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Front Cover: Images on the cover are examples of the history and breadth of research activity in agricultural and forest meteorology at the University of California, Davis (UC Davis). The upper left photograph, taken in 1962, shows W.O. Pruitt standing inside the 6.1-m diameter drag-plate floating lysimeter prior to installation in the field. This second large lysimeter supplemented the 6.1-m weighing lysimeter installed in 1958-59 and was designed and constructed by F.A. Brooks (project leader), W.B. Goddard, F. J. Lourence and Pruitt under sponsorship of the U.S. Army Electronics Command, Fort Huachuca, Arizona. The upper right photo taken in 1963 shows the floating lysimeter in place with Lourence (standing) and Goddard back-filling the lower 30 cm of soil covering the suction-drainage system. This unit provided a measure of evaporation rate along with the weighing lysimeter, and in addition, an absolute measure of surface drag for the 1960s micrometeorological studies at UC Davis. Both lysimeters have provided basic measurements for the testing and calibration of numerous Bowen ratio and eddy flux systems developed in the USA and other countries. They have provided important information regarding the water requirements of many crops, and their data have been used in a large number of major publications worldwide. Both the floating and the weighing lysimeter are still in use some 40 years after construction.

The lower image is recently constructed from the output of a large-eddy simulation (LES) of the flow through and over a horizontally uniform forest canopy. This simulation computes a time-dependent representation of the turbulent flow within a three-dimensional grid array. Shown here is a contour plot of static pressure perturbations over an x-z (streamwise, vertical) slice through the domain at a single time step. Flow is from left to right, and solid and dashed contours represent positive and negative perturbations, respectively. The horizontal dashed line represents treetop height. Of particular interest is the positive pressure perturbation in the center of the domain with peak at the canopy top. Such a zone of positive pressure is a regular feature of canopy flow and is coincident with a sloping scalar microfront separating a downwind ejection of air from the canopy and an upwind sweep of air from aloft. Large-eddy simulation is proving to be a valuable tool in the investigation of canopy aerodynamics, and is an active area of research in biometeorology at UC Davis today.

Lysimeter photos are courtesy of W. O. Pruitt. The contour plot created by R. H. Shaw is from a simulation performed by E. G. Patton.

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ENERGY BALANCE IN A MANGO ORCHARD IN NORTHEAST OF BRAZIL

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INTRODUCTION

Evapotranspiration represents the water [illegible] from a combined surface of vegetation and soil [illegible] the conversion of surface liquid water to the atmosphere water vapor. The process in dynamic, [illegible] by the available energy, and limited by the [illegible] of energy exchange between the surface and [illegible] overlying atmosphere, the available soil water, [illegible] the ability of the plants to conduct water from [illegible] soil to the leaves.

The Bowen ratio method has been used for evapotranspiration estimation since it was introduced by Bowen (1926). The energy balance [illegible] been recognized as an efficient approach when applied in exchange of energy and mass into the boundary layer. In Brazil and abroad, important studies such as those of Villa-Nova (1973), Angus and Watts (1984), Gay (1988), Dugas et al. (1991), Oliveira e Leitão (1998), Prueger el al.(1997), , and Silva et al. (1997), have used that approach.

The main objective of this research was the determination of the energy balance in a mango orchard.

2. MATERIALS AND METHODS

Two field experiments were conducted in the Center for Semiarid Research of the Brazilian Company of Agricultural and Animal Research – Embrapa, located in Petrolina, PE, Brazil (9°S; 40°W; 635m), from August to December, 1998, and from August to December, 1999, in a six-year-old tree mango orchard (*Mangifera Indica* L.) variety Tommy Aytkin, grown in a 8 m between rows by 5 m between plant spacement, and drip irrigated on a 1.2 hectare surrounded by banana and other fruit trees orchards.

The cultural practices such as fertilization, weed and plagues control, followed local technical recommendations. The local climate type is BSwh' according to Koppen classification. A micrometeorological tower was installed between two mango trees for attaching the sensors used in the monitoring of the atmospheric and plant variables. Two net radiometers were installed at 1 m above the mango orchard canopy, trees (one on the top of the canopy and other between rows). The incident (Rs) and reflected solar radiation (Rr) were measured with three radiometers (Eppley star model), installed in the same positions of the net radiometers. Dry and wet bulb temperatures were measured by copper-constantan thermometers installed at 0.5 m and 1.5 m above the top of the mango trees. The plants were irrigated with two drip lines 1.0 m apart and 10 drippers per plant. The data were recorded every one second and averaged every 10 min using a datalogger.

The Bowen ration energy balance can be obtained by:

$$LE = \frac{-(Rn + G)}{1 + \beta}$$

where

$$\beta = \frac{H}{LE} = \frac{p_O . c_P}{L . \varepsilon}\left(\frac{Kh}{Kv}\right)\frac{\partial T / \partial Z}{\partial e / \partial Z} = \gamma\left(\frac{Kh}{Kv}\right)\frac{\Delta T}{\Delta e}$$

is the Bowen ration and H, LE, Rn and G are the flux densities of sensible heat, latent heat, net radiation, and soil heat, respectively, all in ($W.m^{-2}$); p_o is the atmospheric pressure (kPa); c_p is the specific heat of air at constant pressure ($J. kg^{-1}. °C^{-1}$); L is the latent heat of vaporization ($kJ.kg^{-1}$); ε is the molecular weights of water (M_w) to dry air (M_a); K_h e K_v are the turbulent exchange coefficient for sensible heat and water vapor, respectively; ΔT and Δe are the above canopy air temperature and vapor pressure gradients, respectively; and γ is the psychrometric constant. A basic assumption of the method is the equality of the turbulent exchange coefficients of K_h and K_v supported by previous investigations made under nonadvective conditions.

3. RESULTS AND DISCUSSION

The results discussion were made for five days representative of the flowering (August 6), physiological fruits fall (September 18), fruits maturity (October) first fruits harvest (November 17) and last fruits harvest (November 22) phenological phases, all of them obtained in 1998. The daytime values of the energy balance components (Rn, H, LE and G) were obtained for the period of time when Rn ≥ 0.0 as suggested by Prueger et al. (1997). These results are presented in Table 1.

According to Table 1, the mango trees remained lightly warmer than the air during the analyzed days. At the second half of the production cycle there was a sensible reduction in the daily evapotranspiration, probably caused by a reduction in the transpiration rate in this period. By analyzing the trees top temperature it was observed, for several occasions, a change of the sensible heat flux sign. The soil heat flux (G) was, in general, around 5% of the available energy (R_n). This reduced percentage of R_n used for soil heating was mainly a result of the big area soil surface projected tree top ($30m^2$).

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On August 8, 1998, there was a great variability of cloudiness after midday however the magnitude and daytime behavior of the net radiation (Rn), sensible heat (H), latent heat (LE) and soil heat (G) fluxes remained in absolutely agreement with those observed for short height crops. The major available energy latent heat occurred in the flowering phase (70.4% of Rn), while the sensible heat (H) and soil heat (G) fluxes represented 18.6% and 5% of Rn, respectively.

On September 18, corresponding to the physiological fruit fall, the daily evapotranspiration reached maximum value around 5.8 mm, while LE, H and G represented 82.2%, 12.3% and 5.5% of Rn, respectively. In the morning the canopy was warmer than the air, justifying the daily reduced value of H and LE closer to Rn. In the fruits maturity phase (October 18), 68.4% of the available energy was used as latent heat, 24.9% as sensible heat and 6.7% as soil heat. During the fruits harvest phase the percentages of Rn used as latent heat (LE), sensible heat (H) and soil heat (G) changed from 74.6, 23.1 and 2.3, on the first fruits harvest (November [illegible]) to 64.2, 34.8 and 0.99 on the last fruits harvest (November 22), respectively. This day was characterized by high variability of the energy balance components as consequence of the intense cloud cover throughout the daytime.

The average values of the energy balance components are presented in Tables 2 and 3, related respectively with the 1998 and 1999 field experiments. The magnitude of the energy flux components were similar for both years, except in the fruits maturity when H decreased and G increased from 1998 to 1999. The sensible heat flux presented negative values in most of the days, indicating that the mango trees canopy was always warmer than the air surrounding it.

4 CONCLUSIONS

Based on the results obtained it can be concluded that: a) the soil heat flux represented a small fraction of the available energy, in average, less than or equal to 5% of Rn; b) the water vapor flux represented a major fraction of the available energy with higher percentages around 80% in the mango trees physiological phase of fruits fall.

Table 1 – [illegible] components of the energy balance in 1998

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Etr (mm)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4,71
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5,79
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3,75
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3,11

Table 2 – Average values ($w.m^{-2}$) of the energy balance components in 1998 irnango orchard.

Phases	Rn	LE	H	G
Flowering	-	-	-	-
Fruits fall	361.2	-279.9	-63.7	-17.6
Fruit formation	378.9	-282.7	-75.0	-20.2
Fruits maturity	291.5	-238.4	-47.9	-5.1

Table 3 – Average values ($w.m^{-2}$) of the energy balance components in 1999 mango orchard.

Phases	Rn	LE	H	G
Flowering	323.7	-243.0	-75.4	-14.8
Fruits fall	290.9	-264.8	-17.8	-8.3
Fruits formation	386.6	-297.6	-61.5	-27.5
Fruits maturity	360.7	302.3	-26.6	-31.9

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