Nutrient supply and water use of bananas in a subtropical environment.

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FOURNITURE D'ELEMENTS NUTRITIFS ET UTILISATION DE L'EAU PAR LE BANANIER EN MILIEU SUBTROPICAL.

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RESUME - L'utilisation de l'eau par des bananiers 'Williams' en lysimètres de 1 m^3, mesurée chaque semaine dans le cadre d'une expérimentation sur la nutrition, apparaît surtout liée à l'effet de celle-ci sur la surface foliaire. Les conditions ambiantes, étudiées par régression en faisant intervenir la radiation totale, la pression de vapeur d'eau et la vitesse du vent, rendent compte de la moitié du reste de la variation entre semaines (avec un effet très probable de l'énergie d'advection). Il y a donc certainement un fort contrôle interne de la plante sur son utilisation d'eau, attribuable à la résistance stomatique et au repliement des limbes.
Malgré cela, l'utilisation de l'eau est négligeable dans tous les traitements entre juin et septembre (hiver et début de printemps).

INTRODUCTION

The banana plant has a reputation for needing a plentiful supply of water for high production (CHAMPION, 1963 ; SIMMONDS, 1966) although few studies have been made of the factors affecting its water use or responses to water deficits.

Water use has been measured in a range of environments and using different methods. In Israel (SHMUELI, 1953) and Ecuador (AUBERT, 1968) leaf discs were used to measure transpiration but this method has severe limitations (SLATYER, 1967). In Honduras (GHAVAMI, 1972) and the Antilles (MEYER and SCHOCH, 1976) drainage lysimeters were used to establish relationships between measured plant evaporation, E_p and Class A pan evaporation (E_a); they found that E_p was 1.2 to 1.4 E_a for well watered soil where the canopy was complete. ARSCOTT, BHANGOO and KARON (1965) measured changes in soil water in Honduras and estimated water use of between 6 and 9 mm day^{-1}. However, no data on potential evaporation or deep drainage losses were available.

The response of the banana to supplementary irrigation in the New South Wales environment has been documented (KEBBY and EADY, 1956; TROCHOULIAS, 1973). Water use was not measured in either of these studies although growth rates and leaf area index change significantly from one season to another in this environment (TURNER, 1971; TURNER, 1972). The main aim of the experiment reported here was to determine the influence of different nutrient regimes on the growth and nutrient composition of the banana and these results have been reported elsewhere (TURNER and BARKUS, 1980, 1982). Interest in this paper centres on measurements of water use in relation to season and leaf area present, both of which change significantly in the subtropical areas of New South Wales.

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MATERIALS AND METHODS

Bananas (*Musa* sp) of 'Williams' cv (Giant Cavendish AAA Group) were grown in 1 m^3 drainage lysimeters containing river sand. A completely randomized 3 K x 3 Mg x 2 Mn factorial experiment with two replications began in January 1970 and ended in February 1974. The highest amount of K and Mg and the lower amount of Mn represent standard applications and are termed K1, Mg1 and Mn1. The remaining treatments were 1/5 or 1/10 of standard for K and Mg or ten times standard for Mn. Water use data for the first 161 weeks of the experiment was used, these being divided into twelve seasons. The lysimeters were spaced 3 m x 4 m, with one plant per lysimeter; this is about twice the plant spacing normally used in New South Wales. The plants did not form a complete canopy and can be regarded as isolated plants. The area between the lysimeters was covered with short mown grass. Water was added to each lysimeter daily so that some drainage occurred in each 24 hour period. Water use measurements were made daily and summed over periods of one week.

Estimates of potential evaporation , E_o, were made using the tables prepared by McCULLOCH (1965) and data available from a nearby meteorological lawn.

Methods used to measure leaf area have been described elsewhere (TURNER and BARKUS, 1980). The leaf area index, L, was calculated assuming each plant had leaves randomly arranged within a sphere of radius z. Given a leaf area density of 0.8 m^2 m^{-3} (measured in a field crop) and the relationships

$$L = A_p (\pi z^2)^{-1} \qquad 1.$$

where Ap is the area of leaf present on the plant, the volume of the sphere

$$V = A_p \, 0.8^{-1} = \frac{4}{3}\pi z^3 \text{, and}$$

$$z = 0.98 \, A_p^{\frac{1}{3}} \pi^{-\frac{1}{3}} \qquad 2.$$

Substituting in equation 1, the leaf area index can be expressed as

$$L = A_p (0.98 \pi^{\frac{1}{3}} A_p^{\frac{2}{3}})^{-1} \qquad 3.$$

The measured weekly water use, E_λ , was normalized for leaf area index, L, and regressed on the total daily radiation reaching the earths surface Q_e, and a vapour pressure-windspeed factor, $(e_s - e)\sqrt{u}$, giving

$$E_\lambda \, L^{-1} = b + b_1 \, Q_e + b_2 \, [(e_s - e)\sqrt{u}] \qquad 4.$$

where b, b_1 and b_2 are coefficients. Water loss from leaves is influenced by radiation and the vapour pressure gradient from the leaf surface to the air, the latter is expressed as $(e_s - e)$. The resistance to the transfer of water vapour from the leaf surface to the air is proportional to $\sqrt{u}$ (where u is wind speed) and leaf dimensions (MONTEITH, 1965). $(e_s - e) \sqrt{u}$ was used in equation 4 as the leaf dimension factor is incorporated into the coefficient b_2.

Q_e was calculated from the relationship established by HOUNAM (1969) i.e.

$$Q_e = Q_o \, (0.27 + 0.5 \, n \, N^{-1})$$

where Q_o is the radiation received at the top of the atmosphere, n the number of hours of bright sunshine and N the maximum hours of bright sunshine.

RESULTS

The effect of treatment on water use was principally through its influence on leaf area per plant, hence further emphasis on the effects of treatments is not given. Seasonal trends in water use appeared to be related to leaf area present and to potential evaporation (fig. 1). Internal plant control was also important because from June to September E_λ was similar from year to year but leaf area was substantially different.

The multiple regression of E_λ /L on Q_e and $(e_s - e)\sqrt{u}$ was significant at P = 0.01 for all treatments over the period of 161 weeks, but the coefficient of determination was less than fifty percent. Statistically significant relationships between lysimeter water use and environmental variables were found in seven of the twelve seasons studied (Table 1). Agreement was poor when the plants were young and in the second winter and third summer. There appeared to be nothing unusual about the climatic conditions during the second winter and third summer nor with the developmental state of the plants (TURNER and BARKUS, 1980) which may indicate reasons for the poor agreement.

The overall regression coefficient b_1, for the K1 treatment was 0.50 ± 0.05 1 MJ^{-1}, equivalent to about 1.24 J latent heat per J of incoming radiation (Table 2). Because evaporation was normalized for leaf area index much more water was being evaporated than could be accounted for by the incident radiation, let alone the net radiation. There must therefore have been significant interception of radiation reflected from the intervening grass surface and no doubt local advection of heat also. No reliance can be placed on the seasonal estimates of b_1 because of the very large standard errors.

The overall coefficient, b_2, was significant (P =0.01) but negative. E_λ would not be expected to increase with increasing vapour pressure or wind speed if stomatal control or leaf folding were important in controlling water use. When stomata are fully open transpiration increases with increasing vapour pressure deficit. The influence of wind speed is more obscure as its effects are modified by changes in the ratios of internal and external resistances to water vapour transfer (MONTEITH, 1965).

DISCUSSION

The interpretation of these data is difficult because we are dealing with isolated plants projecting well above the intervening lawn and thus subjected to advection and

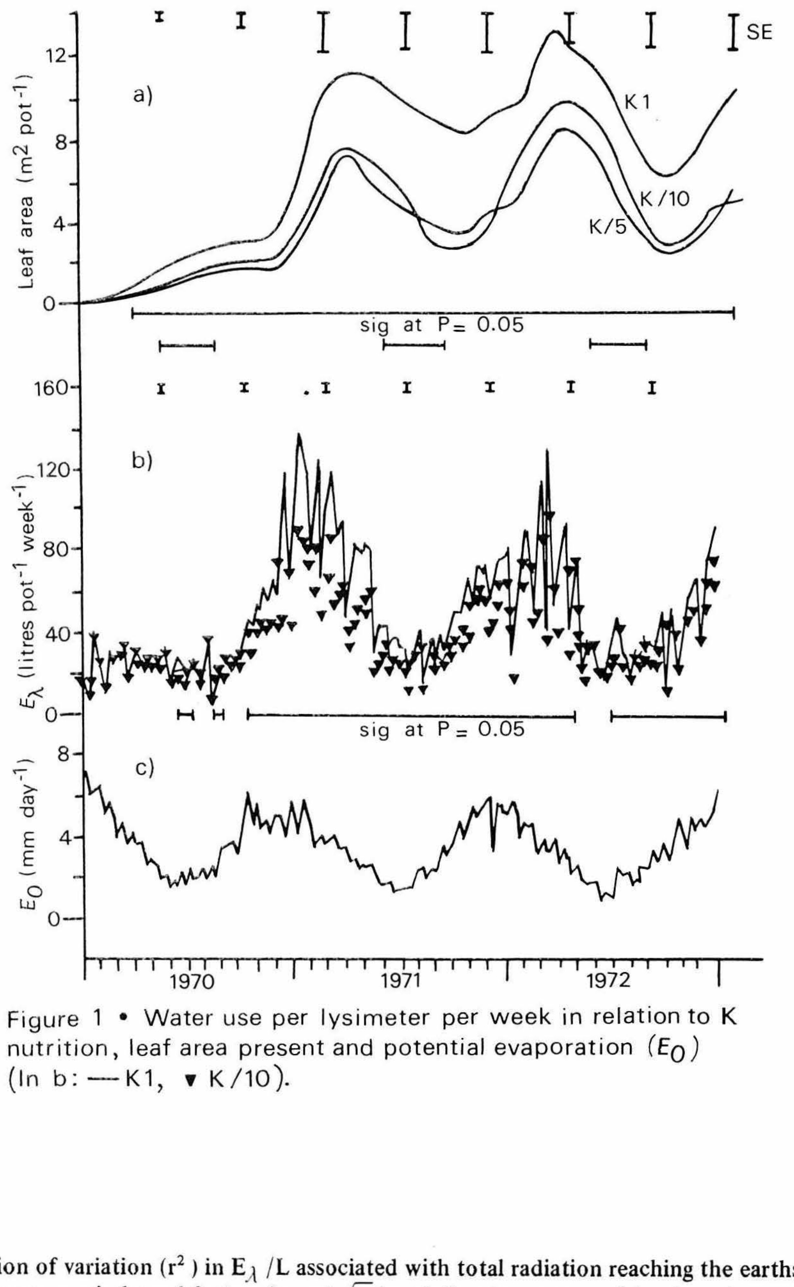

Figure 1 • Water use per lysimeter per week in relation to K nutrition, leaf area present and potential evaporation (E_O) (In b: —K1, ▾ K/10).

TABLE 1 - Proportion of variation (r^2) in E_λ /L associated with total radiation reaching the earths surface (Q_e) and a vapour pressure-windspeed factor, $(e_s - e)\sqrt{u}$, in relation to season and treatment.

Period		Treatment								
		K/10	K/5	K1	Mg/10	Mg/5	Mg1	Mn1	10Mn	No. of obs.
161 weeks		44**	45**	45**	46**	44**	46**	46**	45**	161
1970	Su	48	48	48	50	46	47	50	47	10
	Au	12	7	9	11	10	11	8	13	13
	Wi	16	9	8	8	7	9	9	7	12
	Sp	60**	68**	64**	65**	67**	65**	65**	66**	13
1971	Su	68**	78**	85**	81**	80**	82**	80**	82**	14
	Au	56**	61**	79**	71**	65**	70**	69**	69**	14
	Wi	21	22	3	14	14	13	15	12	13
	Sp	47*	53*	56*	51*	57*	54*	55*	53*	13
1972	Su	28	38	32	32	32	34	32	34	14
	Au	56*	69**	88**	76**	75**	77**	77**	75**	14
	Wi	51*	51*	53*	42	54*	53*	55*	46*	13
	Sp	56*	53	56*	55*	54*	57*	57*	55*	11

* - significant at P = 0.05 ** - significant at P = 0.01

TABLE 2 - Constant, b, and regression coefficients for K1 treatments in equation 4 in relation to season of the year. The mean values of Q_e and $(e_s - e)\sqrt{u}$ are also included.

Period		b	b_1 $1\ MJ^{-1}$	b_2 ($x10^{-3}$) $1\ mg^{-1}\ m^{-2}$ ($m^{-\frac{1}{2}}\ wk^{\frac{1}{2}}$)	Q_e $MJ\ m^{-2}\ wk^{-1}$	$(e_s - e)\sqrt{u}$ $mb\ m^{-\frac{1}{2}}\ wk^{-\frac{1}{2}}$
161 weeks		- 14.5	0.50 ± 0.05	- 1.03 ± 0.29	128	9 721
1970	Su	71.9	-0.43 ± 0.46	6.54 ± 2.58	162	8 321
	Au	16.8	0.20 ± 0.16	- 0.93 ± 1.34	111	6 844
	Wi	17.5	0.03 ± 0.14	1.08 ± 1.23	104	8 710
	Sp	7.5	0.49 ± 0.13	- 2.88 ± 0.72	146	12 132
1971	Su	- 23.1	0.84 ± 0.13	- 2.46 ± 2.04	139	7 621
	Au	- 30.4	0.64 ± 0.10	- 0.36 ± 1.11	111	6 144
	Wi	20.4	- 0.03 ± 0.11	- 0.33 ± 0.59	97	8 477
	Sp	0.3	0.21 ± 0.08	0.55 ± 0.59	155	13 610
1972	Su	- 17.3	0.43 ± 0.22	0.12 ± 1.31	145	8 866
	Au	- 24.0	0.43 ± 0.07	0.90 ± 0.75	104	5 911
	Wi	- 0.1	0.22 ± 0.08	- 0.09 ± 0.55	109	10 732
	Sp	- 43.0	0.47 ± 0.16	0.41 ± 0.44	154	17 732

intercepted radiation reflected from the lawn. The measured water use includes a component coming from the surface of the lysimeter as well as from the plants. Evaporation from the lysimeter surface would have been the major component of water use when the plants were small (less than 1 m^2 of leaf area - Fig. 1) and during the winter months. But even at these times the significance of total radiation term was low.

Accepting these limitations the data point to some areas needing investigation in the field. Poor associations existed between water use and the environmental variables which would be expected to influence it. This makes the estimates of banana plantation water use using simple proportions of environmental demand (e.g. potential evaporation), at least over short periods of a few days, very tentative.

There appears to be very little water use during the winter months despite a large leaf area and irrigation at this time is probably of little use. Conservation of water during winter may be of significance to bananas in New South Wales since the growing areas are characterized by a dry spring.

Three aspects of water use need to be considered when scheduling irrigation. Firstly, environmental demand is important during the spring, summer and autumn and secondly leaf area present influences the amount of water used. In New South Wales leaf area index is least (about 2) in spring and greatest (about 4-5) in autumn (TURNER, 1972). An irrigation schedule based on a set proportion of potential evaporation is therefore likely to result in over supply in the spring and under supply in the autumn. Thirdly, internal plant controls are likely to influence water use, the most likely components being leaf stomatal resistance and leaf folding. At present insufficient is known of the behaviour of internal plant controls in the field to incorporate them into formulae for estimating water use. They would be expected to become significant when the plants were under stress.

A more effective way of scheduling irrigation in banana plantations may be to use soil water sensors such as tensiometers, strategically placed within the plantation. This approach avoids the difficulties inherent in estimating water use using pan evaporation data, whether calculated or measured.

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