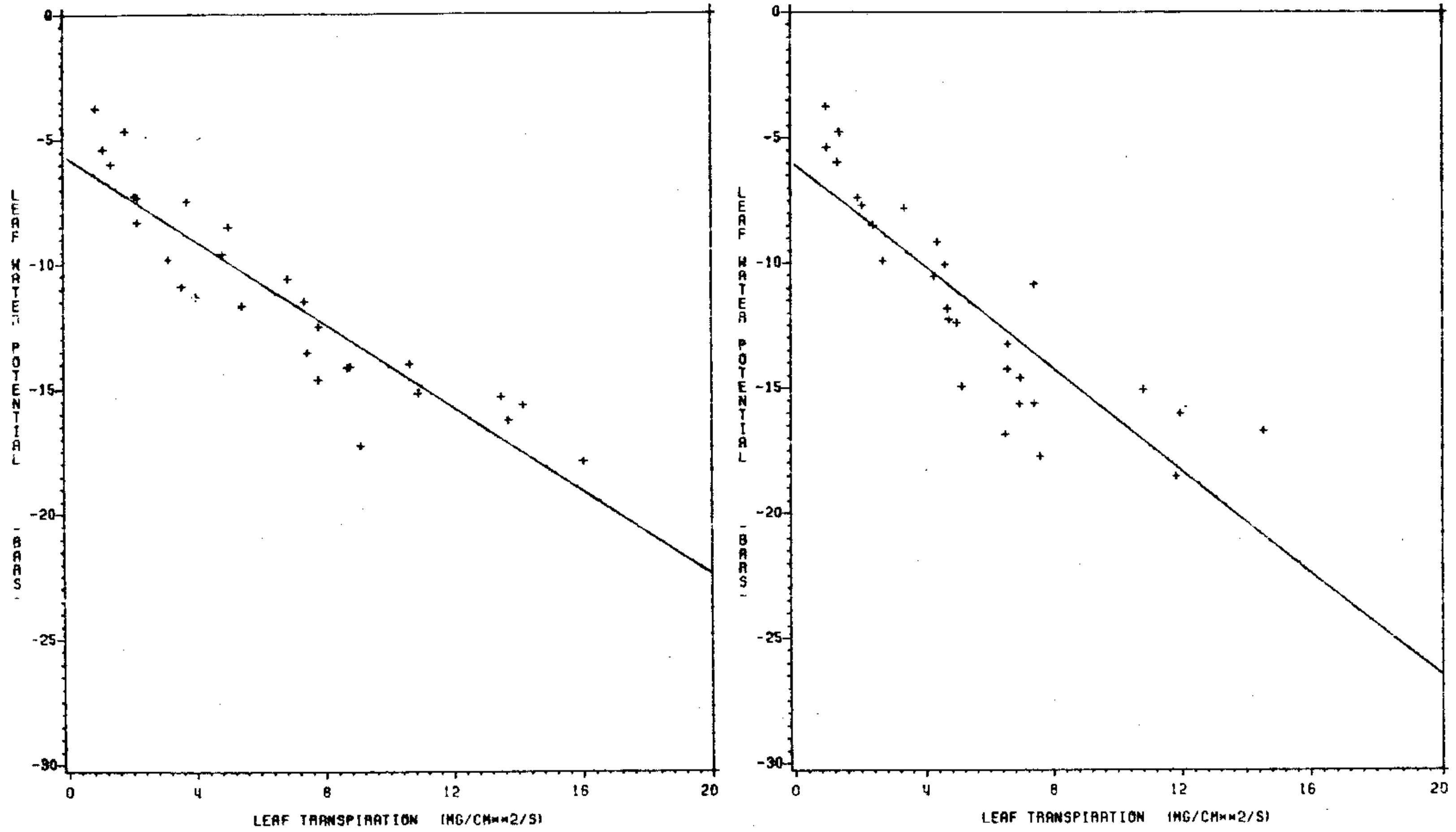

Figure 44: Leaf Water Potential vs. Transpiration for 4- and 3-emitter tree (exposed and shaded) on Day 224 from 0700 to 2000 hours.

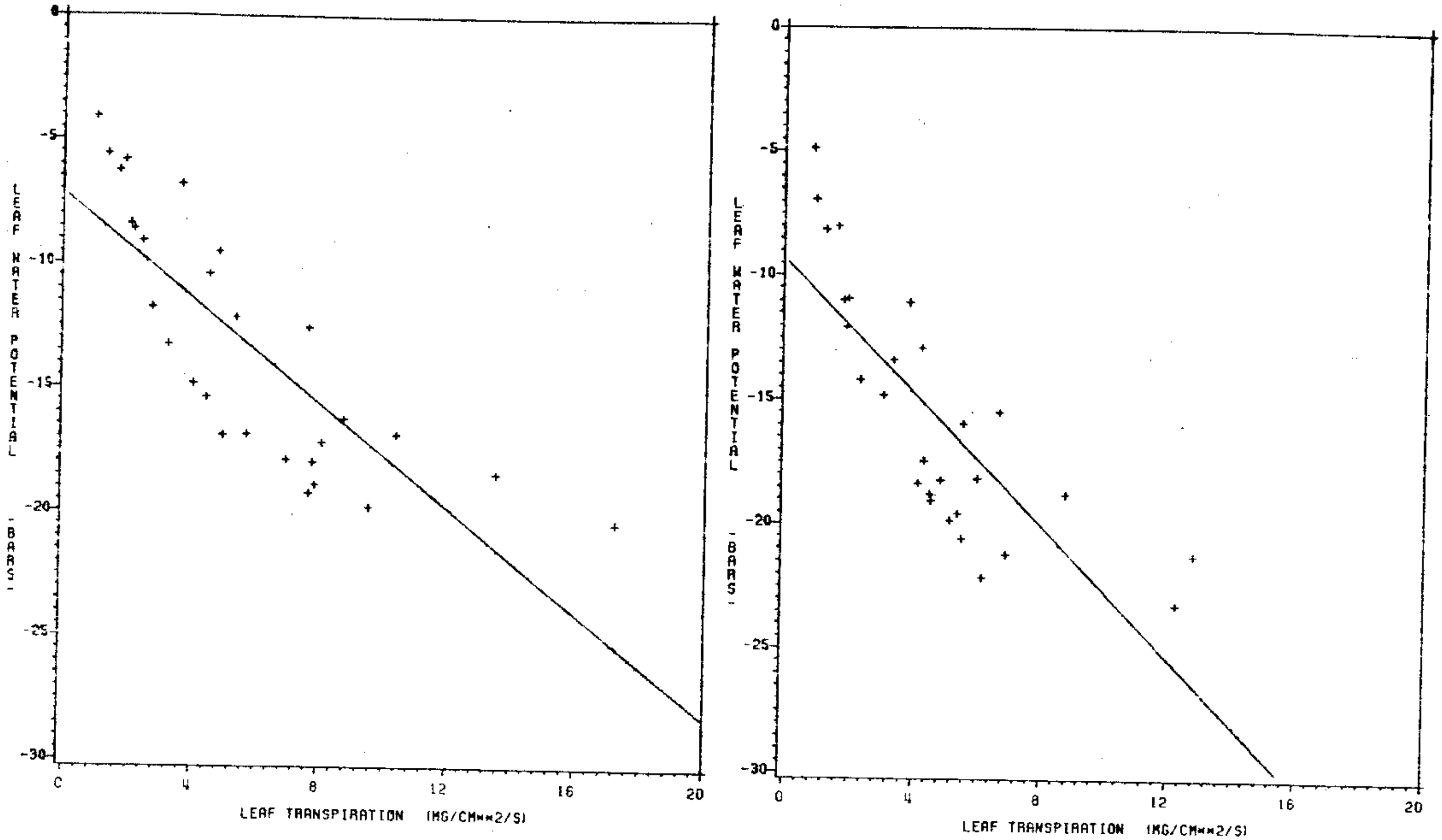

Figure 45: Leaf Water Potential vs. Transpiration for 2- and 1-emitter tree (exposed and shaded) on Day 225 from 0700 to 2000 hours.

TABLE 8

VALUES OF TOTAL RESISTANCE FROM 0700 TO 1200 HOURS AND FROM 0700 TO 1300 HOURS.

	Emitters					Emitters			
	4		3			2		1	
Day	am	pm	am	pm	Day	am	pm	am	pm
	(bar.cm^2.s.ug^{-1})					(bar.cm^2.s.ug^{-1})			
170	2.18	1.62	2.99	1.52	171	1.25	1.46	1.34	1.25
177	1.12	1.24	1.58	1.42	178	2.36	1.69	2.45	1.90
185	1.57	0.77	1.64	1.04	186	1.90	1.47	3.04	2.13
191	1.11	1.29	1.19	1.40	192	1.03	1.40	1.13	1.87
196	0.79	1.20	1.37	1.76	197	1.39	1.24	1.55	1.70
205	1.22	2.24	1.69	1.92	206	1.93	3.26	2.68	3.64
212	0.79	1.20	1.37	1.76	213	1.70	2.65	3.12	4.13
221	0.90	0.71	1.28	0.88	220	1.94	1.81	2.44	2.62
224	1.35	0.66	1.65	0.81	225	1.15	0.89	1.31	1.37
Mean	1.23	1.18	1.64	1.39		1.63	1.76	2.12	2.29
Std. Dev.	0.45	0.51	0.54	0.40		0.45	0.74	0.79	0.99

NOTE: Values in this table represent slopes obtained from assuming a linear relationship between leaf water potential and transpiration. The am values are from 0700 to 1200 and pm from 1300 to 2000 hours.

the opening phase and 1.18 bar $cm^2.s.ug^{-1}$ (1.18×10^9 s) for the closing phase. For the 3-emitter tree mean rt for the opening and closing phase were 1.64 $bar.cm^2.s.ug^{-1}$ (1.64×10^9 s) and 1.39 $bar.cm^2.s.ug^{-1}$ (1.39×10^9 s) respectively, and were slightly higher than for the 4-emitter tree. Mean rt for the opening phase of the 2-emitter tree was 1.63 $bar.cm^2.s.ug^{-1}$ (1.63×10^9 s) and was very close to that obtained for the 3-emitter tree. For the closing phase rt was slightly higher, 1.76 $bar.cm^2.ug.s^{-1}$ (1.76×10^9 s). Mean rt were highest in the 1-emitter tree. For the opening phase mean rt was 2.12 bar $cm^2.s.ug^{-1}$ (2.12×10^9 s) and for the closing phase it was 2.29 $bar.cm^2.s.ug^{-1}$ (2.29×10^9 s). It should be noted that mean rt in the closing phase for both the 4- and 3-emitter trees was lower than in the opening phase, whereas for the 2- and 1-emitter trees it was higher than in the opening phase. The probable reason for this is that the 2- and 1-emitter trees were unable to maintain high wl and Tr in the closing phase, which resulted in lower intercepts and higher slopes. Total resistances obtained here were slightly higher than the single value for each treatment obtained from Table 7. Total resistance was usually higher in the closing phase for the stressed trees, and for the well watered trees when they were being stressed.

R^2 were generally highest in the 4- and 3-emitter trees during both the opening and closing phase. For the 2- and 1-emitter trees R^2 were somewhat lower. For all treated trees R^2 were lower when the trees were being severely stressed such as immediately before harvest. Examining the distribution of points in Figures 46 to 49 suggests that for the 2- and 1-emitter trees which were under stress, a curvilinear relationship between wl and Tr would have fitted the points better. This is clearly evident by examining the closing phase of the 3-emitter tree on day 224, and the 2- and 1-emitter tree on day 225. Each of these figures show that a curvilinear relationship between wl and Tr would fit the data points better than a linear fit. This would account for the lower R^2 during the closing phase for these trees.

If the relationship between wl and Tr is indeed curvilinear as suggested, then the absolute value of the intercepts obtained from a linear fit would tend to be overestimated. Thus without independent measurements of ws as a basis for comparison, the value of the intercept obtained from the relationship between wl and Tr cannot be interpreted meaningfully. It is noted that intercepts became progressively more negative with decreasing number of emitters per tree suggesting the effective soil water potential would be lowest in the root zone of the 1-emitter tree. Intercepts were also more negative prior to harvest and during the closing phase.

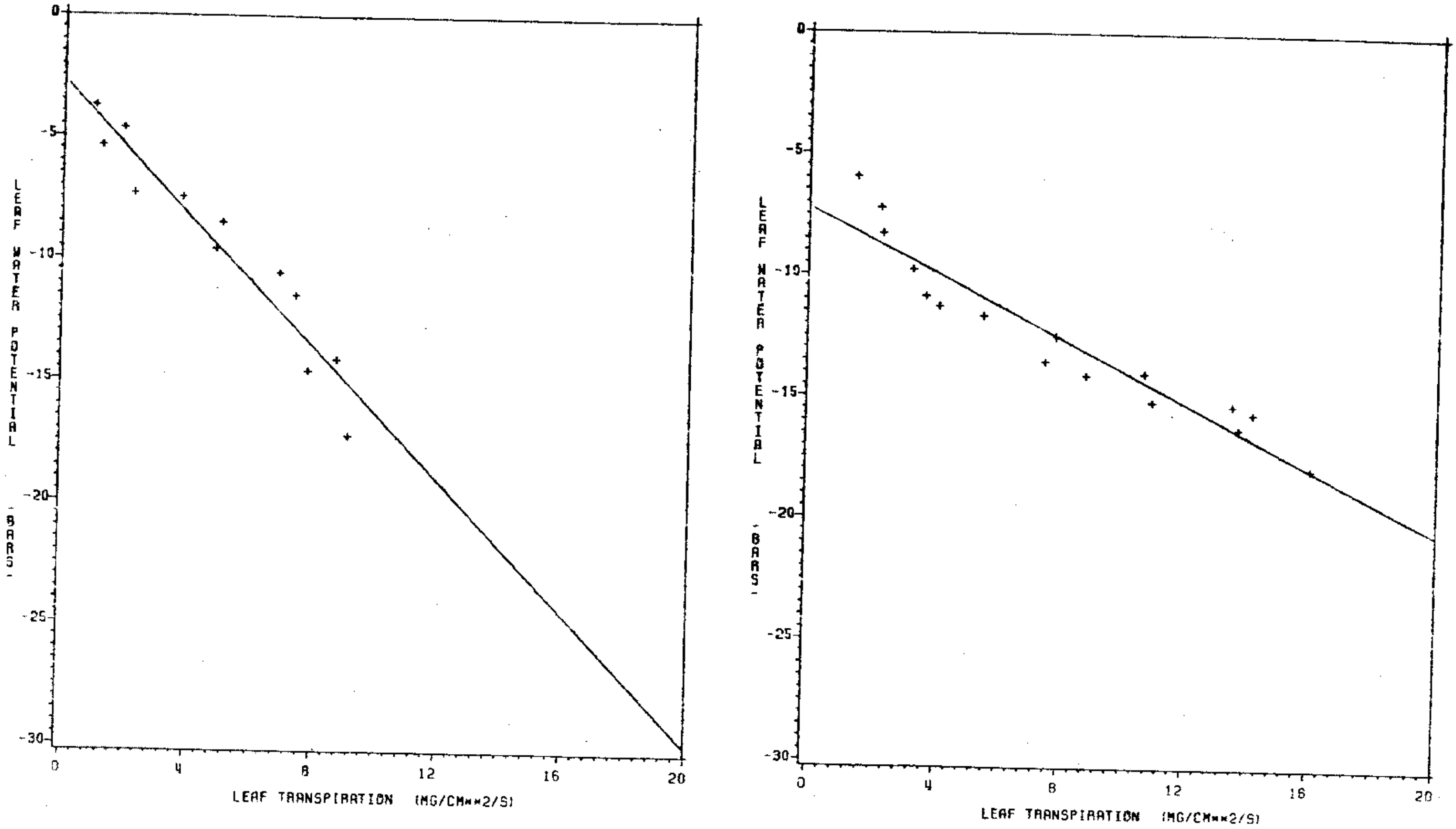

Figure 46: Leaf Water Potential vs. Transpiration for 4-emitter tree (exposed and shaded) on Day 224 from 0700 to 1200 hours and from 1300 to 2000 hours.

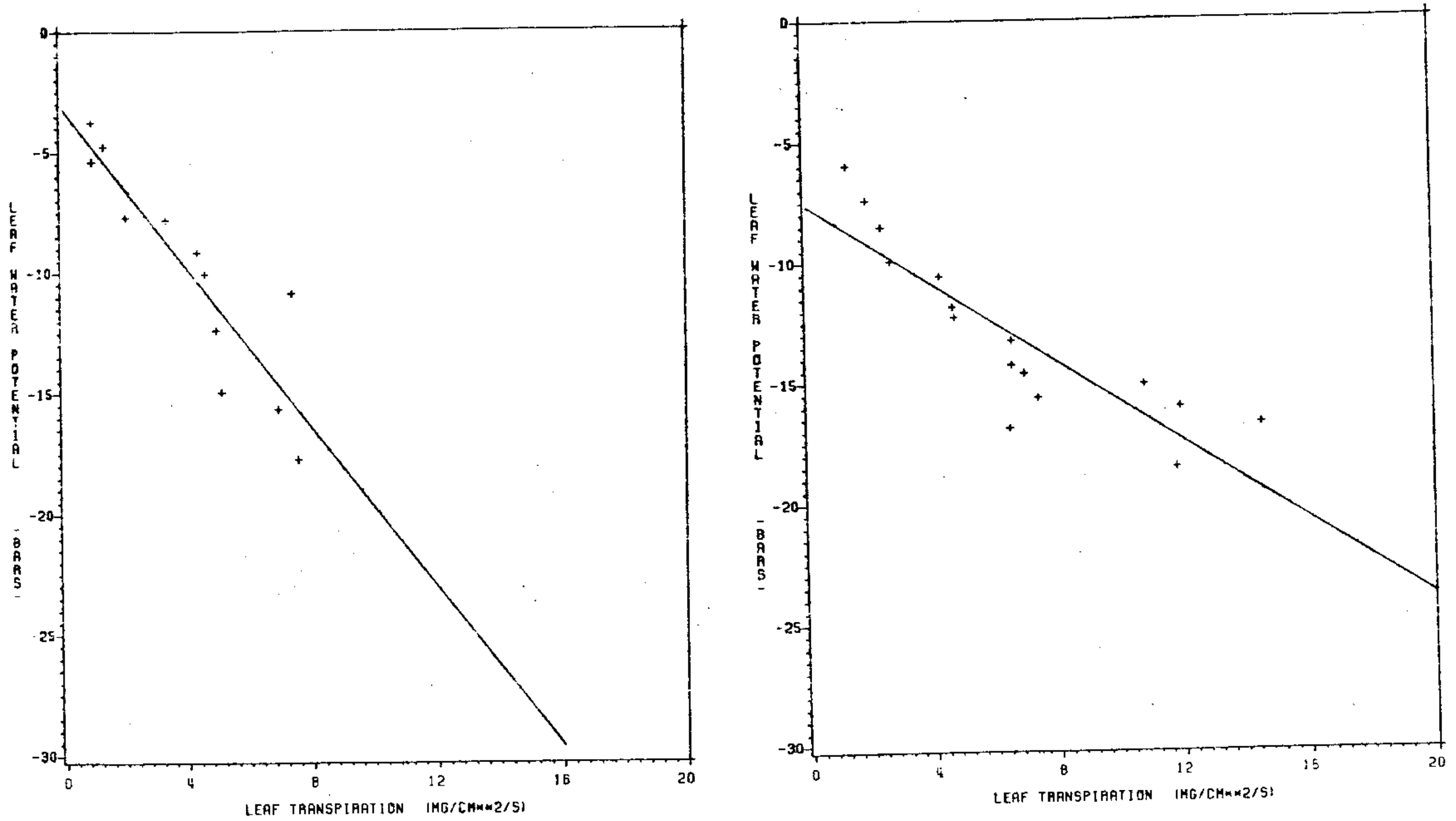

Figure 47: Leaf Water Potential vs. Transpiration for 3-emitter tree (exposed and shaded) on Day 224 from 0700 to 1200 hours and from 1300 to 2000 hours.

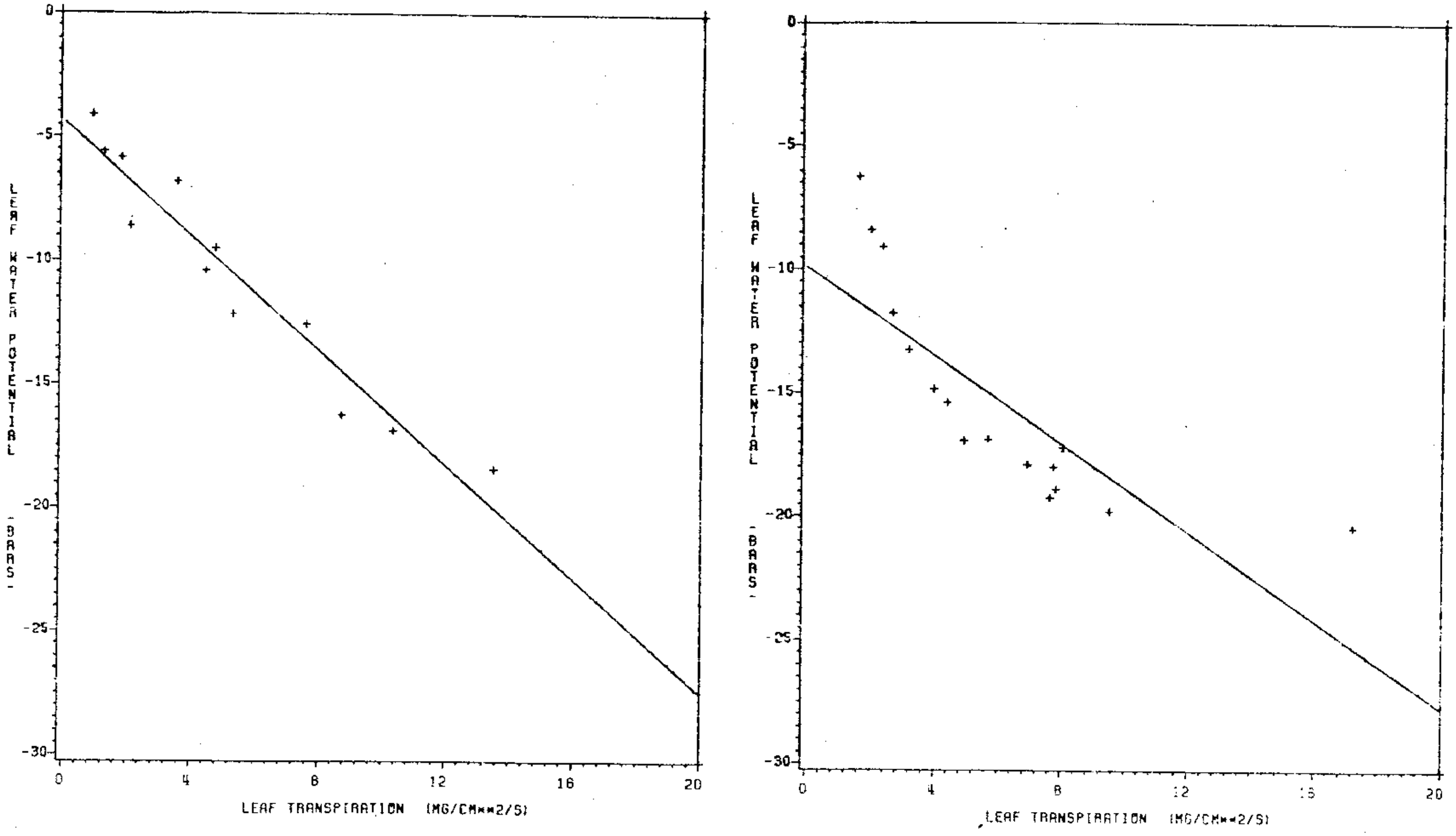

Figure 48: Leaf Water Potential vs. Transpiration for 2-emitter tree (exposed and shaded) on Day 225 from 0700 to 1200 hours and from 1300 to 2000 hours.

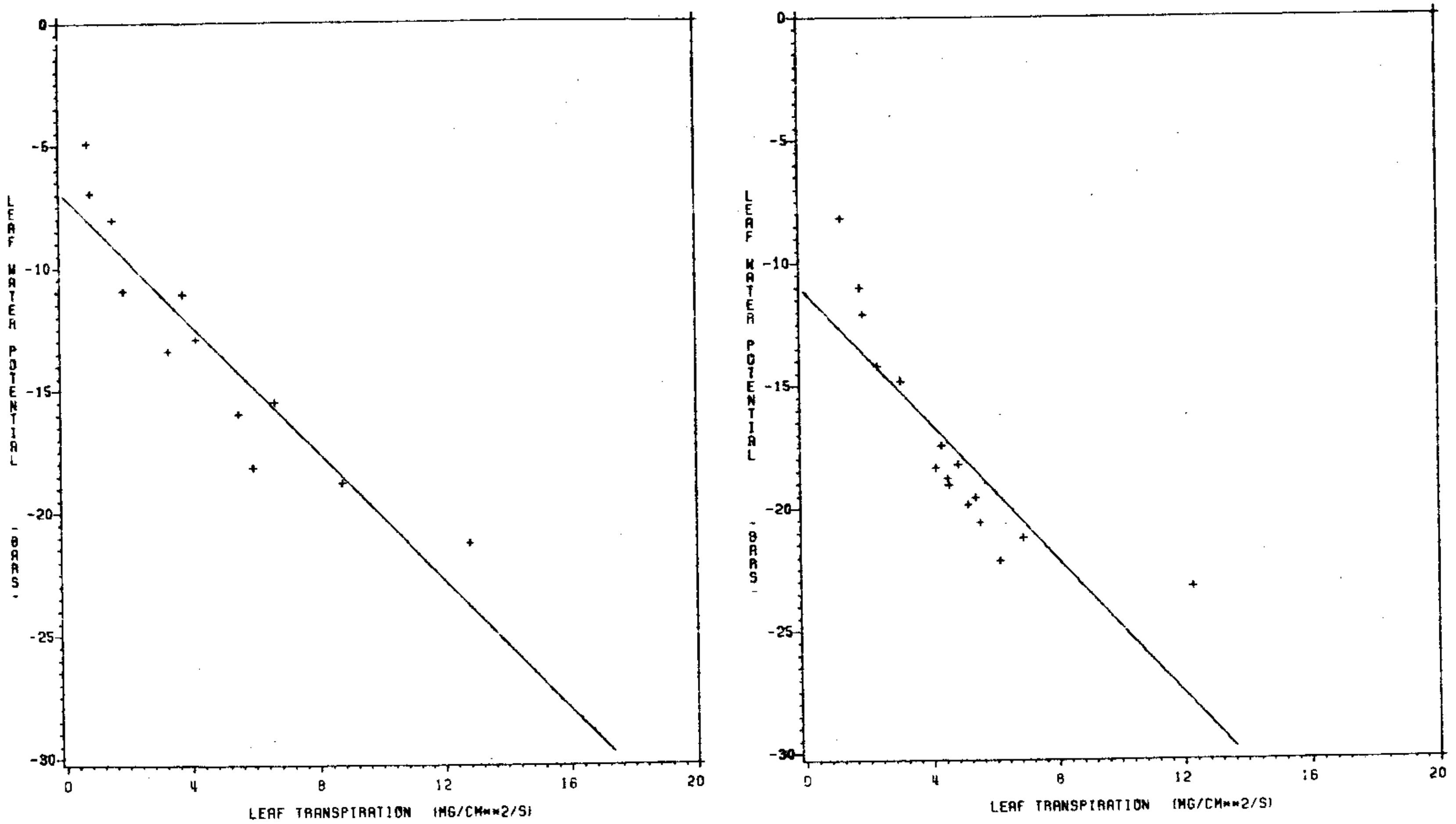

Figure 49: Leaf Water Potential vs. Transpiration for 1-emitter tree (exposed and shaded) on Day 225 from 0700 to 1200 hours and from 1300 to 2000 hours.

Analysis of Yield, Water Use Efficiency, and Pruning Weights

Yields and water use efficiencies of treated trees with ground covers are presented in Table 9. Although there were four replications for each irrigation treatment only one tree from each treatment had a ground cover in order to minimize costs. By comparing water use efficiency (WUE) of each treatment, it is possible to evaluate the effectiveness of irrigation treatments. It is important to realize that WUE does not indicate the profitability of an irrigation treatment. However by comparing both yield and WUE it should be possible to arrive at an optimum irrigation criterion.

Table 10 shows the highest yield and WUE for trees with ground covers occurred for the 3-emitter tree. Yield of the 4-emitter tree was only slightly lower than that of the 3-emitter tree, however, WUE was much lower for the 4-emitter tree. Yield of the 2-emitter tree was 49.4 kg less than the 3-emitter tree, but its WUE was only slightly lower. This suggests that although WUEs are reasonably high for the 2-emitter tree we would sacrifice 49.4 kg per tree in fruit yield thus making this choice unattractive. Yield of the 1-emitter tree was 42.6 kg less than the 2-emitter tree, but its WUE was only slightly lower than the 2-emitter tree. This suggests the 3-emitter tree would be the desired treatment, since both yield and WUE are highest.

TABLE 9

WATER APPLIED, YIELDS AND WATER USE EFFICIENCY OF TREES WITH GROUND COVERS

Number of emitters	Water applied (cm)	Yield (kg)	Water use efficiency ($kg.ha^{-1}.cm^{-1}$)
4	10.6	114.7	1448
3	7.9	127.1	2141
2	5.3	77.7	1960
1	2.6	35.1	1769

TABLE 10

WALLER-DUNCAN K-RATIO T-TEST FOR YIELD AND WATER USE EFFICIENCY

Alpha level = 0.1

Treatment	Yield (kg)	Water Use Efficiency ($kg.ha^{-1}.cm^{-1}$)
4 Emitter	176.7 a*	1005 a*
3 Emitter	172.0 a	1310 ab
2 Emitter	127.6 ab	1460 ab
1 Emitter	82.7 b	1892 b
0 Emitter	71.2 b	

The Waller-Duncan K-ratio t-test was performed using four replications for each irrigation treatment for both yield and WUE. These resulting comparisons are shown in Table 12. Yields were not significantly different for the 3-, and 2-emitter trees. Similarly they were not different for the 2-, 1- and 0-emitter trees. However, the 4- and 3-emitter tree yields were significantly higher than the 1- and 0-emitter trees. Mean yield of the 4-emitter trees was only 2.2 kg larger than the 3-emitter tree, whereas WUE decreased from 1310 kg.ha&S′ -1..cm^{-1} for the 3-emitter tree to 1005 kg.ha^{-1}.cm^{-1} for the 4-emitter tree. The increase in yield of the 4-emitter tree was negligible in comparison to the 3-emitter tree. Therefore the additional cost of 25 percent more water may not be justified. For the 2-emitter tree WUE increased only to 1460 kg.ha^{-1}.cm^{-1}, whereas yields decreased considerably from 78.0 kg for the 3-emitter tree to 57.9 kg for the 2-emitter tree or a difference fo 20.1 kg. It may be concluded that even though yields were not significantly higher for the 3-emitter tree, such a large difference in yield could be economically significant to the farmer. A serious limitation in analyzing the yield data is that we have only four replications per treatment. Increasing the number of replications for each treatment would definitly show that yields of the 3-emitter tree were significantly higher. Water use efficiencies were highest for the 1-emitter tree, however the sacrifice in yield is too great, therefore this treatment is not recommended. It is recommended that the 3-emitter schedule would give the best results in terms of yield and benefit to the farmer.

The yield analysis was carried a step further to examine differences if any in yield of the treated trees within a given size range of peaches. Only two size ranges showed significant differences and these are presented in Table 11. The effect of irrigation was most pronounced in the size range of 5.0 to 5.7 cm. In this range, yield of the 4-emitter tree was not significantly higher than the 3-emitter tree, but it was significantly higher than the 2-, 1- and 0-emitter trees. The 3- and 2-emitter tree yields were not significantly different, but both were significantly higher than yields from the 1- and 0-emitter trees. Yield of the 3-emitter trees was 8 kg higher than the 2-emitter trees, and 21.6 kg higher than the 1-emitter tree. The 1- and 0-emitter yields were not significantly different and were less than half the yield of the 2-emitter tree.

In the size range of 6.4 to 7.0 cm only the 4-emitter tree showed significantly higher yields than the 0-emitter tree. All other treatments were not significantly different. However, yield of the 4-emitter tree was twice that of the 2- and 1-emitter trees. More conclusive and

TABLE 11

WALLER-DUNCAN K-RATIO T-TEST FOR SIZE OF FRUIT

Alpha level = 0.1

Size Range	5-5.7 (cm)	6.4-7 (cm)
Treatment	(kg)	(kg)
4 Emitter	78.9 a*	10.3 a*
3 Emitter	75.0 ab	7.3 ab
2 Emitter	57.4 b	5.9 ab
1 Emitter	27.4 c	4.8 ab
0 Emitter	22.7 c	2.2 b

*Means followed by the same letter are not significantly different.

All other size ranges showed no significant differences

TABLE 12

DUNCANS MULTIPLE RANGE TEST FOR PRUNING WEIGHTS

Alpha level = 0.05

Trees	Pruning weight (kg)
With Ground Covers	20.1 a*
Without Ground Covers	10.3 b

*Means followed by the same letter are not significantly different.

detailed information on yield can be obtained by increasing the number of replications for each treatment. However, these preliminary investigations revealed that proper irrigation management can increase total yields and also the number of fruit within a marketable size range, and would be economically beneficial to the farmer.

The effect of ground covers on pruning weights was evaluated by comparing means of the pruning weights of all trees with ground covers to those without ground covers and are presented in Table 12. Duncan's multiple range test indicated that pruning weights of trees with ground covers were significantly higher than for trees without ground covers. Pruning weights were twice as high for trees with ground covers. It may be hypothesized that since the ground covers eliminated surface evaporation from the wetted areas around the emitters, the additional water was used for increased vegetative growth and may also have been used for increased yields in trees with ground covers.

SUMMARY

A peach irrigation research project was conducted to examine the effect of environmental variables on leaf water potential, leaf resistance, canopy resistance and transpiration rate; and to evaluate their ultimate effect on yield, water use efficiency, and pruning weights for trees under four drip irrigation regimes. The project was conducted on an experimental drip irrigated peach orchard of the Texas Agricultural Experiment Station at Stephenville, Texas, during the growing season of 1981. Four irrigation treatments, replicated four times were tested on the peach variety, Redskin. Each treatment was instrumented with 1-, 2-, 3- or 4-emitters per tree. One tree from each treatment was facilitated with ground covers. An additional plot of four trees with 0-emitters was also established, these were not facilitated with ground covers. Leaf water potentials were measured with a pressure chamber, and leaf resistance, transpiration rate and leaf temperatures were measured with a LI-1600 steady state parometer. Measurements were made hourly on sunlit and shaded leaves of the irrigated treatments on selected days during the growing season.

Several points can be made about the effect of irrigation treatment on the diurnal trends of wl, rl and Tr. Leaf water potentials of exposed leaves exhibited a more pronounced diurnal cycle than did shaded leaves. At local solar noon wl of all trees were generally the minimum value measured. Leaf water potentials measured at 2000 hours had not fully recovered to their morning value, indicating a lag time during the recovery period. Combined effects of higher temperatures and vapour deficits after local solar noon resulted in lower wl, and higher rl at 2000 than at 0700 hours. Shaded wl were higher (under less stress) than for exposed leaves, however, rl was higher in shaded leaves resulting in reduced Tr rates.

An increase of 3 to 4 bars in early morning wl measured at 0700 hours indicated that irrigation had decreased stress in the 4-emitter tree. However, shaded leaves of the 1-emitter tree had lower wl and higher rl than exposed leaves of the 4-emitter tree indicating that the 1-emitter tree was under considerable stress. Downward shift in wl curves, a sharp decline in early morning wl, and higher rl for exposed and shaded leaves for all treatments indicated the trees were being severly stressed prior to harvest. Some of the effects of stress on lowered wl would be compensated by changes in rl, thus it is important to measure both parameters when evaluating plant water stress.

Measurements indicated that peach trees with heavy fruit load were sensitive to stress and developed stress faster. In the 4- and 3-emitter trees the decrease in stress after harvest was attributed to the removal of the fruit load and to higher irrigation rates. The 1-emitter tree recovered at a much slower rate and had not recovered completely even after removal of the fruit.

Different irrigation treatments determined the level of stress in the trees. High irrigation rates decreased stress in the 4- and 3-emitter trees but lower irrigation rates applied to the 2- and 1-emitter trees had little effect in alleviating stress. Stress occurred earlier in trees that were subjected to severe water deficits. Seasonal averages of wl indicated that 4- and 3-emitter trees had significantly higher wl than the 2-emitter tree which in turn was also significantly higher than the 1-emitter tree. Plant water stress decreased significantly for the 3-emitter tree relative to the 2- and 1- emitter trees, but did not for the 4-emitter tree suggesting that 3-emitters per tree would be the best recommendation for the peach orchard in Stephenville. Lowest mean hourly wl were measured in trees receiving the lowest amount of water and compared to other treatments the 1-emitter tree recovered at a much slower rate. Lower wl, higher rl, and stomates closing earlier in the day for the 1-emitter tree suggested that it was being severely stressed. Stress in the 2- and 1-emitter trees resulted in progressively higher mean daily rl during the growing season. The recovery in mean daily wl was much slower in trees subjected to severe water deficits and this was due primarily to slower recovery in rl. However, wl recovered much sooner than rl for all treatments. It is interesting to note that although seasonal averages of wl and rl were not significantly different for the 4- and 3-emitter trees, the effect on Trsa resulted in significantly higher water loss from the 4-emitter tree. In the 1-emitter tree the lower irrigation rate resulted in partial stomatal closure which decreased Tr severely.

Solar radiation was the single most important factor governing wl and therefore most of the morning decline in wl can be explained as a function of Rs. Results indicated that for both opening and closing phase a linear fit may be used to describe the relationship between wl and Rs for non stressed and stressed trees. Early morning and late evening measurements of wl from non stressed and stressed trees would establish the value of the intercept and could then be used to calculate reasonable estimates of wl from measured Rs. For all treatments rl decreased exponentially with increasing Rs. Distinctive opening and closing patterns in rl were noted in both exposed and shaded leaves. Leaf resistances were higher in the closing phase than in the opening phase for a given level of Rs. Differential response between opening and closing phase was due to higher temperatures and vapour deficits, and lower wl during the closing phase. Stomata of well-watered trees began to respond at lower levels of Rs than in stressed trees. Minimum rl were lower in non stressed trees for a given range of Rs.

Relationships between wl and rl and wl and Tr showed considerable diurnal hysteresis. Values of rl between 5 and 10 $s.cm^{-1}$ occured at 0700 hours and decreased to between 2 and 3 $s.cm^{-1}$ as wl decreased from -5 to -12 bars. There was little change in rl as wl decreased from -12 to -21 bars, and tended to increase in rl as wl decreased below -21 bars. Critical wl for well-watered trees was -18 bars for shaded leaves and -21 bars for exposed leaves. In stressed trees the critical wl were somewhat lower suggesting some degree of adaptation to stress. Therefore the relationship between wl and rl varied according to the degree of stress the plant was being subjected to. Limiting soil moisture and/or physiological stress caused by a heavy fruit load would also affect this relationship. Leaf water potentials decreased linearly with increasing Tr rate. Total resistance (sum of plant and soil resistance) obtained from the slope of the above relationship, increased with increasing severity of stress in the trees. Mean total resistance for the

4-emitter tree was around 1.0 bar $cm^2.s.ug^{-1}$ (1.0×10^9 s) and increased to 2.0 bar $cm^2.s.ug^{-1}$ (2.0×10^9 s) for the 1-emitter tree. Total resistance was usually higher in the closing phase for the stressed trees, and for the well-watered trees when they were subjected to stress. For the 2- and 1-emitter trees which were under stress a curvilinear relationship between wl and Tr would have fit the points better than a linear fit.

By comparing WUE of each treatment it is possible to evaluate the effectiveness of irrigation treatments. Results indicate the 3-emitter tree would be the desired treatment, since both yields and WUE are relatively high. Effect of irrigation was most pronounced in the size range of 5 to 5.7 cm resulting in higher yields in the 4- and 3-emitter trees. Proper irrigation management increased total yields and also the number of fruit within a marketable size range, while maintaining high WUE, this would result in economic benefits to the farmer. Pruning weights were twice as high in trees with ground covers. It was hypothesized that since the ground covers eliminated surface evaporation from the wetted areas around the emitters, the additional water was used for increased vegetative growth and may also have been used for increased yields in these trees.

CONCLUSIONS AND RECOMMENDATIONS

A peach irrigation research project was conducted to examine the effect of environmental variables on leaf water potential (wl), leaf resistance (rl), canopy resistance (rc) and transpiration rate (Tr); and to evaluate their ultimate effect on yield, water use efficiency, and pruning weights for trees under four drip irrigation regimes at Stephenville, Texas. Treatments selected were instrumented with 1-, 2-, 3- and 4-emitters per tree, and one tree from each treatment was facilitated with a ground cover. Plant responses were measured hourly on sunlit and shaded leaves of each treatment.

Specific conclusions of this study were:

1. Maximum values of wl occurred at 0700 hours, and minimum values at 1300 hours. Leaf water potentials measured at 2000 hours had not fully recovered to their early morning value, indicating a lag time during the recovery period. This was due to higher temperatures and vapour deficits after local solar noon.
2. Leaf water potentials and leaf resistances were higher in the shaded leaves for all treatments, resulting in reduced transpiration.

3. An increase of 3 to 4 bars in early morning wl measured at 0700 hours indicated that irrigation had decreased stress in the 4- and 3-emitter trees.
4. Lower wl and higher rl indicated the trees were being severely stressed prior to harvest. Peach trees with a heavy fruit load were sensitive to stress and developed stress faster. In the 4- and 3-emitter trees the decrease in stress after harvest was attributed to the removal of the fruit load and to higher irrigation rates.
5. Stress occurred earlier in trees that were subjected to severe water deficits. Plant water stress decreased significantly for the 3-emitter tree relative to the 2- and 1-emitter trees, but did not for the 4-emitter tree. Therefore, 3-emitters per tree was the best recommendation for the peach orchard.
6. Lower wl and higher rl resulted in stomatal closure earlier in the day thereby restricting Tr for the 1-emitter tree. The effect of the 1-emitter tree being severly stressed resulted in very low yields.
7. Leaf water potentials decreased linearly, whereas leaf resistance decreased exponential with increasing solar radiation. Leaf water potentials were lower and leaf resistances were higher in the closing phase

than in the opening phase for a given level of solar radiation. Differential response between opening and closing phase of the stomates was due to higher temperatures and vapour deficits, and lower leaf water potentials during the closing phase.

8. There was little change in rl as wl decreased from -12 to -21 bars, and started to increase in rl as wl decreased below -21 bars. This relationship varied according to the degree of stress the plant was being subjected to.
9. Leaf water potentials decreased linearly with increasing Tr rate. Total resistance (sum of plant and soil resistance) obtained from the slope of this relationship, increased with increasing severity of stress in the trees. Total resistance was usually higher in the closing phase for the stressed trees, and for the well watered trees when they were subjected to stress. For the 2- and 1-emitter trees which were under stress a curvilinear relationship between wl and Tr would have fit the points better than a linear fit.
10. The 3-emitter tree was recommended, since yield and water use efficiency are relatively high. Proper irrigation management increased total yields and also the number of fruit within a marketable size range,

while maintaining high WUE, resulting in economic benefits to the farmer. Pruning weights were twice as high in trees with ground covers, suggesting the water saved by eliminating surface evaporation from the wetted areas around the emitters was used for increased vegetative growth and may also have been used for increased yields in these trees.

Recommendation for Future Research

It is recommended that experiments similar to those conducted in this study be conducted on other types of plants. Also several additional studies in peach irrigation are needed.

Specific recommendations are listed below:

1. Measure the osmotic potential along with measurements of leaf water potential, specially in trees subjected to water stress.
2. Measure photosynthetically active radiation at the surface of the leaf.
3. Conduct field studies of the relationship between (ws-wl) and Tr along with independent evaluation of rs, in order to determine rp. This would be of great use in simulation models of water flow in plants.
4. Conduct field studies of the root distribution of peach trees in order to evaluate the amounts of

stress the plant is being subjected to by restricting the wetted volume of the root zone.

5. Compare predicted transpiration rate by the leaf area method with measured values of transpiration by precision weighing lysimeters.
6. Develop simulation models to predict rl in order to use the leaf area method to estimate rc and determine the actual water loss from crop canopies. This would add greatly to our knowledge of water use by various crops.
7. Measurements of the net CO2 flux into the leaf along with water vapour flux out of the leaf could be used to calculate water use efficiency and to determine how it is affected by plant water stress and environmental variables.
8. Evaluate the effects of changing water supply by simultaneous measurement of photosynthesis, transpiration , stomatal aperture, and soil and plant water status for different plant species to determine the effect on plant growth and yield.

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