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COMPETITION FOR LIGHT AND WATER IN A SUGAR CANE/MAIZE INTERCROP

Final Report on ODA Project 215

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Contents

Summary

In areas where land and/or water are limiting intercropping is sometimes used in an attempt to increase or stabilise crop production. For example, in Mauritius, many food crops such as potatoes, maize, groundnuts, beans and tomatoes are grown in the interrows of sugar cane. These food crops are planted after a previous cane crop has been harvested and may compete with the new cane crop for light, water and nutrients. The degree to which the interrow crop has a detrimental effect on the cane yield is an important aspect of this type of cropping system.

This report presents measurements of the amounts of light intercepted and water transpired by plant and first ratoon sugar cane (*Saccharum officinarum* c.v. R570) with interrow crops of maize (*Zea mays* c.v. UR22). Concurrent measurements of direct soil evaporation are also presented and shown to be a substantial portion of the total evaporation from the mixed crop.

The comparatively slow development of the plant cane canopy led to low light interception and a very small surface conductance. Hence there was very little transpiration from the plant cane. Conversely, the maize canopy developed rapidly and, despite having lower stomatal conductances than the cane at the beginning of the season, it intercepted much more of the light and transpired most of the water used by the mixed crop. Some examples are shown illustrating that with plant cane, the mixed crop system may have been adequately irrigated at the beginning of the season and under irrigated later in the season.

After the first ratoon, the sugar cane developed more rapidly and competed more vigorously with the maize for light. Transpiration rates from the cane and maize canopies were much more similar than they were for the plant cane, although the maize still used the greatest amount of water for most of the season. Only towards the end of 1987, when the maize began to senesce, did the cane use more water than the maize. Irrigation rates for the first ratoon cane and maize intercrop were slightly high at the beginning and in the middle of the season. However, as in 1986, the mixed crop was under-irrigated towards the end of the 1987 season.

1. Introduction

Throughout the developing tropics intercropping is now recognised as a very common practice which can increase or stabilize yield (eg. Willey 1979a, b). In Mauritius where land is limited, intercropping is used both to increase total yield and to diversify crop production. For example, food crops such as potatoes, maize, beans, tomatoes and groundnuts are grown in the interrows of sugar cane. These food crops are planted either in plant or ratoon cane with which they may compete for light, water and nutrients. Previous agronomic trials with maize intercropping (MSIRI 1985, Govinden 1986) have indicated that sugar cane yields are decreased under rainfed conditions but that any depressive effect of the maize on cane growth may be alleviated if adequate irrigation is provided. However, the definition of an 'adequate' amount of irrigation for an intercrop is not a simple matter and current methods of estimation, bases on potential evaporation and crop coefficients (Doorenbos and Pruitt 1977), have not been rigorously tested against independent measurements of actual crop evaporation. Indeed, Govinden (1986) has even suggested that the most common objection to intercropping is associated with the difficulty of estimating inputs such as irrigation and fertilizer. Furthermore, the generality of the results from a given set of intercrop trials in any particular year is limited by the lack of understanding of the underlying processes of competition for light and water etc.

This report contains the results of a detailed study of the partitioning of light and water in a drip irrigated plant cane/maize mixture grown during the winter (April-August 1986) season. Data are also reported for the following season (August-December 1987) after the first ratoon. This work formed part of a larger, more comprehensive drip irrigation study, results from which are also presented elsewhere (Batchelor *et al.* 1988; Bell *et al.* 1988; Cooper, Wellings and Ah Koon 1988). In the current study diurnal and seasonal trends in light interception and stomatal conductance in the two species are used to calculate their individual transpiration rates. These values of transpiration were combined with direct measurement of soil evaporation to compare the total evaporation from the mixed crop with the estimated irrigation requirement. Comparisons are made between the plant cane and first ratoon cane in terms of their competition with maize intercrops for light and water.

2. Site, Seasons and Crops

The site used for the intercropping trials was on the Belle Vue Sugar Estate (20°5'S, 57°33'E), the site of the Mauritius Sugar Industry Research Institute (MSIRI), Mauritius - Institute of Hydrology (IH) drip irrigation research project. The site has a maritime climate, tropical during summer and sub-tropical during winter, with a long term (1962-1980) mean rainfall of 1432 mm (Padya 1984). Table 1 compares the rainfall received during the 1986 and 1987 food crop seasons with the long term mean. Rainfall was well below average in the first four months of the 1986 season and the total for the entire 5 months was only 60% of the long term mean. Also shown is the potential evaporation during 1986 which again greatly exceeded the rainfall for most of the season. Rainfall was also (40%) below average in the 1987 season and only amounted to less than 20% of the potential evaporation. During these seasons, therefore, the crops would have experienced substantial soil moisture stress in the absence of any irrigation.

The soil of the trial area is a highly ferruginous (21-25% W/W Fe_2o_3) reddish-brown clay containing residual weathered basalt stones. It is stable, well aggregated and, therefore, freely draining. Further details of the soil type are given by Batchelor *et al.* (1985) and Cooper, *et al.* (1988).

The crops studied were a mixture of sugar can (*Saccharum officinarum* c.v. R570) and maize (*Zea mays* c.v. UR22). The sugar cane setts were planted on 9 April 1986 in alternate wide and narrow rows 2.26 m and 0.97 m ('pineapple spacing' i.e. 7 x 3 'French feet') apart respectively, Figure 1. The rows had an orientation of 140° from magnetic north. The 1986 maize crop was sown on 14 April in the wide interrow as two rows 0.8 m apart with an intra row plant spacing of 0.15 m. The plant cane crop was harvested from 4 to 6 August 1987 and a second maize intercrop planted on 17 August 1987. The cane dripline, containing emitters every 0.75 m each with an output of 2 l h^{-1}, was placed at the centre of the 0.97 m interrow at a depth of 0.20 m. A similar dripline was placed on the soil surface at the centre of the two maize rows. The irrigation regime aimed to provide the cane/maize crop mixture with sufficient water to replace its estimated total evaporative loss. These estimates were based on mean values of Penman potential evaporation (calculated for the previous two weeks) and crop factors given by Doonenbos and Pruitt (1977). Effective rainfall was also taken into account and full details of the methods used are given by Batchelor *et al.* 1985.

3. Measurements

3.1 LIGHT INTERCEPTION

3.1.1 Instrumental arrangement

The amount of light intercepted by the cane and maize canopies was measured using tube solarimeters (Type TSL Delta-T Devices, Cambridge, UK). Two plots were instrumented, in the first the amount of solar radiation intercepted by the combined cane and maize intercrop was measured using four tube solarimeters below the canopy and one above. The four tubes below the canopy were arranged to sample the radiation reaching ground level between the mid points of two adjacent narrow cane rows (ie. Points D1 and D3 in Figure 1). The signals from the radiation instruments were integrated and logged at hourly intervals using a solid state logging system (Monolog System, Computing Techniques, Billingshurst, UK).

In the second plot a similar arrangement of below and above canopy tube solarimeters was used, however, in this plot the maize plants were removed from around the sensors so that only the cane plants were left to intercept light. To compensate for any change in the cane canopy which might have resulted from the removal of the maize, the complete set of sensors were moved further along the row into undisturbed cane/maize intercrop every two weeks. The maize plants were then again removed. Both the radiation interception logging systems were operated continuously during the plant cane season from 4 May 1986 until the maize harvest, on 22 August 1986 and also after the first ratoon, from 8 September 1987 to the maize harvest on 15 December 1987. During the 1987 season light interception was also monitored in a sole cane plot, using a further set of above and below canopy tube solarimeters in a similar arrangement to that used in the mixed crop plots.

Between the two seasons all of the tube solarimeters were calibrated against a Kipp solarimeter on the Belle Vue Meteorological site. These calibration data indicated that the tube radiometers gave values within a few per cent of that recorded by the Kipp so the only adjustment to the manufacturer's calibrations was a correction for the small overnight offset, generally $\mp$ 5 Wm^{-2}, probably caused by the logging system rather than the sensors.

3.1.2 Light interception theory

An exact theoretical description of the diurnal behaviour of light interception by a plant canopy is very complex and depends on a great many variables (eg. solar angle, ratio of direct to diffuse radiation, canopy architecture. See Ross 1981). However, one simplified description can be derived by assuming that the leaves angles are randomly orientated over a sphere and in such a case it can be shown that the radiation intercepted by a plant canopy with a leaf area index L is given by

$$I = 1 - \exp - (K\ L) \qquad (1)$$

where K is the extinction coefficient and is given by

$$K = K' / \mathrm{Sin}\beta \qquad (2)$$

K' is the minimum value of the extinction coefficient occurring when the solar angle (β) is 90°.

The equation (1) is usually applied to a single species canopy uniformly distributed over the ground. One of the objectives of the current study is to evaluate the applicability of this simple description to a mixed cane/maize row crop. The maize variety used here was much taller than the plant cane (2.5 m and 0.6 m respectively) for most of the 1986 food crop season. In this situation we have assumed that the incident solar radiation S_i is first attenuated by the maize foliage to a value S according to

$$S = S_i \exp - (K_m L_m) \qquad (3)$$

where K_m and L_m are the extinction coefficient and leaf area index of the maize. The radiation S is further attenuated by the cane foliage to a value at the soil surface, S_s where

$$S_s = S \exp - (K_c L_c)$$

where K_c and L_c are the extinction coefficient and leaf area index of the cane canopy.

Substituting for S from equation (3) gives

$$S_s = S_i \exp - (K_m L_m + K_c L_c) \tag{4}$$

It follows that the fraction of the incident radiation intercepted by the maize canopy is

$$F_m = 1 - \exp - (K_m L_m) \tag{5}$$

and the equivalent for the cane canopy is

$$F_c = [\exp - (K_m L_m)]\ [1 - \exp - (K_c L_c)] \tag{6}$$

The fraction of incident radiation intercepted by the mixed crop is therefore

$$F_m + F_c = 1 - [\exp - (K_m L_m + K_c L_c)] \tag{7}$$

Note that this is less than the sum of the individual amounts of light interception (F_s) which would occur if similar quantities of the two species were grown completely separately, viz:

$$F_s = \{1 - \exp - (K_m L_m)\} + \{1 - \exp - (K_c L_c)\} \tag{8}$$

For this reason the maize canopy light interception is not simply given by the difference between that intercepted by the maize and the cane alone.

After the first ratoon the above theory is not strictly applicable since the can canopy is not as dominated by the maize crop as it was in the case of the plant cane. Therefore, it is not correct to consider the entire maize canopy to intercept light 'first' and the resultant transmission to fall on the cane canopy. A theoretical model to define light interception of mixed species of similar heights was therefore developed as follows.

There are two extremes to amount of light a crop (M) can intercept when it is mixed with another crop (C). Firstly, crop M can dominate, in which case the fractional light interception is given by equations (5) and (6) as already discussed. We will need to distinguish this from the next case so we add a superscript, 1, to these equations giving

$$F_m^1 = 1 - \exp \quad (K_m L_m) \tag{9}$$

and

$$F_c^1 = [\exp - (K_m L_m)]\ [1 - \exp - (K_c L_c)] \tag{10}$$

Now the second or opposite extreme is where crop C dominates, in which case

$$F_m^2 = [\exp - (K_cL_c)]\ [1 - \exp(-K_mL_m)] \tag{11}$$

and

$$F_c^2 = 1 \quad \exp(- K_cL_c) \tag{12}$$

When the two crops one of comparable heights their fractional light interception will be somewhere between these two extremes. So we can write

$$F_m = [F_m^1 \quad F_m^2]\ f + F_m^2 \tag{13}$$

and

$$F_c = [F_c^1 - F_c^2]\ (f - 1) + F_c^1 \tag{14}$$

Where f is a scaling factor between 0 and 1 which is a function of the two crop heights h_m and h_c. An exact description of the form of $f(h_m, h_c)$ will depend on the detailed canopy architecture of the two crops involved. However, for practical purposes a simple function which has the correct symmetry and limiting conditions is

$$f = \frac{1}{2}\left\{1 + \left[\frac{1}{2^{h_c/h_m}} \qquad \frac{1}{2^{h_m/h_c}}\right]\right\} \tag{15}$$

The form of this function is shown in Figure 2 and it can be seen that it has the following properties

(a) $f \rightarrow 1$ when $h_c \rightarrow 0$, which means that F_m tends to the value F_m^1 appropriate to the crop M dominating.

(b) $f \rightarrow 0$ when $h_m \rightarrow 0$, which means that F_m tends to the value F_m^2 appropriate to the crop C dominating.

(c) When $h_m = h_c$, $f = 0.5$ so F_m and F_c tend to values half way between their tow extremes when the crops are of equal height.

(d) f is symmetrical in the sense that its values are the same irrespective of which crop is defined as M or C, i.e. it is reversible.

Notice that other forms of f were also examined, for example, a simple linear function and an exponential function, and neither of these meet all the necessary criteria above.

The total fraction of incident light intercepted by the mixed crop is $F_m + F_c$, given by the sum of equations (13) and (14). This can be reduced to give an expression of the form,

$$F_m + F_c = F_m^1 + F_c^1 = F_m^2 + F_c^2 \tag{16}$$

This formulation implies that the total light interception by the mixed crop ($F_m + F_c$) is independent of crop height, whereas the individual fractions, F_m and F_c, are not.

The leaf area indices of the maize and cane canopies were measured approximately weekly between 6 May and 22 August 1986 and between 8 September and 15 December 1987. On each sampling date the leaf area of all the leaves on five maize and five cane plants were measured using a portable leaf area meter (LI-3000, LI-COR, Nebraska, USA). Crop height was also measured weekly from 14 May until 15 August 1986 and from 8 September to 15 December 1987. During 1987 the widths of the cane and maize canopies were also recorded.

3.2 TRANSPIRATION

The transpiration component of the total crop evaporation was estimated using stomatal conductance measurements made with an automatic diffusion porometer (AP3, Delta-T Devices, Cambridge, UK) at weekly intervals throughout the two seasons. Measurements were made on the upper and lower surfaces of the six (eight later in the season) uppermost maize leaves and the four uppermost cane leaves. On each day, readings were taken on five plants from each species at two hour intervals from 0800 and 1700. These stomatal conductance measurements were combined with leaf area estimates to calculate the canopy conductances of the maize (G_m) and cane (G_c). Transpiration from the maize E_m and the cane E_c were then calculated using a modified form of the Penman-Monteith equation (Monteith 1965) viz:

$$\lambda E_m = \frac{\Delta\ F_m R_n + \rho c_p D\ G_a}{\Delta + c_p/\lambda(1 + G_a/G_m)} \tag{9}$$

and

$$\lambda E_c = \frac{\Delta\ F_c R_n + \rho c_p D\ G_a}{\Delta + c_p/\lambda(1 + G_a/G_c)} \tag{10}$$

Where F_m and F_c are the fractions of the incident radiation which are intercepted by the maize and cane canopies, D is the specific humidity deficit of the air, Δ is the rate of change of saturated specific humidity with temperature, ρ and c_p are the density and specific heat (at constant pressure) of air and λ is the latent heat of vaporization of water. G_a is the reciprocal of the aerodynamic resistance, r_{av}, of the crop canopy which was calculated from the height of the maize (h) and windspeed (u) using

$$r_{av} = \frac{\ln^2[(z - d)/z_o]}{k^2 u} + \frac{\ln(z_o/z_{ov}) \ln[(z - d)/z_o]}{k^2 u} \tag{11}$$

Assuming that the turbulence was dominated by the taller maize crop, then $d = 0.63h$, $z_o = 0.13h$ (Monteith 1973) and in $(z_o/z_{ov}) = 1.5$ (Garratt and Hicks 1973). Any errors in transpiration arising from the above assumptions are likely to be small since a 50% change in r_{av} only produced a 5-10% change in λE_m and a 1-2% change in λE_c. Hourly wind speeds at 4 m were recorded manually on porometry days as were values of wet and dry bulb temperature in the Stevenson screen on the Belle Vue meteorological site. Net radiation was recorded using an automatic weather station (Strangeways 1972).

3.3. SOIL EVAPORATION

The evaporation from the soil between the plants was measured directly on porometry days using five small soil lysimeters (Figure 1). The lysimeters were made by hammering a plastic tube (15 cm diameter by 30 cm deep) into the soil between the crop rows. The soil around the tube was removed and the soil monolith removed and a perforated base securely attached to the bottom of the lysimeter. In another part of the field under an identical irrigation regime five holes were carefully dug at 65 cm spacing between the crop rows and lined with a plastic tube (20 cm diameter x 30 cm deep). The lysimeters were then lowered into these liners to complete the installation, ready for weighing during the following day. After the first ratoon the cut cane leaf litter was left piled between the narrow cane rows. During the 1987 first ratoon season is was, therefore, assumed that evaporation from the soil below this deep pile of leaf litter was zero. Hence, only four lysimeters were installed across the cane/maize rows in 1987, since the fifth would have been below the litter.

The battery powered electronic balance used to weigh the lysimeters had a capacity of 30 kg ± 1g, which gave an equivalent resolution of the lysimeters of 0.06 mm. New soil lysimeters were taken every week on the day before the porometry day. This ensured that they were in a representative condition during the porometry day when soil evaporation was also being measured.

4. Results

4.1 LIGHT INTERCEPTION

4.1.1 1986 plant case season

Figure 3(a) shows the diurnal pattern of solar radiation interception by the plant cane when the maize intercrop was removed. The data shown are mean values for six dry, sunny (but not completely cloud free) days, between 26 July and 5 August 1986, with similar total light interception. The greatest percentage of radiation was intercepted in the early morning and late afternoon, with little change in interception, of around 15%, during the rest of the day and a minimum interception between 09h00 and 10h00. Figure 3(c) shows that the values of extinction coefficient, calculated using the above interception data in equation (1), following the pattern in Figure 3(a). The curve in Figure 3(c) is of the form of equation (2) with K_c chosen as 0.25 so that the curves fit the data around mid-day. Substituting this value of K_c into equation (1) gave the curve shown in Figure 3(a). Neither of these curves fit the data very well, so the simple theoretical description appropriate for homogeneous monocrops is not suitable for use in this very low leaf area, (LAI = 0.6) widely spaced sugar cane canopy.

Figures 3(b) and (d) show the equivalent data for the combined cane and maize mixture for 6 sunny days earlier in the season between 30 May and 4 June 1986. In this higher leaf area (LAI = 3.0) mixed canopy the amount of radiation intercepted was greater that that intercepted by the cane alone, some 45% around midday. Also the fit of the simple theoretical model (equations (1) and (2)) is better than in the sparse cane canopy on its own. There is still, however, significant deviation between the simple model and measurements in the late afternoon and early morning.

Figure 4 shows the seasonal change in the daily total amount of light intercepted by the mixed cane and maize crop and from the cane alone when the maize intercrop was removed. In early May only about 8% of the incident solar radiation was intercepted by the cane. This increased to around 13% at the beginning of June as the plant cane leaf area slowly developed, Figure 5. Between June and mid-July there appears to have been little change in cane light interception. Towards the end of July the cane canopy development accelerated, increasing the leaf area slowly developed, Figure 5. Between June and mid-July there appears to have been little change in cane light interception. Towards the end of July the cane canopy development accelerated, increasing the leaf area index to around 1.0 and the light interception to 20%.

Figure 4 also shows the seasonal change in light interception of the mixed cane/maize crop. The pattern is very different from that for the cane alone with a sharp rise in light interception to around 60% between early May and mid-June. This was caused by the rapid development of the maize canopy at the beginning of the season (Figure 5). After mid-June the green leaf area of maize declined steadily, but for some time the light interception was maintained. This can be partly accounted for by the increase in cane leaf area during the same period and, to a lesser extent, because the senescent maize leaves still intercepted light.

Ignoring the role of senescent leaves can lead to anomalously high values of the extinction coefficient. This is illustrated in Figure 6(a) which shows that the daily mean values of extinction coefficient calculated using both green and total (green and dead) leaf area indices. The values based on total leaf area increases almost linearly between early May and the beginning of August, thereafter declining slightly up until the maize harvest. Figure 6(a) also shows the corresponding values of daily total light extinction coefficient for the cane canopy K_c. The early season values of K_c were very variable, probably because of the large uncertainty involved in measuring the very low (Ca 0.2) leaf areas indices at that time and for clarity are not reproduced in Figure 6. Later in the season when the leaf area was greater and the cane canopy more uniform, the variability in the $\bar{K}_c$ values was less and these data (Figure 6(a) give the most reliable estimates of the daily total extinction coefficient for cane. Again there appears to have been a decrease in the cane extinction coefficient during August, similar to that observed in the mixed cane/maize canopy.

The light interception and extinction coefficient of the maize ($\bar{K}_m$) alone can be derived by combining the data obtained in the mixed crop and the sole cane. However, because the amount of light intercepted by successive equal increments of leaf area is not the same once the leaf area exceeds ~ 1, the maize canopy light interception is not simply given by the difference between that intercepted by the cane/maize mixture and the cane alone. The extinction coefficient of the maize can be calculated using Equation 4 by substituting the values of the extinction coefficient for can (K_c), the values of light interception measured in the cane/maize mixture along with the measured values of maize and cane leaf area indices. Up to the middle of July $\bar{K}_c$ is assumed to be equal to the mean of all the values measured later in the season, i.e. 0.26 ($\mp$ 0.04). Any errors in K_m due to this assumption will be very small, because the cane leaf area was such a small fraction of the total leaf area during that period. Figure 6(b) shows the values of $\bar{K}_m$ obtained by this method and as in Figure 6(a) the extinction coefficient for the maize appears to increase almost linearly throughout the season. Some of the deviation in $\bar{K}_m$ towards the end of the season could be due to inaccuracies in the measurements of maize leaf area, particularly in the senescent tissue, at that time.

The competition for light between the plant cane and maize is shown in Figure 7. Here the cumulative amount of light intercepted by the different plant canopies is plotted throughout the 1986 season. The mixed cane/maize crop intercepted 40% of the incident solar radiation, therefore, there was substantial incident light which was not utilized by either crop, especially early in the season. However, the presence of the maize crop did reduce the amount of light that the plant cane intercepted, to about one quarter of that intercepted by a sole cane crop. The mechanism for this was by the suppression of the leaf area development of the cane canopy; already illustrated in Figure 5. In turn, this suppression of cane leaf area was due to a reduction in filler production in the intercropped cane, Figure 8. For most of the food crop season, between 10 and 20 weeks after planting, tiller numbers remained virtually constant in the intercropped cane. This is in sharp contrast to the tillering pattern in sole cane, which continued to increase to about three times that of the intercropped cane. Once the maize crop was removed, however, tillering increased in the intercropped cane, whereas, at the same time tiller numbers were falling in the sole cane. The net result was that at the final cane harvest, tiller numbers were almost identical in the intercropped and sole cane stands.

4.1.2 1987 first ratoon season

Figure 9 shows the seasonal change in the daily total amount of light intercepted by the mixed ratoon cane and maize crop and from the cane alone when the maize intercrop was removed. The mixed crop showed a rapid rise in light interception, with around 80% of the incident solar radiation being intercepted by 2 months after the maize sowing. This is higher than the 60% light interception achieved by the plant cane/maize crop (see Figure 4). Another striking difference between the 1986 and 1987 seasons was the ability of the first ratoon cane to complete much more vigorously for light compared with the previous plant cane crop. Figure 9 shows that in 1987 the cane canopy light interception rose steadily throughout the food crop season and became dominant during November and December. This was because the first ratoon can canopy developed much more rapidly than the plant cane canopy, and this can be seen by comparing Figure 10 with Figure 5. Although the maize leaf area initially dominated during 1987, after the end of October, when the maize began to senesce, the cane canopy developed very rapidly and by mid-November there was more green leaf area in the cane canopy than in the maize canopy. Figure 10 also shows that the sole cane leaf area index was consistently higher than that of the intercropped cane throughout the 1987 food crop season.

Figure 11 shows the daily total extinction coefficients for sole cane, intercropped cane and maize throughout the 1987 food crop season. As in 1986, the values derived for intercropped cane were high and variable when the leaf area index was low. Later in the season extinction coefficient values for intercropped cane were less variable and more consistent with the values calculated for the sole cane plot. Once the leaf area indices of the different crops were greater than about 1, there was little discernible seasonal trend in their extinction coefficients. Seasonal mean values of the crop extinction coefficients were therefore calculated at times when the leaf area indices were greater than 1. The resultant values were 0.37 (± 0.03) for sole cane, 0.39 (± 0.06) for intercropped cane and 0.42 (± 0.03) for maize. The 1987 mean extinction coefficient for intercropped cane (0.39) is higher than that observed in 1986 (0.26); possibly due to the leaves being more vertically orientated in 1986 as a result of the highly dominant maize canopy in that year. The extinction coefficient of maize was fairly constant in 1987, at about 0.42, whereas in 1986 it appeared to increase steadily throughout the season from 0.2 to 0.55 (Figure 6(b)). There is no obvious explanation for this different behaviour in the two years.

Figure 12 shows the net effect of the maize intercrop on cumulative light interception during the 1987 season. Much more light was intercepted by the ratoon cane (22%, Figure 12) than by the plant cane (4%, Figure 7). Sole cane still intercepted more light than intercropped cane, but the relative difference was much less than in the 1986 plant cane season. Less light was intercepted by the maize intercrop in 1987 compared with the 1986 crop, because of the more vigorous competition by the ratoon cane in 1987. The total light interception of the mixed crop was higher in 1987 (52%) than in 1986 (40%). The tiller development in the first ratoon cane canopy is illustrated in Figure 13. Compared to the tillering in the plant cane season (Figure 8) the ratoon cane was much less affected by the presence of the maize intercrop. However, when compared with a sole cane crop there was still an influence of the maize intercrop on cane tiller production and leaf area in 1987.

4.2 STOMATAL CONDUCTANCE

4.2.1 1986 plant cane season

Figure 14 shows three examples of the diurnal behaviour of the stomatal conductance of the plant cane and maize leaves at different times of the 1986 season. In general, conductances were low in the morning, maximum around midday and declined rapidly in the afternoon. However, close inspection of the data reveals some more interesting features. In the maize canopy the oldest leaves, lowest in the canopy, generally had the lowest conductances. Conversely, the highest conductances were not, as might be expected, observed in the youngest leaves, but rather tended to occur in the 3rd to 4th leaves below the uppermost leaf. No similar ranking of leaf conductances were observed in the plant cane canopy. Early in the reason when leaf areas were low, the conductances of cane leaves were much greater than those in the maize canopy (Figure 14(a)). However, later in the season the maize canopy dominated the shorter cane canopy and depressed the conductance of the cane leaves during the first half of the day (Figure 14(b) and (c)). In the afternoon cane leaf conductances remained higher than those in the maize canopy, probably because this was the time of day when the sun shone along the rows, thereby minimising the shading effect of the maize. The idea that it was the shading effect of the maize canopy which depressed leaf conductances during the early part of the day is supported by the data shown in Figure 15. Here the mean conductance of all the green leaves in the intercropped cane canopy are compared with the equivalent data from a nearby sole cane plot. Clearly the conductances in the sole cane plot were much higher than those in the intercropped cane, especially in the morning. Again in the afternoon, intercropped and sole cane conductances were similar, implying minimal shading of the intercropped cane at this time of day.

Figure 16 shows the seasonal change in the midday mean leaf conductance for maize and cane grown together and for cane grown on its own. Midday means were calculated from all the individual leaf conductances measured between 10h00 and 15h00. At the beginning of the food crop season cane leaf conductances were higher than those in the maize canopy, but as the maize developed the conductances of the two species tended to be more similar. In contrast, conductances in the sole cane plot remained higher than those in the mixed crop throughout the food crop season. On average, sole cane conductances were 27% higher than those of the cane with maize intercrop.

4.2.2 1987 first ratoon season

The values of stomatal conductance and their dirunal behaviour observed after the 1987 ratoon were broadly similar to those measured in 1986. For example, maximum stomatal conductances in the maize canopy occurred several leaves below the uppermost leaf. The ranking of conductances in the cane canopy was less obvious, except that the youngest leaves, which were not fully expanded, tended to have the lowest conductances; particularly later in the season.

Figure 17 shows the mean stomatal conductance of all the green leaves in the intercropped cane, maize and sole cane canopies on three days at the beginning, middle and end of the 1987 food crop season. The mean stomatal conductance in the intercropped cane canopy was greater than that in the maize canopy, with the difference between them again tending to decrease during the season. However, in contrast to 1986, no afternoon row orientation effect on intercropped cane stomatal conductances was observed during 1987. Figure 17 also shows that the highest stomatal conductances were observed in the sole cane canopy, again as in 1986. Figure 18 confirms that the presence of the maize intercrop decreased the cane conductances during 1987. Initially the intercropped cane conductances exceeded the maize conductances, but they tended to become more similar later in the season. Sole cane conductances were higher that those of the intercropped cane, especially in the middle of the season. On average, sole cane conductances were about 17% higher than those in the intercropped cane; this difference being smaller than that observed during 1986 (ie. 27%). This smaller difference between intercropped and sole cane conductances concurs with the light interception measurements which indicated that the 1987 first ratoon cane was much less shaded by the maize intercrop than the 1986 plant cane.

4.3 CANOPY CONDUCTANCE AND EVAPORATION

4.3.1 1986 plant cane season

The total conductance of the two canopies in the cane/maize mixture were calculated from the above stomatal conductances and measurements of leaf area index. Figure 19 shows the diurnal change in canopy conductance for three days at different time of the 1986 season. Although maize leaf conductances did not vary greatly during the season (Figures 14 and 16), the total conductance of the maize canopy did vary in accordance with the change in green leaf area (Figure 5). Maize canopy conductance was low at the beginning of the season, reached very high values (ca 15 mm s^{-1} or 600 mmol m^{-2} s^{-1}) when the canopy had its maximum green area and decreased again as senescence increased later in the season. In marked contrast the total conductance of the cane canopy was much lower throughout the season, despite the fact that individual leaves had equal (or higher) conductances than the maize leaves (Figure 14). This was, of course, due to the very low leaf area of the cane canopy (Figure 5).

The canopy conductances shown in Figure 19 were used to calculate transpiration and the results are shown in Figure 20. Direct measurments of soil evaporation are also shown to complete the water balance on the three example days. On all three days evaporation increased during the morning, reached a maximum around midday and decreased again during the afternoon. However, the proportions of water lost from the cane, maize and soil varied widely during the season. Of a total evaporative loss of 4.0 mm in mid May (Figure 20(a)) transpiration from the cane contributed only 3%; maize transpiration was ten times this at 27%, but by far the greatest water loss was as direct soil evaporation (70%). In contrast, when the maize canopy had developed its maximum green area in mid June, transpiration from this source increased to 68% and soil evaporation was reduced to 24% of the total

(Figure 20(b)). Again, the smallest contribution to the total evaporation came from the cane leaves (8%). Cane transpiration increased further to 14% of the total evaporation later in the season (Figure 20(c)), but because the soil evaporation and maize transpiration were lower on this day the absolute amount of evaporation, 3.6 mm, was less than on the two previous days.

Table 2 summarises the components of evaporation measured on the three days shown in Figure 20 and for comparison includes the estimates of evaporation used to determine the amounts of irrigation applied, which were calculated using the Penman values and crop coefficients for the maize and cane. In the early part of the season and when the soil was wet (9 May 1986) the total actual evaporation was slightly greater than the Penman value, and the estimated total evaporation was the same as the actual evaporation. Later in the season, however, actual evaporation exceeded the Penman potential by as much as 60% and, in consequence, the estimated total evaporation fell short of actual evaporation by about 20 and 30%.

4.3.2 1987 first ratoon season

Figure 21 shows the diurnal change in canopy conductance for three days at different times of the 1987 season. At the beginning of the season both cane and maize canopy conductances were low and of similar magnitude. Canopy conductances were much higher in the middle of the season and when the maize crop had its highest leaf area index, its canopy conductance was nearly twice that of the cane crop. Later in the season as the maize crop senesced and the cane continue to grow, the conductance of the cane canopy increased rapidly, reaching values twice as high as those in the maize (eg. Figure 21(c)). Although the pattern of maize canopy conductance during 1987 was fairly similar to those observed during 1986, there were marked differences in the values of cane canopy conductance between the two seasons. During 1986 cane canopy conductances remained very low and never approached the levels observed in the maize canopy. In contrast, during 1987, the cane canopy conductance was much higher throughout the season and eventually became the dominant conductance of the mixed crop.

The more vigorous growth and conductance of the cane canopy during 1987 is also reflected in the components of evaporation from the mixed crop. This is illustrated in Figure 22 for the same three example days chosen in Figure 21. Hourly values of transpiration are shown for both the cane and maize crops along with the independent measurements of soil evaporation. The total evaporation was lowest at the beginning of the season, eg. in mid September (Figure 22(a)) where of a total daily evaporative loss of 3.5 mm, 67% came directly from the soil, 29% from the maize and the least, 18%, from the cane. The low transpirational loss and high soil evaporative loss may be expected at this time of the season since the crop leaf area indices were very low, totalling only 0.52 for the mixed crop on 11 September. In the middle of the season crop leaf areas were much higher, e.g. 2.8 on 21 October and thus produced a different distribution of evaporation on this day, Figure 22(b)). Maize transpiration dominated at 50% of the total loss, cane transpiration cane had increased to 26% and soil evaporation was reduced to 24%; the smallest but still not insignificant component. Figure 22(c) also shows that towards the end of the 1987 food crop season the relative water use of the two crops was reversed and transpiration from the cane became dominant at 52%, whereas the maize transpiration was reduced to 34%. Direct losses of water from the soil at this time were the lowest recorded during the season at ~14%, but were still significant even though the mixed crop leaf area index was over 4 at this time.

Table 2 summarises the evaporation components measured on the above 3 days in 1987 and compares them with the estimates of evaporation used to determine the irrigation amounts. Measurements indicate that much more water was used by the mixed crop in 1987 than in 1986. However, estimated cane evaporation based on Penman potential and crop factors, consistently overestimated the actual cane crop water use. Total estimated evaporation for the mixed crop was about 10% greater than that measured on the first two example days in 1987. Conversely, as in 1986, the estimated total evaporation was around 20% lower than measured evaporation toward the end of the 1987 season.

5. Discussion and Conclusions

The diurnal patterns of light extinction in the sole cane and cane/maize intercrop, as described by equations 1 and 2 (Figure 3), have been observed in other monocrops (eg. Tooming and Ross 1964; Baldocchi, Verma and Rosenberg 1985). In a dense sole maize canopy Ross (1981) tested the validity of this type of formula and found comparatively good agreement for a value of K' = 0.5. This value is similar to that obtained here for maize during 1987 and at the end of the 1986 season. However, early in the 1986 season much lower maize extinction coefficients were obtained in the present study. Much of this difference could be due to the very different crop density and planting arrangement used in the two studies, since it is recognised that horizontal inhomogeneities such as sparse and/or row planting of crops leads to increased light penetration and, therefore, to an effective reduction in their extinction coefficient (Ross 1981). However, in the present study the different behaviour of the maize extinction coefficient in the two seasons, 1986 and 1987 (Figure 6(b) and 11) remains unexplained. The existence of a defined row structure has also been shown to affect the diurnal pattern of light interception. For example, in a row crop of maize, M'Chaughey and Davis (1974) found a very marked minimum in the extinction coefficient 2 hours before solar noon as this coincided with the time at which the sun's rays were parallel to the rows. In the present study the low values of K observed during 1986 around 15h00 (Figure 3) also coincided with the time of day when the sun shone along the rows, however, using the McChaughey and Davis model in the present study produced much too strong a response to row orientation and fitted the data less well than the simple K/Sinß (equation 2) model. Even the simple model (equation 2) did not fit the data particularly well, especially in the very low leaf area cane canopy. Furthermore, both of the above models only work under cloudless skies, the exception rather than the rule at the site concerned. The error involved in using a constant value of extinction coefficient for the entire day is small, and only produces a ~ 5% underestimate in radiation interception around midday.

The use of a constant daily value of extinction coefficient should, therefore, suffice for many purposes (e.g. calculating hourly transpiration rates).

The values of daily mean extinction coefficient obtained here for the cane canopy differed between the two seasons, i.e. $\overline{K}_c$ = 0.26 in 1986 and $\overline{K}_c$ = 0.39 in 1987. The difference possibly reflects the uncertainty in determining cane leaf area indices, which was high particularly as the leaf area was low. The most reliable values cane extinction coefficient are therefore associated with the highest leaf areas which occurred towards the end of the 1987 season. Similar values of cane extinction coefficient can be derived from previous light interception studies in plant cane (Batchelor *et.al.* 1985), where K_C was in the range 0.2 to 0.3 for a fully developed canopy. In the present study the different values of cane and maize extinction coefficient observed during and between the two seasons indicate that the simple light extinction model used here may not apply very well in widely spaced, low leaf area canopies.

The stomatal conductances observed in the maize canopy were high (6-7 mm s^{-1} or 250-300 mmol $m^{-2}s^{-1}$) and similar to values obtained in other studies of well watered maize (see, for example, Uchijima 1976; Körner, Scheel and Bauer 1979 and Waldren 1983). The decrease in stomatal conductance with leaf age has also been reported for maize by Dwyer and Stewart (1986) and Williams (1985). Even higher stomatal conductances were observed here in the sugar cane canopy at the beginning of the season (up to 10 mms^{-1} or 400 mmol $m^{-2}s^{-1}$) and these values are characteristic of sugar cane growing under optimal conditions (Inmar-Bamber and De Jager 1986; Roberts *et al.* 1988). Although the cane stomatal conductances were high at the beginning of the season they declined as the maize canopy developed. Assuming there was an adequate supply of soil water, the reduced conductances in the intercropped cane leaves were caused by shading of the cane canopy by the maize intercrop. This shading not only reduced leaf conductances but also diminished the size of the sugar cane canopy in the intercrop compared with a sole cane crop. For example, in late July 1986 the sugar cane tiller density in the mixed crop was less than half of that in a sole cane plot. The net effect of the maize intercrop was therefore to reduce both the amount of cane leaf area and its rate of water loss per unit leaf area. Combining a 30% reduction in stomatal conductance with a reduction in leaf area of 50% implies that the canopy conductance of the intercropped cane was only one third of that in a sole cane crop. In turn, this much reduced canopy conductance in conjunction with a lower amount of intercepted radiation gives a greatly reduced rate of transpiration in the intercropped cane. Using the above figures the ratio of intercropped cane transpiration to sole cane transpiration would be 1:3. The combined effect of reduced light interception and reduced transpiration in the intercropped cane undoubtedly produced much retarded cane growth during 1986. This effect was smaller, but still significant after the first ratoon in 1987.

The components of evaporation found in the present study indicate a large loss of water as direct soil evaporation. In an incomplete sole cane canopy Thompson (1976) also found large losses of water as direct soil evaporation, e.g. about 50% of total evaporation came from the soil when the canopy cover was 25%. However, the absolute amount of soil evaporation depends on a number of factors including canopy cover, frequency of soil wetting and soil type. Thompson (1976) also showed that the practice of leaving trash in the interrows greatly reduces direct soil evaporation losses. In the present study soil evaporation was reduced after the first ratoon by leaving trash in the narrow cane interrow. However, in plant cane where trash was not left on the soil surface it may have still been possible to reduce this waste of water by using a different planting arrangement. For example, using equally spaced cane rows (1.62 m x 1.62 m) with a single row of maize in each interrow. This should give a more even ground cover especially early in the season, when the soil evaporative losses are greatest. This planting arrangement is used in sugar cane/intercrop mixtures with overhead irrigation, but may prove prohibitively expensive in drip irrigation systems due to the extra dripline equipment required.

Total crop evaporation is normally estimated using potential evaporation and crop coefficients. On the six days presented in this report, the effective crop coefficients ranged from 0.8 to 1.7, much higher than the values for a sole cane crop during the first 3 months of its crop cycle (i.e. 0.6 to 1.0, Batchelor *et al.* 1985). The presence of the intercrop therefore increased the crop coefficient and some allowance must be made for this in calculating the irrigation requirement. In the present study this was attempted by using crop coefficients for maize (as if it were grown on its own) and multiplying the resultant figure by 0.5 to allow for the fact that the maize was planted at only half of its sole crop density. The estimated evaporation from the sugar cane was then added to the above estimate for the maize crop to give the total water requirement of the mixed crop. Although this approach appears to have worked early in the 1986 season (Table 2) the estimated total evaporation, and hence irrigation requirement, were underestimated later in that year. During 1987 the mixed crop was slightly over-irrigated early on and again under-irrigated towards the end of the season. Furthermore, the agreement between the estimated and measured evaporation at the beginning of the 1986 and 1987 seasons is somewhat fortuitous since it resulted from an overestimate of the sugar cane evaporation and an underestimate of the maize evaporation. This point is illustrated more clearly in Table 3, where the soil evaporation is partitioned between the two crops according to the rates of loss given by the individual lysimeters (Figure 1). The degree of underestimation of the maize evaporation tended to increase during the season, as did the overestimation of the cane evaporation during 1986. These two substantial errors in estimated evaporation only compensated at the beginning of the season when the soil was wet.

The above results have some implication in terms of below ground competition for water. They suggest that throughout the growing season the maize intercrop was abstracting water in excess of its irrigation application and must have achieved this by foraging for water in the soil zone beneath the sugar cane. When the overirrigation of the sugar cane fully compensated there would have been adequate water for both crops. However, where the total irrigation was less that the total water requirement of the mixed crop, it is feasible that there was some competition for water, which may have benefited the dominant maize crop; particularly during the 1986 season. The conclusion that the maize crop abstracted water from the soil zone below the sugar cane is supported by soil moisture measurements made concurrently in a similar intercropping trial (Hodnett, M.G. personal communication 1987).

The above conclusions should be regarded as tentative since they are based on the results from six individual days chosen arbitrarily from the beginning, middle and end of the two food crop seasons. As previously mentioned, the total evaporation and the relative contributions of soil and plants will depend on a number of factors such as the prevailing weather, leaf area of the component species and soil surface wetness, which, in turn, is principally a function of the time since the last rainstorm. To compute the total and components of evaporation over much longer (weeks to months) periods encompassing a complete range of weather and soil conditions, further analysis is needed, which may involve some modelling. Only then can these early results be fully assessed. However, the current report does illustrate techniques which can be used to partition light and water in the complex situation of a mixed row crop; techniques which should be equally applicable in many dryland as well as irrigated intercropping systems. The information obtained by these methods is rarely available but is invaluable in understanding the performance of such complex cropping systems.

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Table 1 Comparison of 1986 and 1987 food crop seasons rainfall (mm) with long term mean. Penman potential evaporation (mm) for the two seasons is also shown.

	Labourdonnais* Rainfall (1962-1980)	Belle Vue Rainfall 1986	Belle Vue Potential 1986	Belle Vue Rainfall 1987	Belle Vue Potential 1987
April	158	45	116		
May	119	80	96		
June	82	52	79		
July	79	16	92		
August	66	110	112	49	158
September	43			27	183
October	44			49	220
November	58			46	243
December	123			32	245
Food Crop Season Total					
April-August	504	303	495		
August-December	334			203	1049

Table 2 ***Summary of the components of sugar cane/maize intercrop water use on six days at different times of the 1986 and 1987 seasons.***

	MEASURED EVAPORATION (mm)				ESTIMATED EVAPORATION (mm)				
Date	Maize	Cane	Soil	Total	*Penman	Maize	Cane	Total	Ratio of Estimated to measured
9 May 1986	1.1	0.1	2.8	4.0	3.6	1.8	2.2	4.0	0.99
11 June 1986	3.0	0.4	1.0	4.4	2.8	1.4	1.8	3.2	0.72
9 July 1986	2.5	0.5	0.6	3.6	2.9	1.0	1.9	2.9	0.78
11 Sept 1987	0.5	0.6	2.3	3.5	4.2	1.3	1.5	3.8	1.09
21 Oct 1987	2.4	1.2	1.1	4.8	4.9	2.4	2.9	5.4	1.13
25 Nov 1987	2.9	4.5	1.2	8.6	5.2	1.6	5.2	6.7	0.78

*(Mean value recorded in the two weeks prior to the week containing the day concerned.)

Table 3 *Comparison of sugar cane and maize measured and estimated evaporation on six days at different times of the 1986 and 1987 seasons*

		EVAPORATION (mm)		
		Measured	Estimated*	Estimate/measured
9 May 1986	MAIZE	2.5	1.8	0.72
	CANE	1.5	2.2	1.47
	TOTAL	4.0	4.0	0.99
11 June 1986	MAIZE	3.4	1.4	0.40
	CANE	1.0	1.8	1.88
	TOTAL	4.4	3.2	0.72
9 July 1986	MAIZE	2.8	1.0	0.36
	CANE	0.9	1.9	2.14
	TOTAL	3.6	2.9	0.78
11 Sept 1987	MAIZE	2.4	1.3	0.54
	CANE	1.1	2.5	2.27
	TOTAL	3.5	3.8	1.09
21 Oct 1987	MAIZE	3.3	2.4	0.73
	CANE	1.5	2.9	1.93
	TOTAL	4.8	5.4	1.13
25 Nov 1987	MAIZE	3.9	1.5	0.38
	CANE	4.7	5.2	1.11
	TOTAL	8.6	6.7	0.78

*(Using Penman potential evaporation and crop factors.)

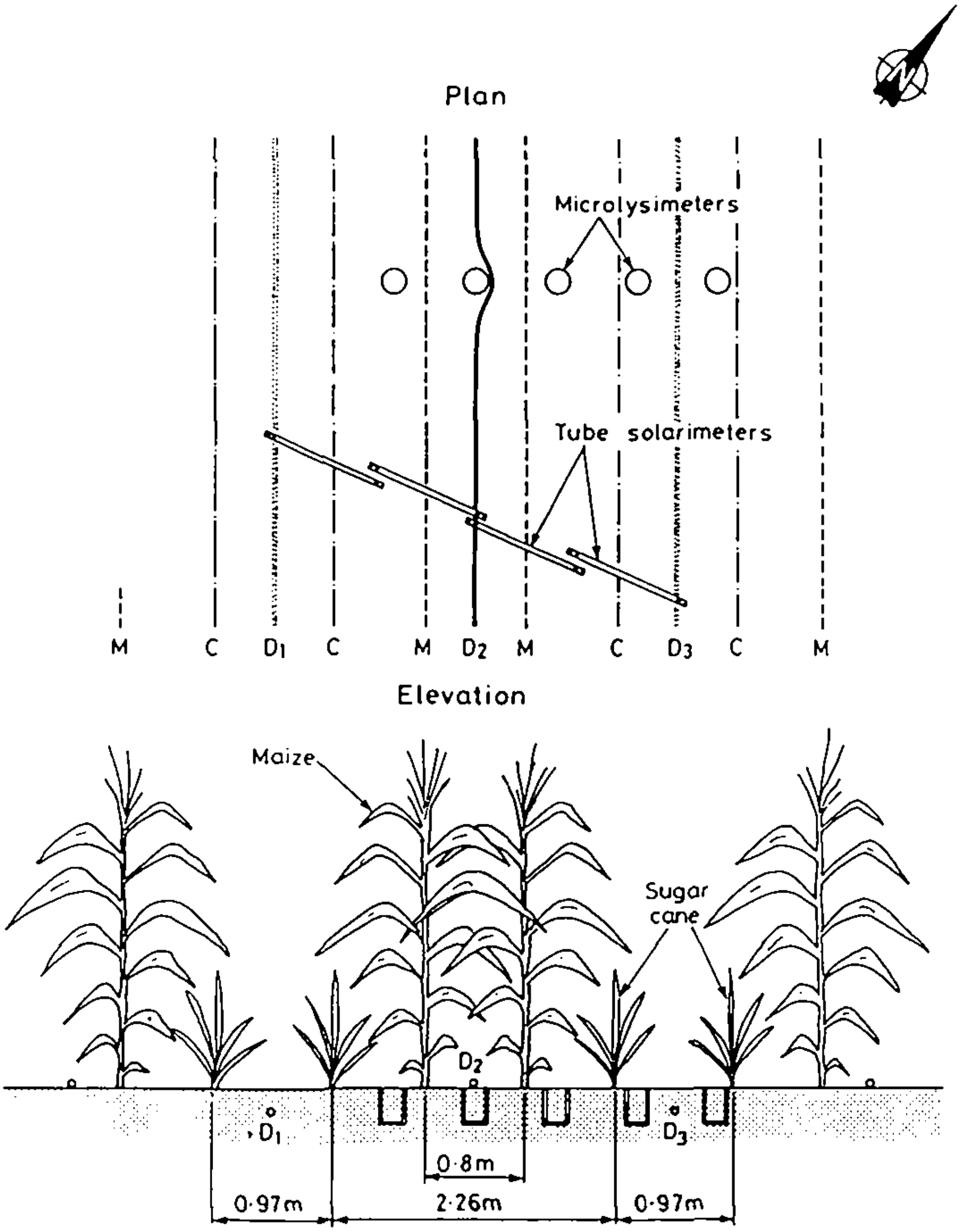

Figure 1 *A schematic diagram showing the maize (M) and cane (C) planting pattern, the placement of the irrigation drip lines (D1, D2 and D3) and the arrangement of the tube solarimeters and microlysimeters.*

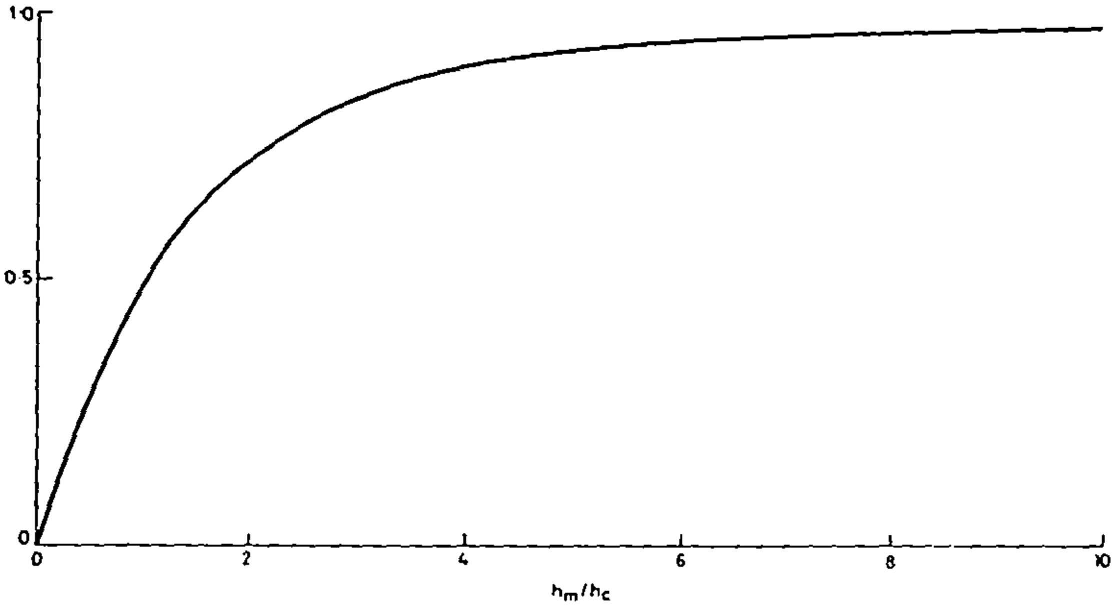

Figure 2 *The form of the scaling factor f as a function of the ratio of the heights of the maize and cane crops h_m/h_c.*

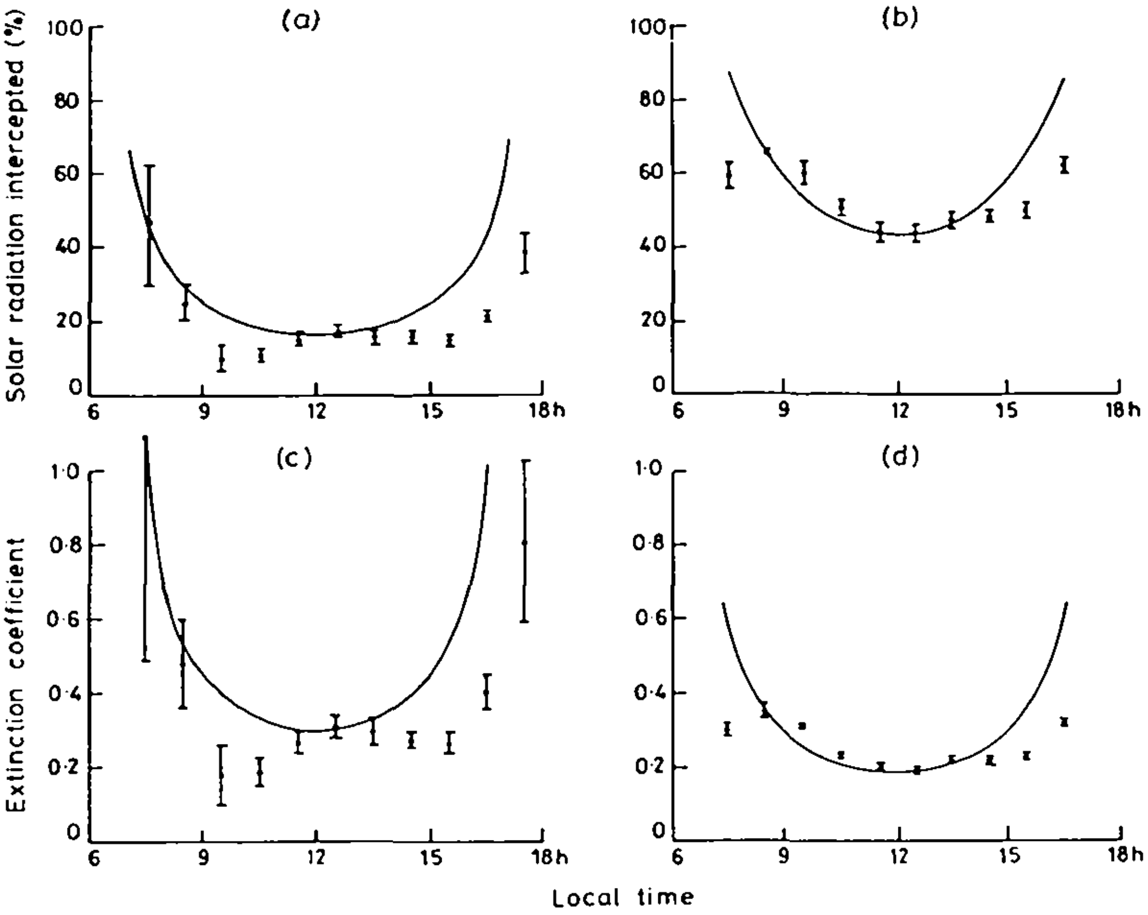

Figure 3 *The diurnal pattern of (a) solar radiation interception and (c) extinction coefficient of sugar cane (after maize removed) observed during the 1986 plant cane season. The equivalent data for the cane/maize mixture, (b) and (d) respectively, are also shown.*

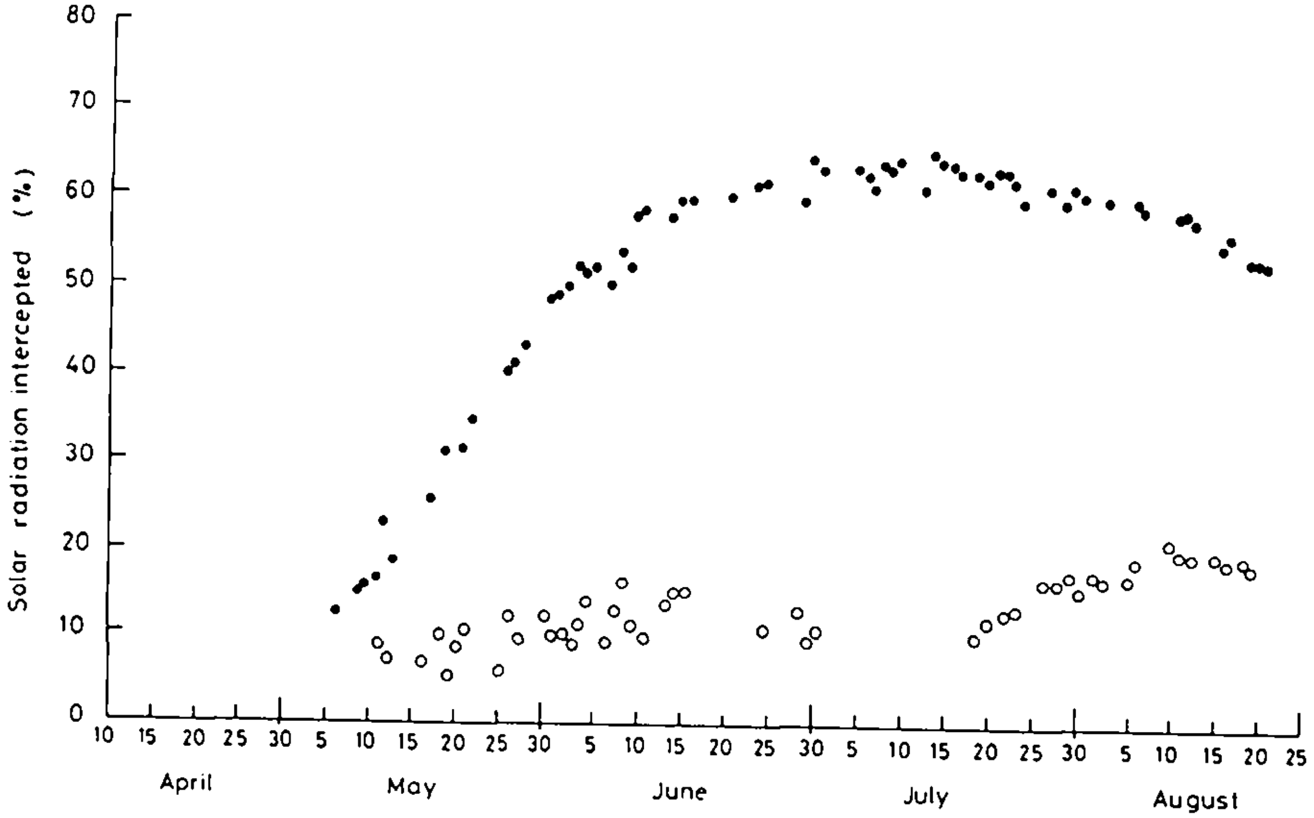

Figure 4 *Seasonal change in daily total solar radiation intercepted by the cane/maize mixture (●) and by the sugar cane alone (after maize removed) (○) during 1986.*

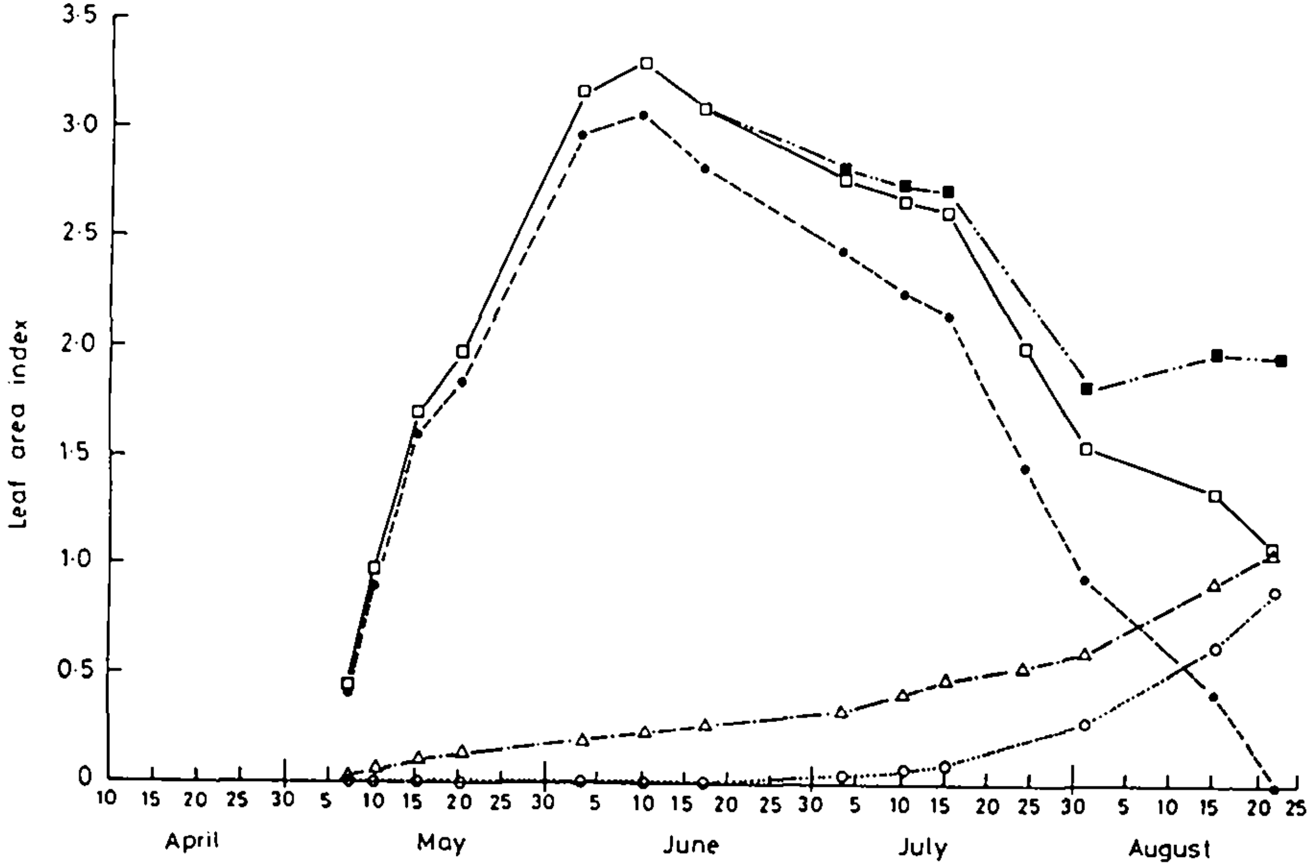

Figure 5 *Seasonal variation in the leaf area index of maize (green (●), dead (○)) and sugar cane (green (∆)) during 1986. The leaf area index of the combined cane and maize canopy are also shown (green (□) and green + dead (■)).*

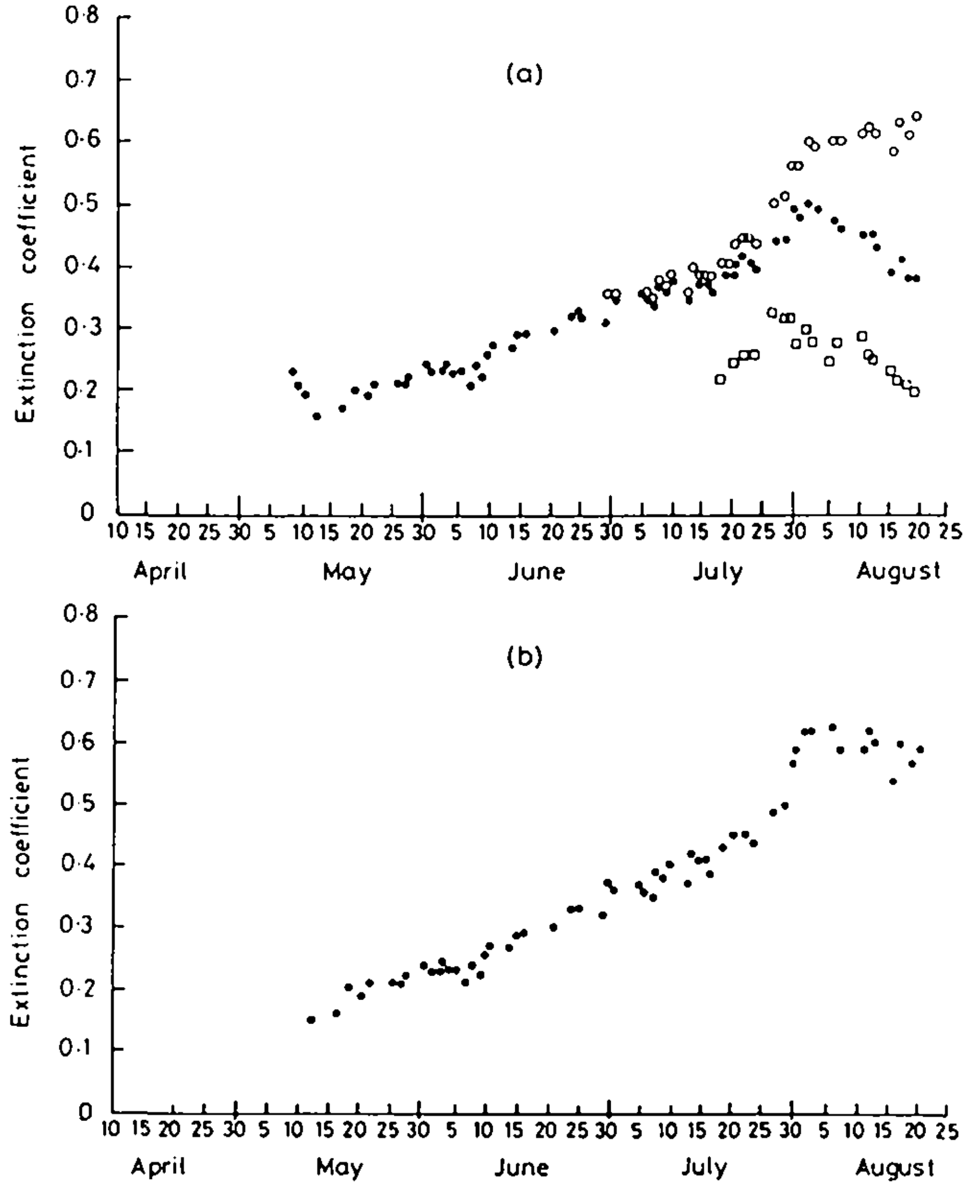

Figure 6(a) Seasonal change in daily mean extinction coefficient for the cane/maize mixture (●) and the sugar cane alone (after maize removed) (□) during 1986. Also shown (○) are the values of cane/maize extinction coefficient derived using green leaf area index only.

(b) Seasonal change in daily mean extinction coefficient for maize alone (●) during 1986.

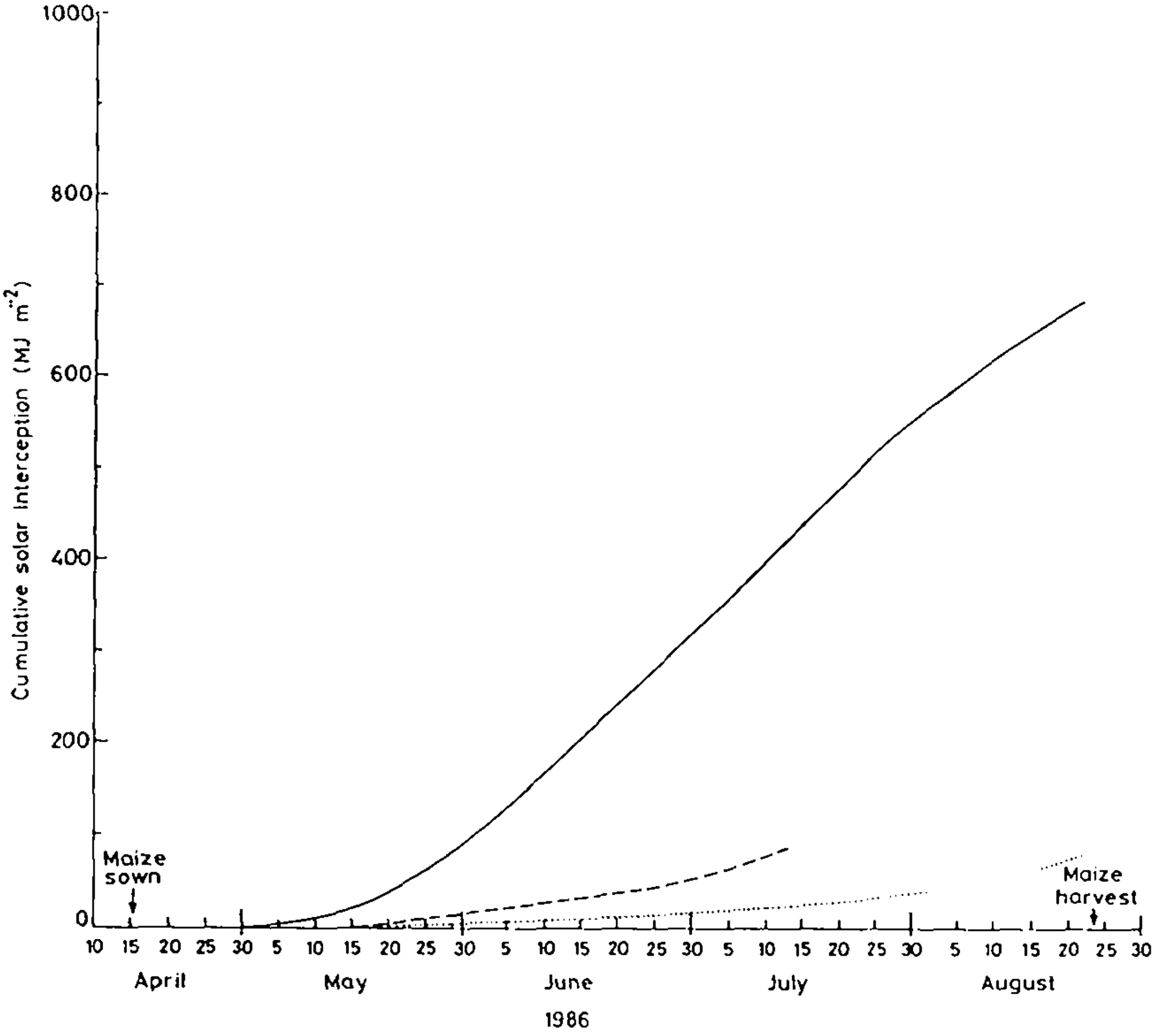

Figure 7 *The cumulative amount of solar radiation intercepted by cane (. . . . .), maize (——) and sole cane (- - -) between maize sowing and harvest during the 1986 plant cane season.*

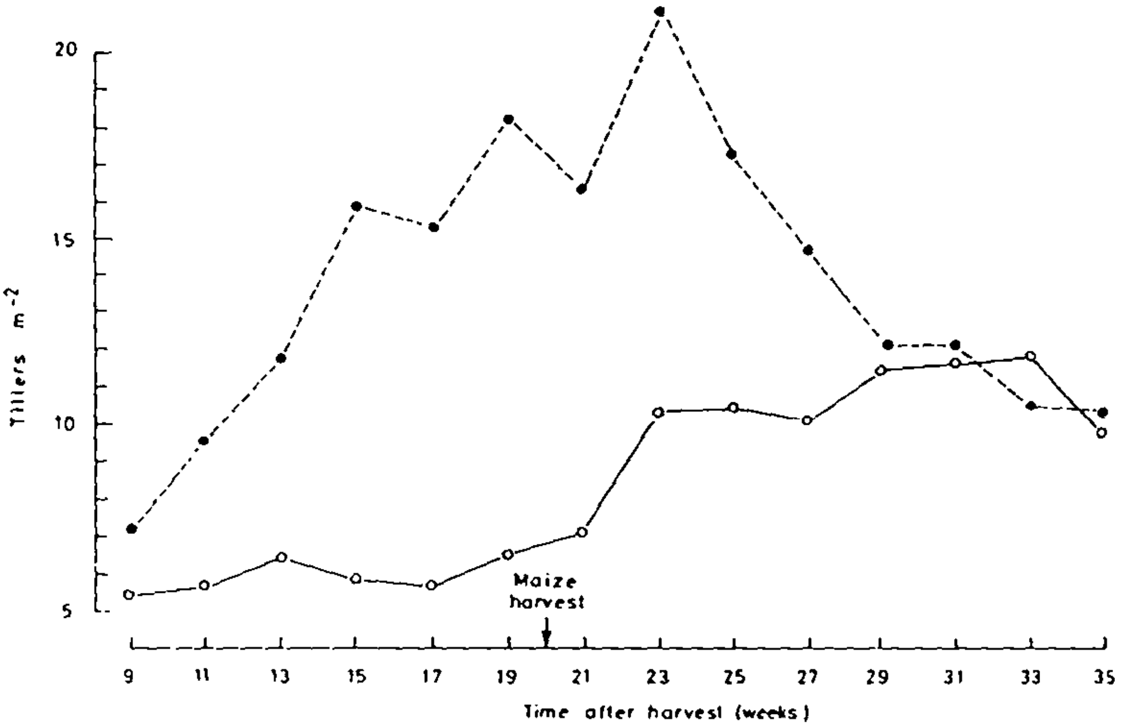

Figure 8 *A comparison of the tiller densities in intercropped cane (○ — ○) and sole cane (● — ●) during the 1986 plant cane season.*

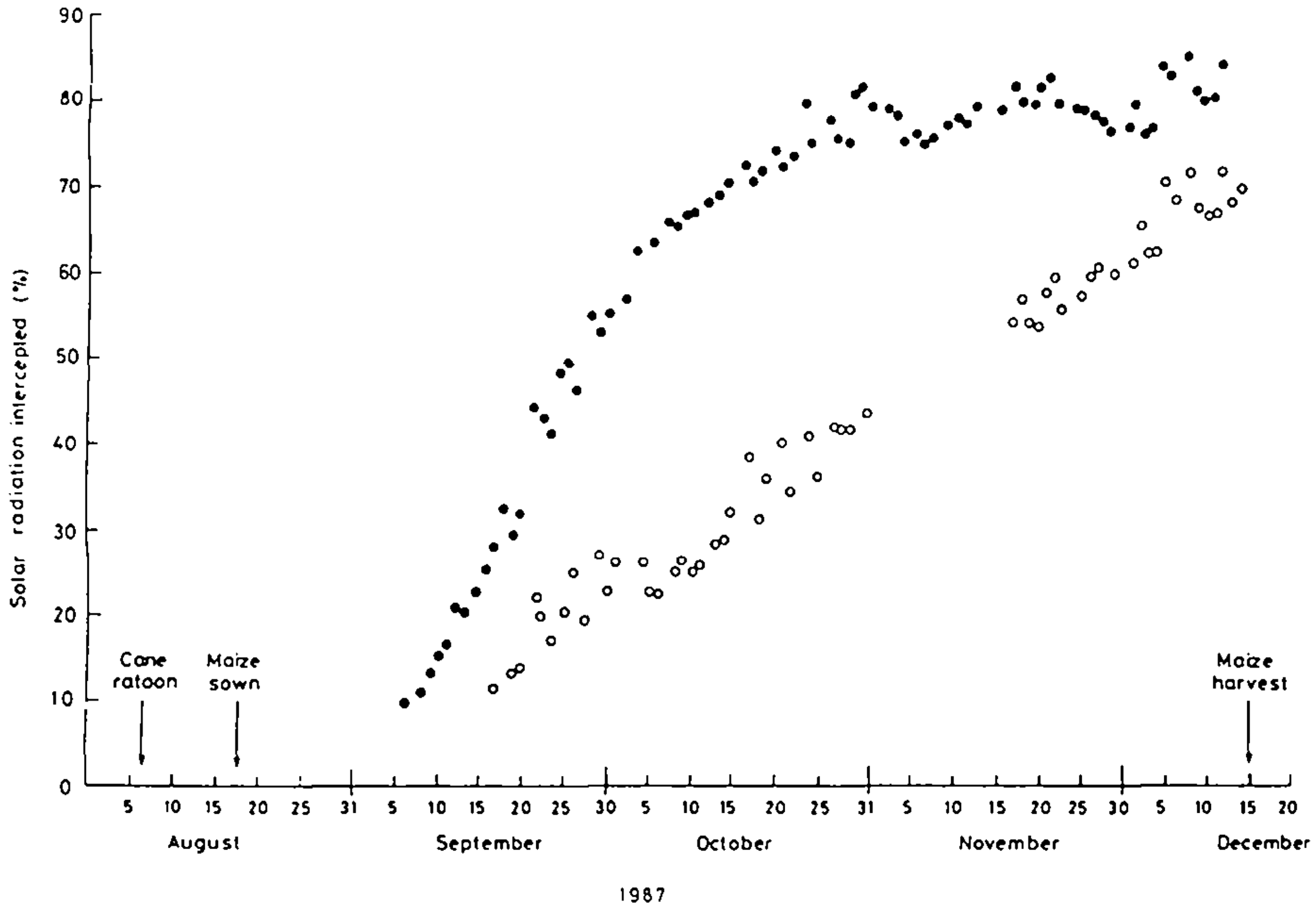

Figure 9 *Seasonal change in the daily total solar radiation intercepted by the cane/maize mixture (●) and by the sugar cane along (after maize removed), (○), during 1987.*

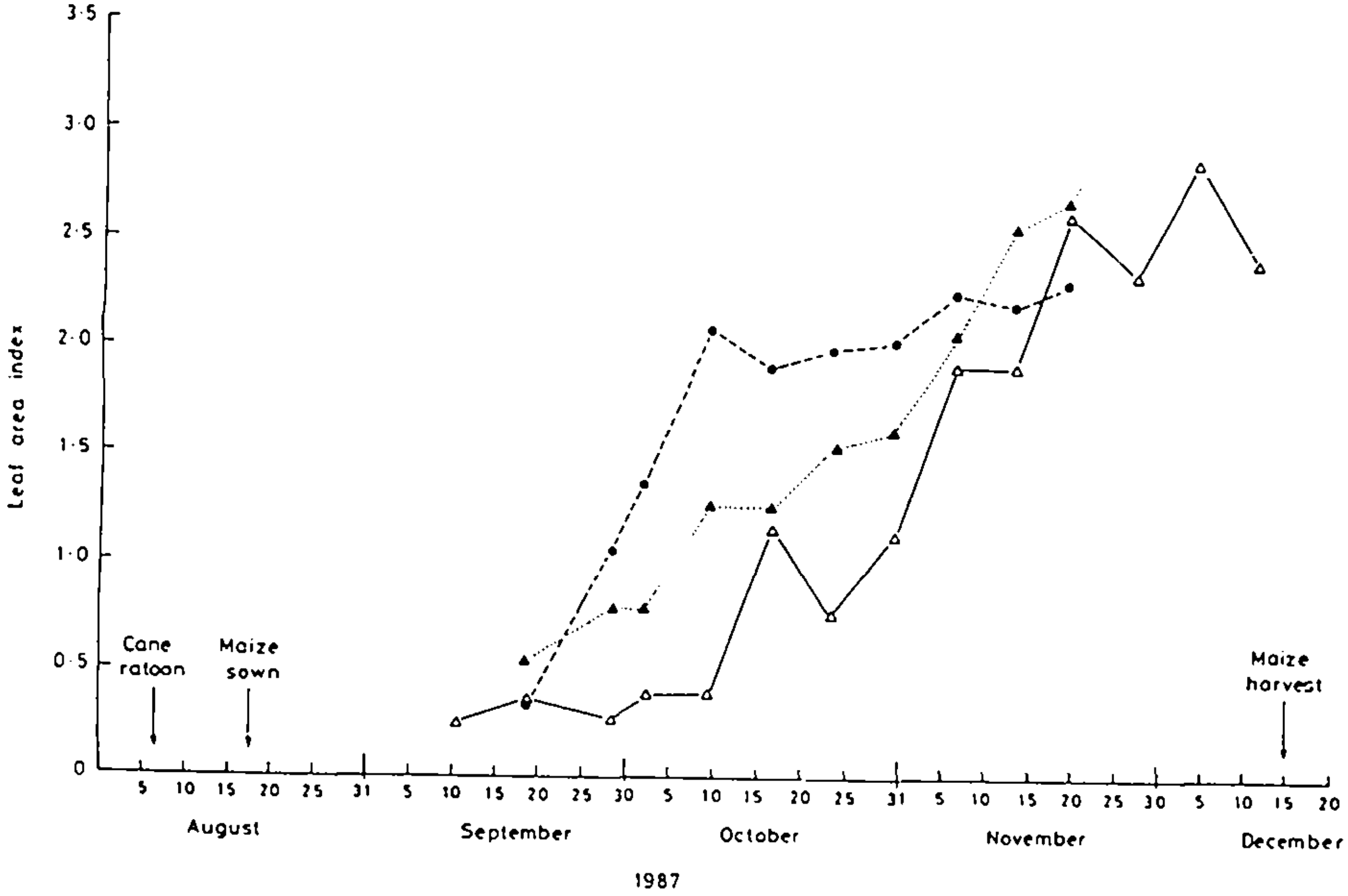

Figure 10 *Seasonal variation in the leaf area index of maize (●) and intercropped sugar cane (△) during 1987. The leaf area index of sole cane (▲) is also shown for comparison.*

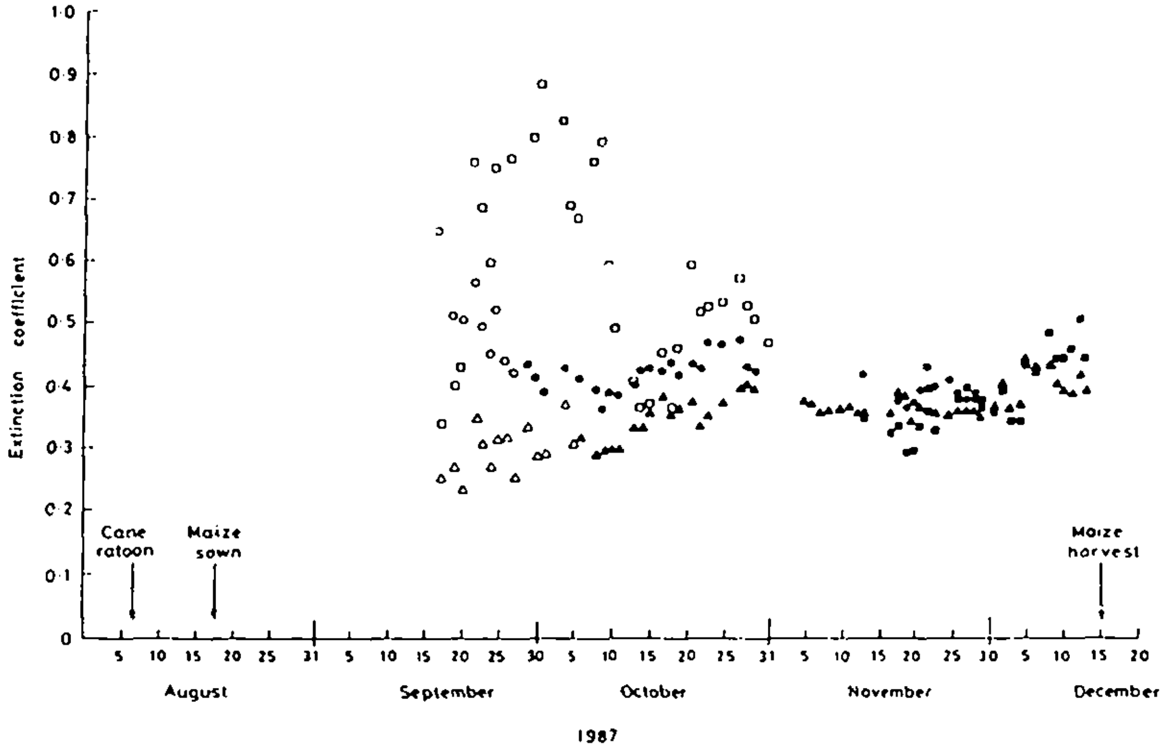

Figure 11 Seasonal change in the daily mean extinction coefficient of maize (●, O) and intercropped sugar cane (■, □) during 1987. Daily mean extinction coefficients of sole cane (▲, △) are also shown for comparison. The open symbols refer to data calculated with leaf area indices less than 1.0. Closed symbols are for leaf area indices greater than 1.0.

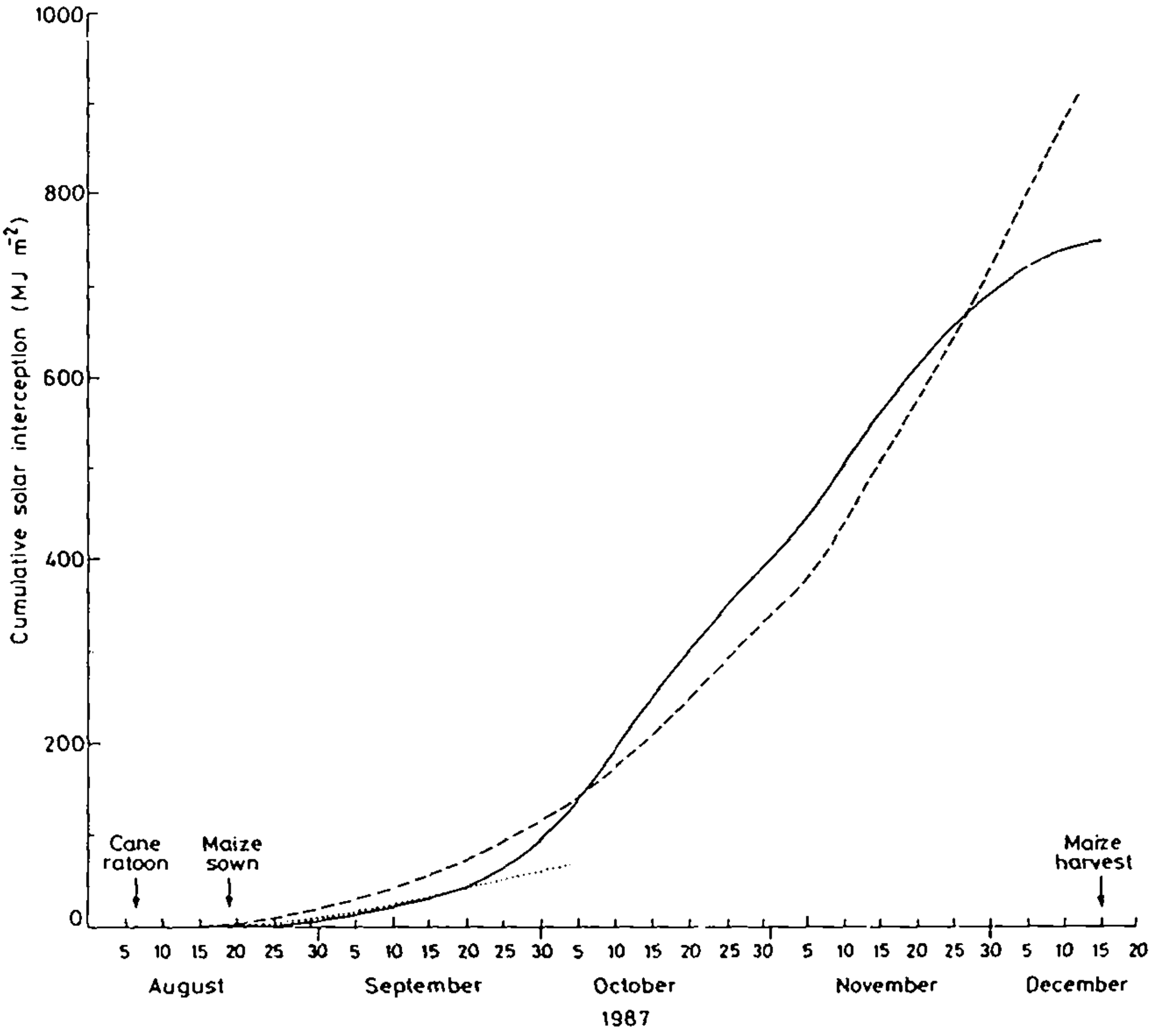

Figure 12 *The cumulative amount of solar radiation intercepted by cane (. . . . .), maize (———) and sole cane (- - -) between the first ratoon and the maize harvest during the 1987 season.*

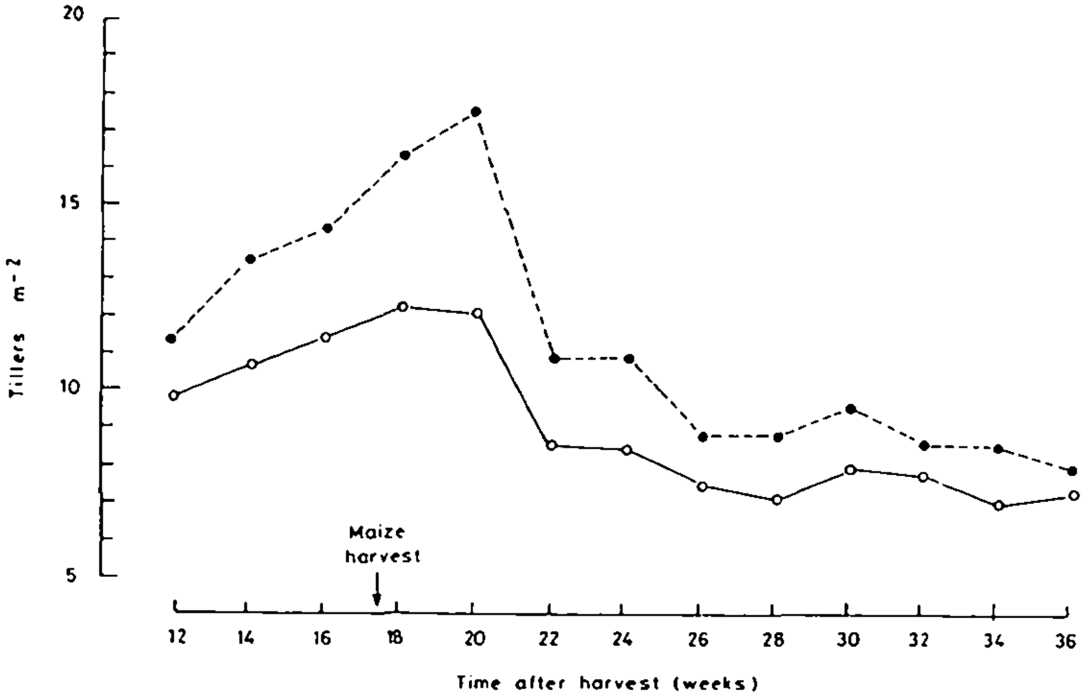

Figure 13 *A comparison of the tiller densities in intercropped cane (O— O) and sole cane (●— ●) during the 1987 first ratoon season.*

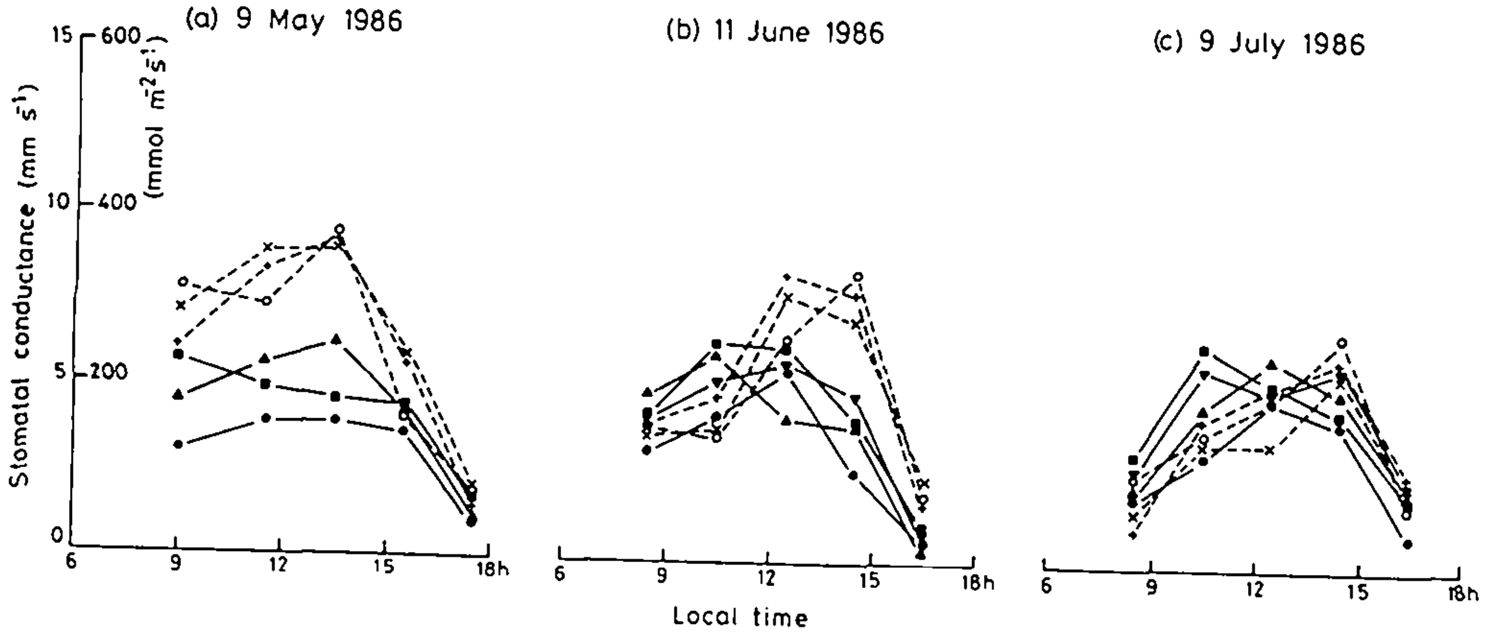

Figure 14 *The diurnal change in stomatal conductance of maize (——) and Cane (- - -) leaves on three days at different times of the 1986 season. The key to the symbols is:*

LEAF AGE	MAIZE	CANE
Oldest	●	
	▲	
	■	
Youngest	▼	

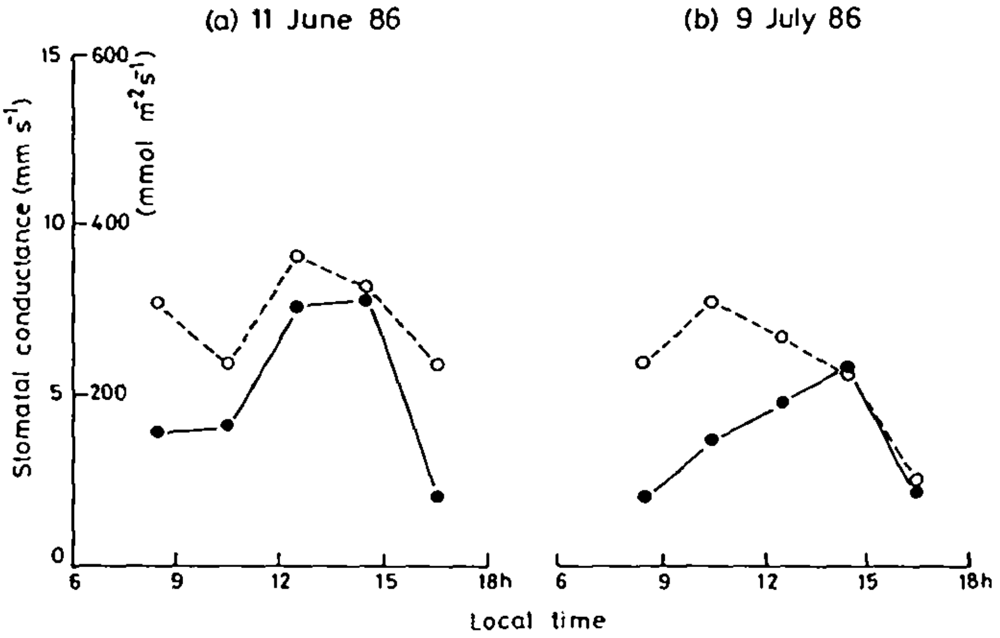

Figure 15 *A comparison of the diurnal behaviour of stomatal conductance in intercropped cane (●) and sole cane(○) on two days during 1986 when the maize canopy was fully developed.*

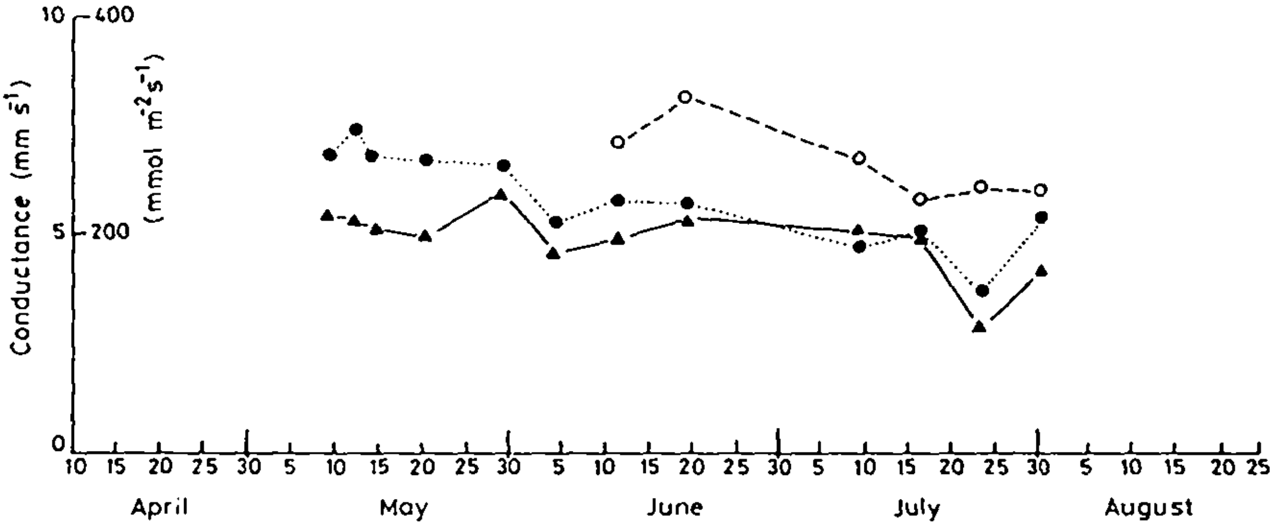

Figure 16 *Variation in midday (10h00 to 15h00) mean stomatal conductance for maize (▲) and cane (●) grown together and for cane grown on its own (○), during the 1986 season.*

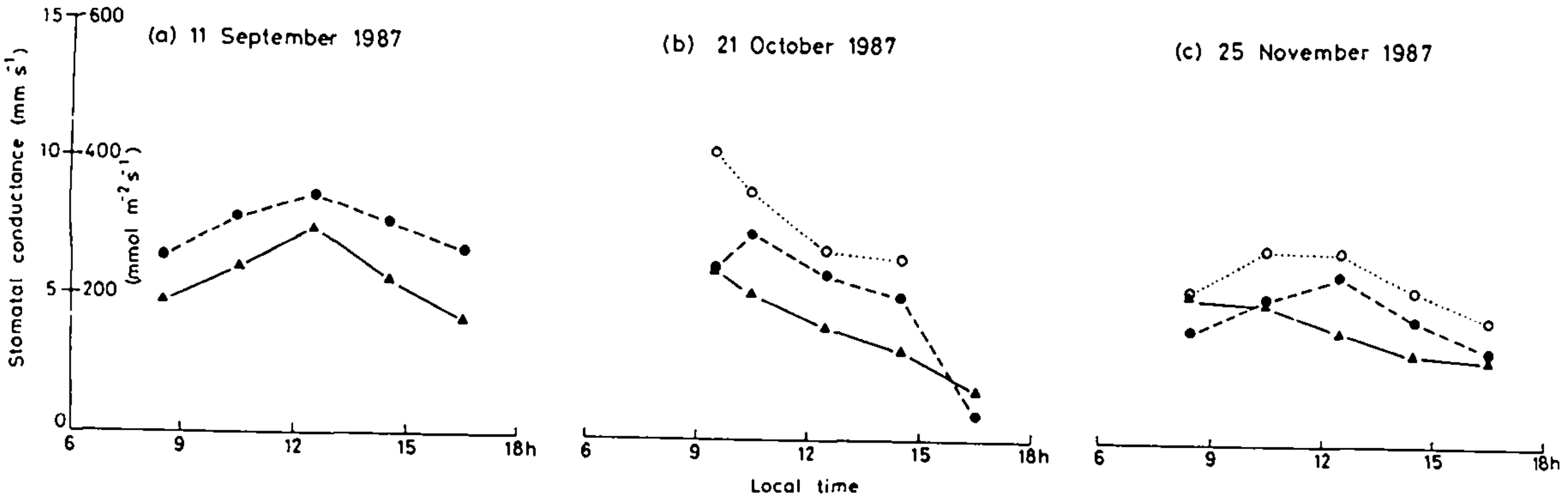

Figure 17 *The diurnal change in the mean stomatal conductance of maize (▲ — ▲) and intercropped cane (● · ●) on three days at different times of the 1987 season. For comparison, the mean stomatal conductances of sole cane leaves (○ · · ○) are also shown for two of these days.*

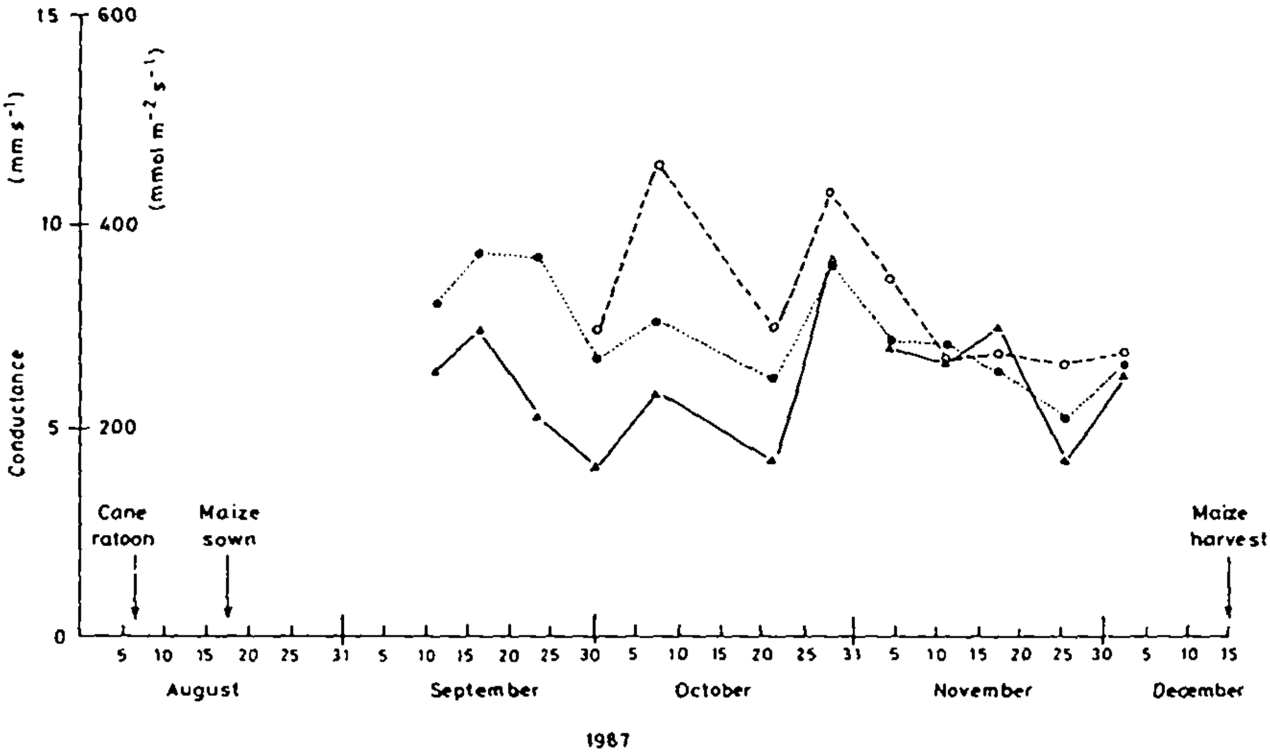

Figure 18 *Variation in midday (10h00 to 15h00) mean stomatal conductance for maize (▲) and cane (●) grown together and for cane grown on its own (○), during the 1987 season.*

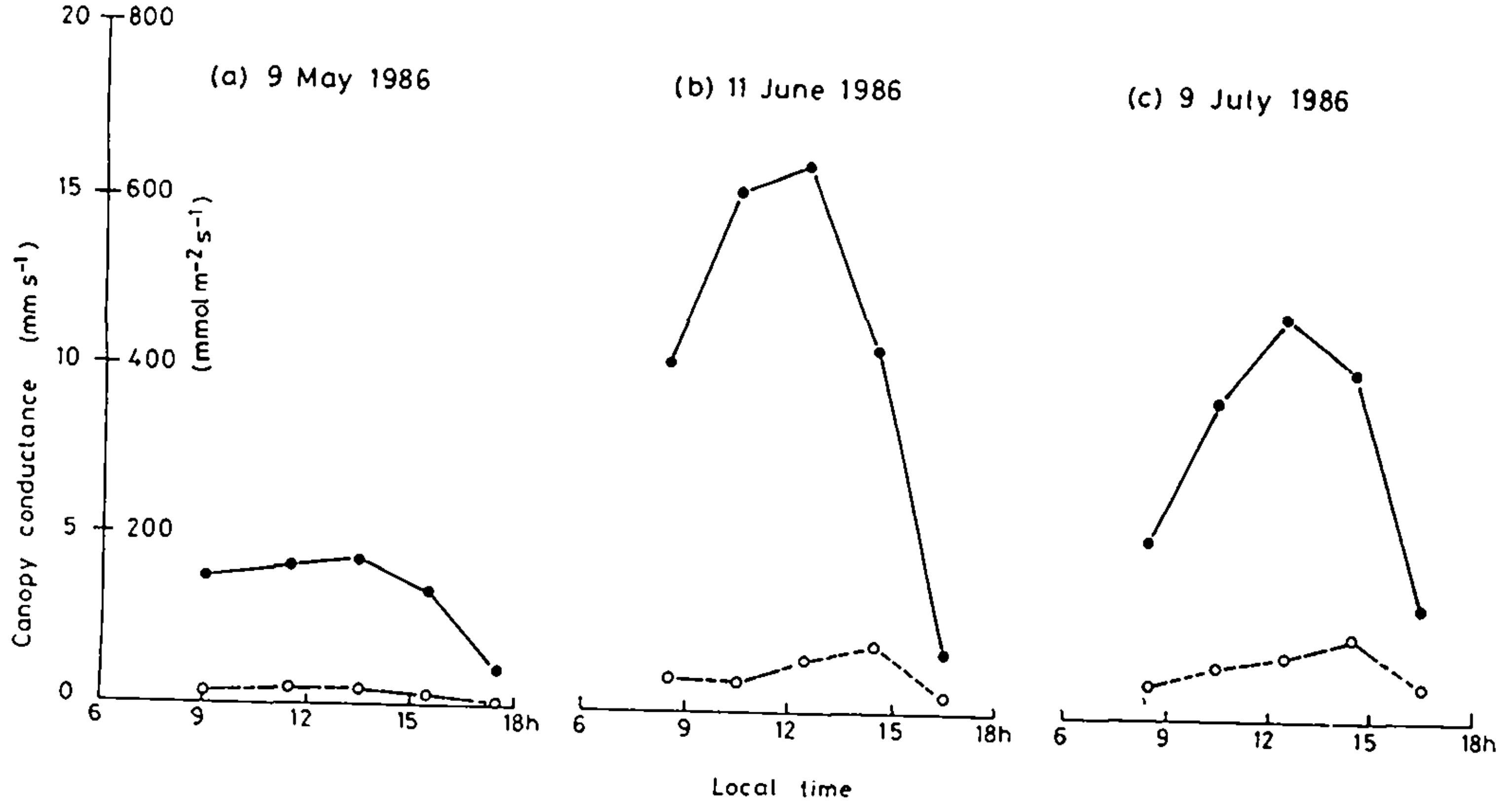

Figure 19 *The diurnal pattern of total canopy conductance for the maize (●—●) and cane (○- -○) grown as a mixed crop on three days at different times of the 1986 season.*

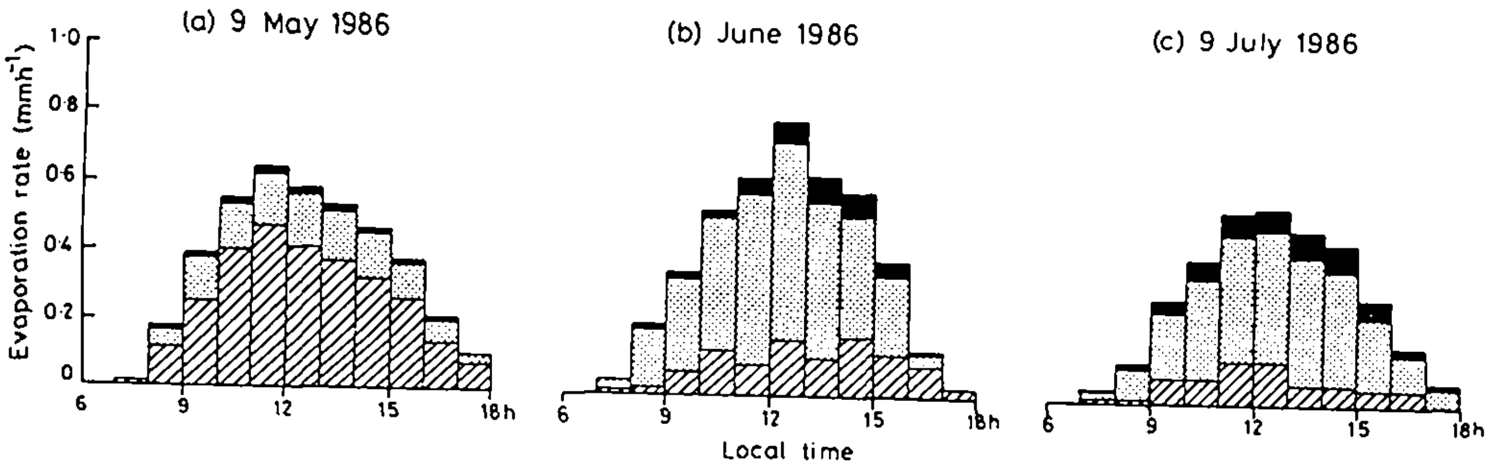

Figure 20 *The diurnal pattern of evaporation from the maize (▒), cane (■) and soil (▨) on three days at different times of the 1986 season.*

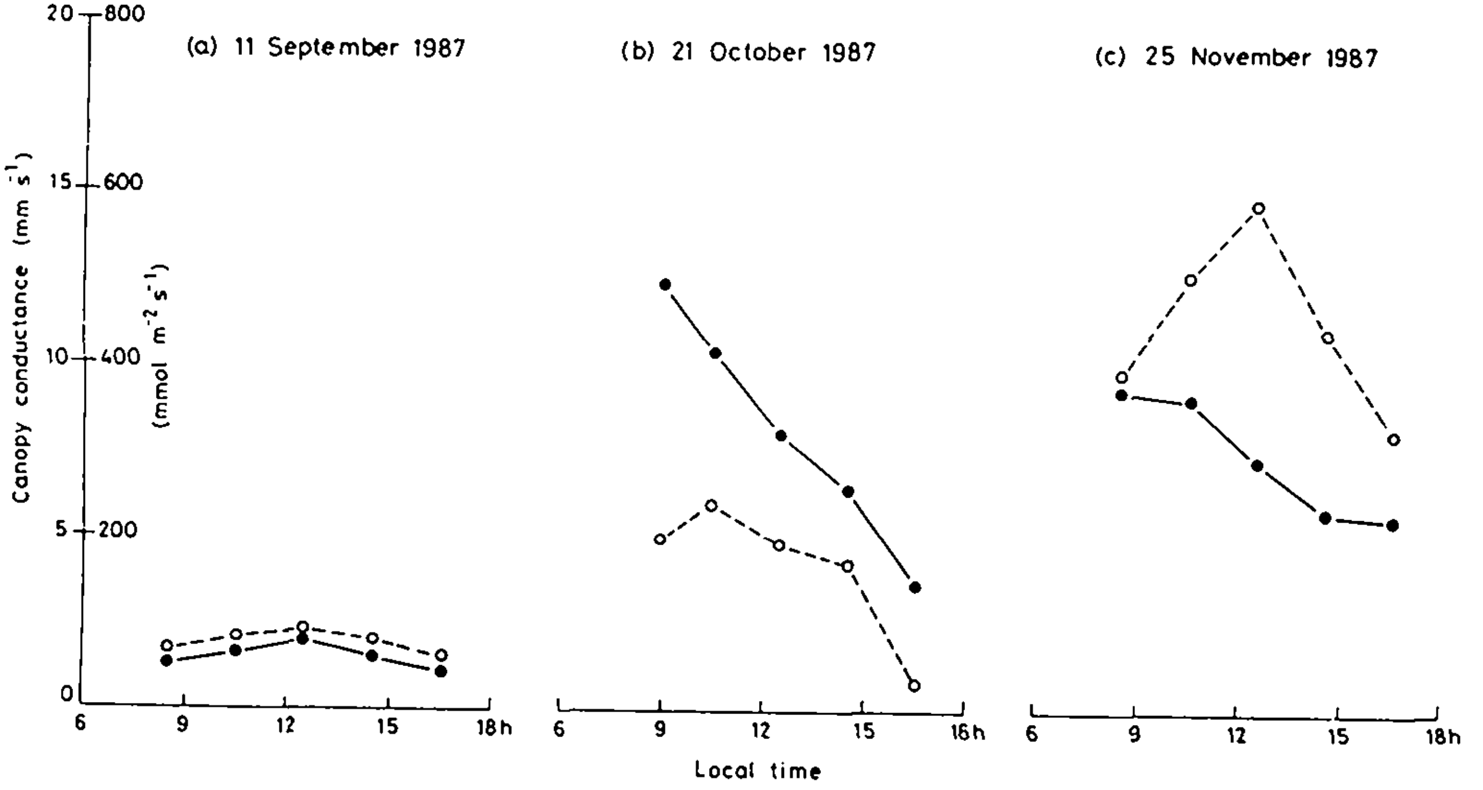

Figure 21 *The diurnal pattern of total canopy conductance for the maize (●—●) and cane (○- - -○) grown as a mixed crop on three days at different times of the 1987 season.*

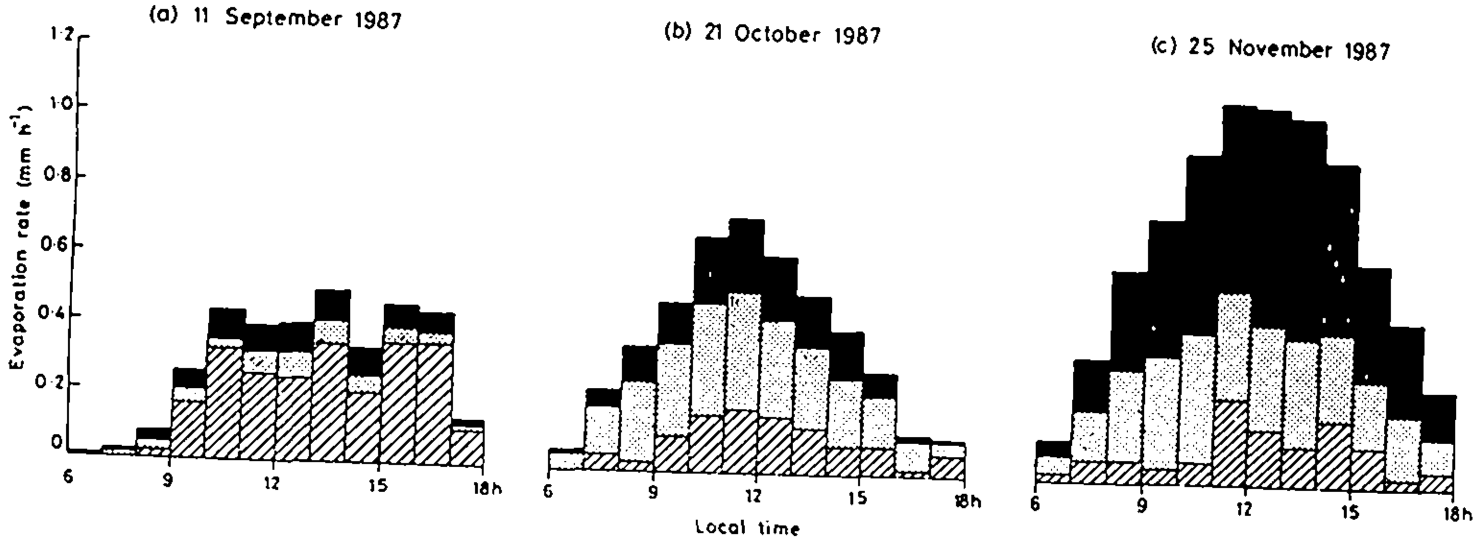

Figure 22 *The diurnal pattern of evaporation from the maize (▭), cane (■) and soil (▨) on three days at different times of the 1987 season.*