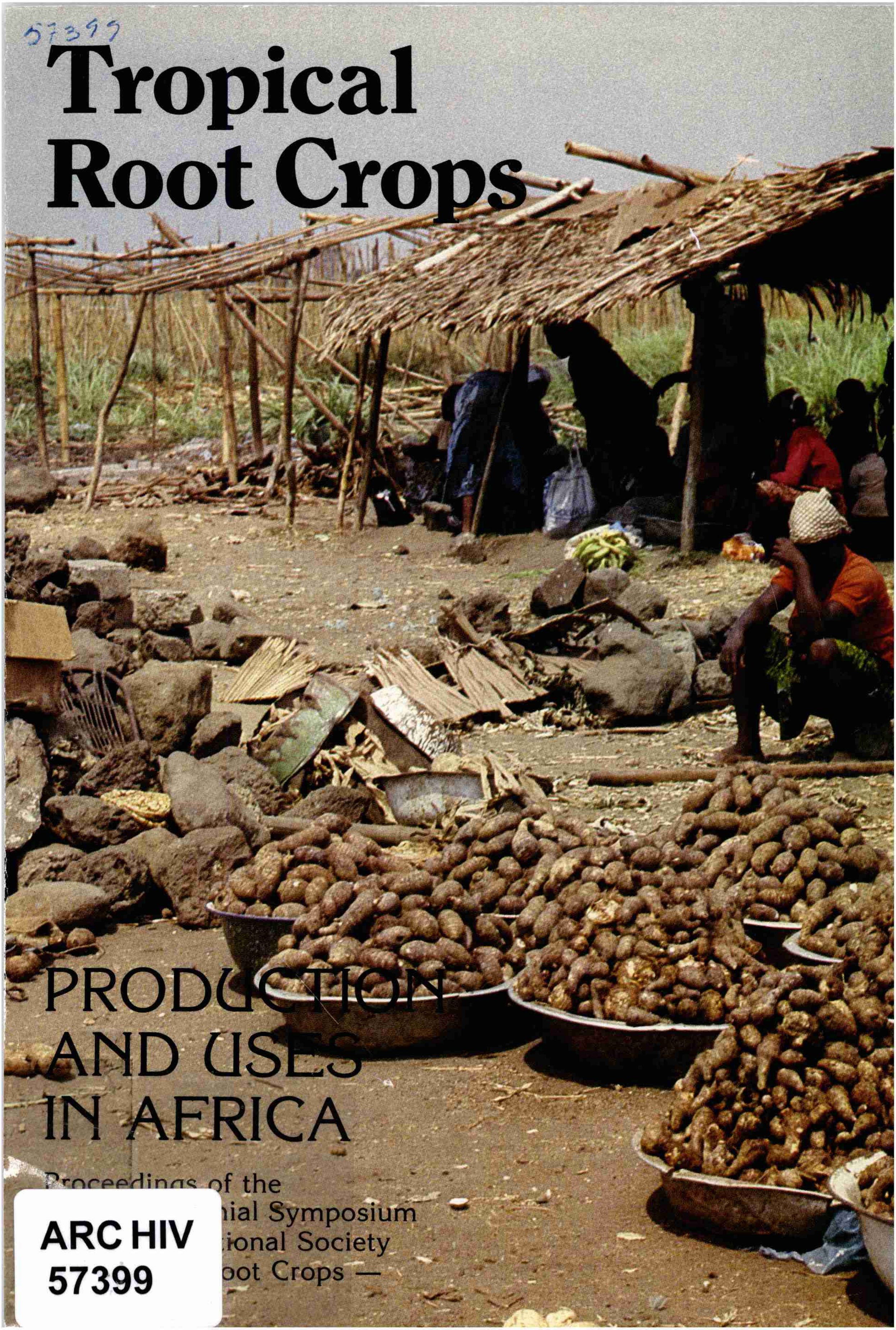
Tropical Root Crops



PRODUCTION AND USES IN AFRICA

Proceedings of the
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The International Society for Tropical Root Crops — Africa Branch was created in 1978 to stimulate research, production, and utilization of root and tuber crops in Africa and the adjacent islands. The activities include encouragement of training and extension, organization of workshops and symposia, exchange of genetic materials, and facilitation of contacts between personnel working with root and tuber crops. The Society's headquarters are at the International Institute of Tropical Agriculture in Ibadan, Nigeria, but its executive council comprises eminent root and tuber researchers from national programs throughout the continent.

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TROPICAL ROOT CROPS: PRODUCTION AND USES IN AFRICA

Abstract

A mixture of original research, updates on procedures, literature reviews, and survey reports, this document resulted from the second symposium of the International Society for Tropical Root Crops — Africa Branch, with 77 participants from 16 countries. The focus was cassava, yams, cocoyams, and sweet potatoes, from the perspectives of breeders, agronomists, soil specialists, plant pathologists, entomologists, nutritionists, food technologists, etc. Learning from past successes and failures, many of the researchers directed their efforts toward problems obstructing progress in reaching improved production and use of root crops and attempted to view, realistically, the context in which their results would be applied.

Résumé

Résultats de recherches récentes, mises à jour sur les méthodes de recherche, revues de publications et rapports de sondages sont contenus dans ce document issu du Deuxième symposium de la Société internationale pour les plantes-racines tropicales — Direction Afrique, qui a réuni 77 participants de 16 pays. Des communications sur le manioc, le taro, le yam et la patate douce ont été présentées par des phytosélectionneurs, des agronomes, des pédologues, des phytopathologistes, des entomologistes et des spécialistes de la nutrition et des aliments, entre autres. Tirant leçon de leurs succès et de leurs échecs, beaucoup de ces chercheurs ont dirigé leurs efforts vers la solution des problèmes qui entravent l'augmentation de la production et de la consommation des plantes-racines et ont tenté de considérer d'un œil réaliste le contexte qui sera celui de l'application de leurs recherches.

Resumen

Una mezcla de investigaciones originales, actualizaciones de procedimientos, reseñas de literatura e informes de encuestas, este documento es el resultado del segundo simposio de la Sociedad Internacional de Raíces Tropicales, Filial Africana, que contó con 77 participantes de 16 países. El simposio se centró en la yuca, el ñame, el cocoñame y las batatas, desde la perspectiva de los fitomejoradores, los agrónomos, los especialistas en suelos, los patólogos vegetales, los entomólogos, los nutricionistas, los tecnólogos alimenticios, etc. A partir de los éxitos y fracasos anteriores, muchos de los investigadores encaminaron sus esfuerzos hacia los problemas que obstaculizan el avance para lograr una producción y un uso mejorados de las raíces y trataron de obtener una visión realista del contexto en que los resultados pueden ser aplicados.

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TROPICAL ROOT CROPS:
PRODUCTION AND USES IN AFRICA

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PROCEEDINGS OF THE SECOND TRIENNIAL SYMPOSIUM OF THE INTERNATIONAL SOCIETY FOR TROPICAL ROOT CROPS — AFRICA BRANCH HELD IN DOUALA, CAMEROON, 14 – 19 AUGUST 1983

CONTENTS

Effects of Water-Table Depth on Cocoyam

B.S. Ghuman and R. Lal[1]

Physiological response of cocoyam (*Colocasia esculenta*) to different water tables was investigated in a lysimeter study during the dry season of 1981–82. Test cultivars were TCe 23 and TCe 36. Water tables were maintained at 15, 30, 50, and 70 cm below the soil surface. The control was without a water table, the plants being watered equal to an average pan evaporation on alternate days. The differences in water table did not affect stomatal resistance of the cultivars. In general, the stomatal resistance was minimal, about 3 seconds/cm, just after sunrise, increasing slowly to 6.5 seconds/cm just before sunset in all treatments. The average leaf-water potential at 1515 h increased from −6.6 to −5.1 bars in TCe 23 and from −6.4 to −4.0 bars in TCe 36 with the lowering of water table from 15 to 50 cm, and there was not appreciable change with further lowering of water table. In the controls, leaf-water potential was −3 bars in TCe 23 compared with −5 bars for TCe 36 at 1515 h. There was no direct relationship between stomatal resistance and air temperature, solar radiation, or relative humidity, but leaf-water potential of both cultivars decreased rapidly with increasing air temperature and solar radiation and decreasing humidity. Total water use was the highest, 68.8 cm in 89 days, in lysimeters that had a water table at 15 cm deep and the lowest, 14.9 cm, in lysimeters with a water table at 70 cm.

Physiologically, little is known about the response of cocoyam to environmental variables, e.g., thermal and moisture patterns of the soil, air temperature, incoming radiation, and atmospheric humidity. An understanding of these parameters could permit their optimal use in production and could facilitate breeding programs, as has been demonstrated for maize (Kilen and Andrew 1969), soybean (Sammons et al. 1978), and *Solanum* potato (Krug and Wiese 1972). Although little work has been done on cocoyam (Haynes et al. 1967), Caesar (1980) used leaf-diffusion resistance as a criterion to assess the level of water stress in cocoyam plants.

This paper presents observations of stomatal and leaf-water potential of cocoyam at different water-table depths. Effects of evapotranspiration rates and other environmental variables are also discussed.

Materials and Methods

The experiment was conducted during the dry season of 1981–82 in field lysimeters constructed on the farm of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. The mean annual rainfall is about 125 cm, of which less than 2% falls during the dry season (November–March). Metallic drums, 200 L each (58 cm diameter and 86 cm deep), were used as lysimeters. Bottoms intact, they were buried flush with the ground surface in two rows, 10 drums each. The distance between and within the rows was 100 cm and 50 cm, respectively.

Quartz gravel was poured into each drum to form a 5-cm thick layer and then covered with soil (bulk density of packing 1.4 g/cm^3). The soil, sandy loam in texture and containing about 2% organic carbon (Moormann et al. 1975), belongs to the Apomu series and is classified as Psammentic Ustorthent. In the centre of each drum, a rigid plastic pipe, 5 cm diameter, with 3-mm wide holes at 5-cm intervals along two opposite sides, was installed so that the water table could be regulated by a Mariotte bottle technique. The lysimeters, thus, could be drained through this central tube with a manually operated water pump.

Cormels with young suckers intact were cut from the old crop corms and used as a propagating material. The two cultivars tested were TCe 23 and TCe 36. One sucker of each cultivar was

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planted per lysimeter on 16 November 1981. To each lysimeter, urea, single superphosphate, and muriate of potash were added at planting to supply NPK, 50 kg of each element/ha. Under optimal water and nutrient supply, both cultivars average 100–200 cm high, yielding 10–18 t/ha, and maturing in 6–9 months, although TCe 36 is relatively early maturing (M.N. Alvarez, personal communication).

There were four treatments in which the water table was maintained at 15, 30, 50, and 70 cm below the soil surface, and the control was a drum in which no water table was present and the plants were irrigated every other day with water equal to mean pan evaporation during the dry season, i.e., 4.5 mm/day (IITA 1979, 1980). The treatments, which were imposed on 15 December 1981 (29 days after planting) till 22 March 1982 (harvest), were replicated thrice in a randomized block design. The plants were harvested just before the onset of the rainy season owing to the difficulty in maintaining water tables.

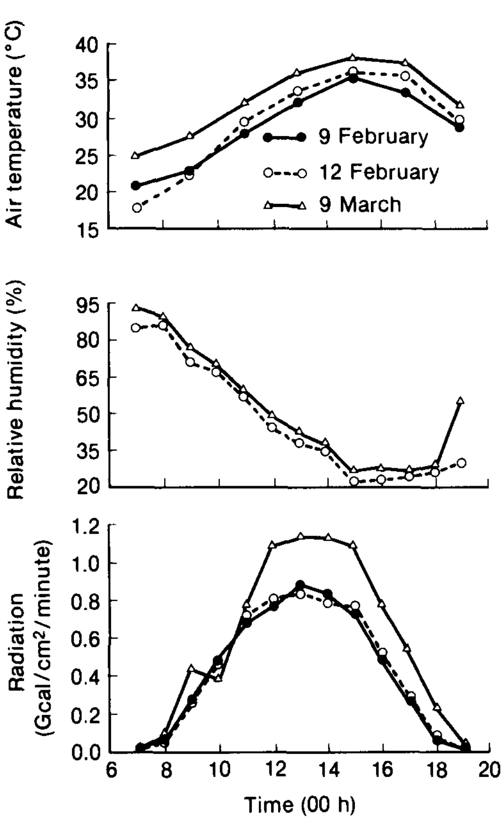

Fig. 1. *Solar radiation, relative humidity, and air temperature on 9 and 12 February and 9 March 1982.*

In the evening preceding measurement days, leaves were covered with perforated paper bags to keep dew from forming on them. Stomatal resistance was measured with a Lambda model LI 60 diffusion porometer (Kanemasu et al. 1969). A preliminary greenhouse experiment revealed that the stomata were predominantly present on the lower side of the leaf, and first, second, and third leaves from the top responded similarly to soil-moisture stress. The measurements reported here were made at one position on the lower side of the second leaf at 2-hour intervals throughout the day. The measurements at the existing leaf temperature were corrected to 25°C.

Leaf-water potential of the third leaf was measured with a pressure chamber (Scholander et al. 1965). A strip about 8–10 cm long along the secondary vein of the leaf was cut with a sharp razor blade and transferred quickly to the pressure chamber lined internally with moist filter paper; within 2–3 minutes the leaf portion around the secondary vein was stiffer than the portion between veins and gave concordant readings.

The air temperature was measured at 1 m above ground with a mercury-in-glass thermometer that was shaded from direct sunlight. The incoming radiation was measured from a pyrheliograph chart using a planimeter. The relative humidity was monitored by a hygrothermograph. The daily pan evaporation was measured by a class-A pan evaporimeter.

The water in the Mariotte bottles was replenished daily at 0830–0900 h, and the amount added was recorded — assumed to be equal to the water transpired by two plants plus that evaporated from the soil surface in the lysimeter. These records were used to calculate the evapotranspiration rate on a daily basis.

Results and Discussion

During the dry season in Nigeria, conditions throughout the day remain hazy because of a fine dust blowing from the Sahara desert. After sunrise at about 0700 h, the incoming radiation increases gradually till noon (to a per-minute peak of about 0.82 Gcal/cm^2 on 9 and 12 February and about 1.12 Gcal/cm^2 on 9 March). The peak incoming radiation was maintained till 1500 h and then gradually decreased to zero at about 1900 h (Fig. 1). The morning air temperature (18°, 21°, and 25°C) rose to 36°, 36°, and 38.5°C about 1500 h on 9 February, 12 February, and 9

March, respectively. On the latter 2 days of measurements, the relative humidity of the atmosphere was at a maximum, about 90%, in the morning, decreased to about 26% at 1500 h and increased again toward evening.

Predawn values for stomatal resistance of both cultivars were high, 24–59 seconds/cm, decreasing to a minimum, 2–4 seconds/cm, at 0845 h (Fig. 2). The stomatal resistance of TCe 23 increased suddenly to 10.5 and 30 seconds/cm in lysimeters with water tables at 15 and 50 cm, respectively, and 23 seconds/cm in the control at 1045 h on 9 February. An increase was also observed with the TCe 36 control. On other days, resistance increased slowly to an average of 6.5 seconds/cm about 1645 h irrespective of the cultivar and water table. However, stomatal resistance increased rapidly after sunset. Caesar (1980) also measured stomatal resistance values

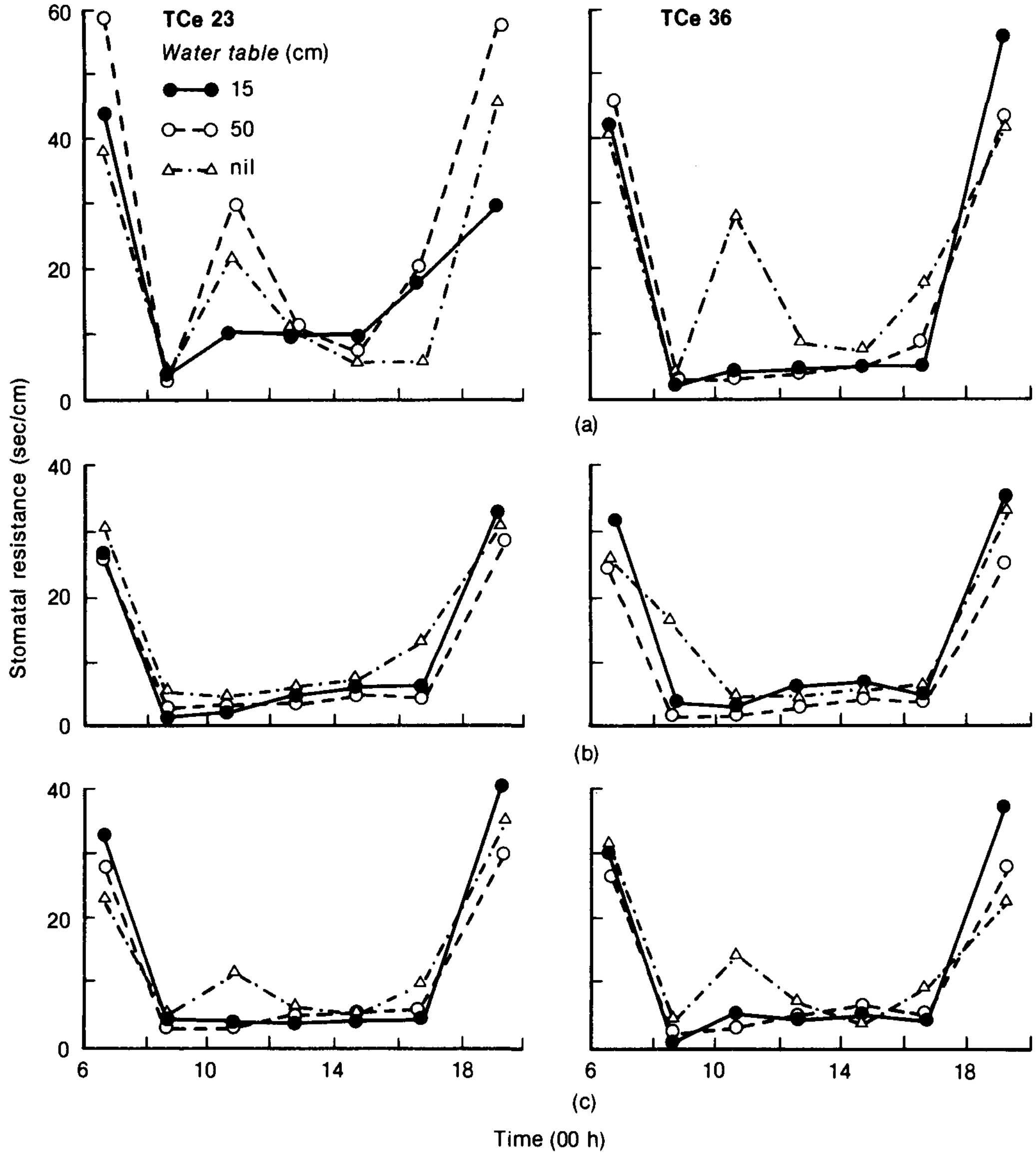

Fig. 2. *Stomatal resistance, on (a) 9 February, (b) 12 February, and (c) 9 March 1982, of TCe 23 and TCe 36 grown in lysimeters with two different water tables (15 and 50 cm) compared with the control plantings (no water table).*

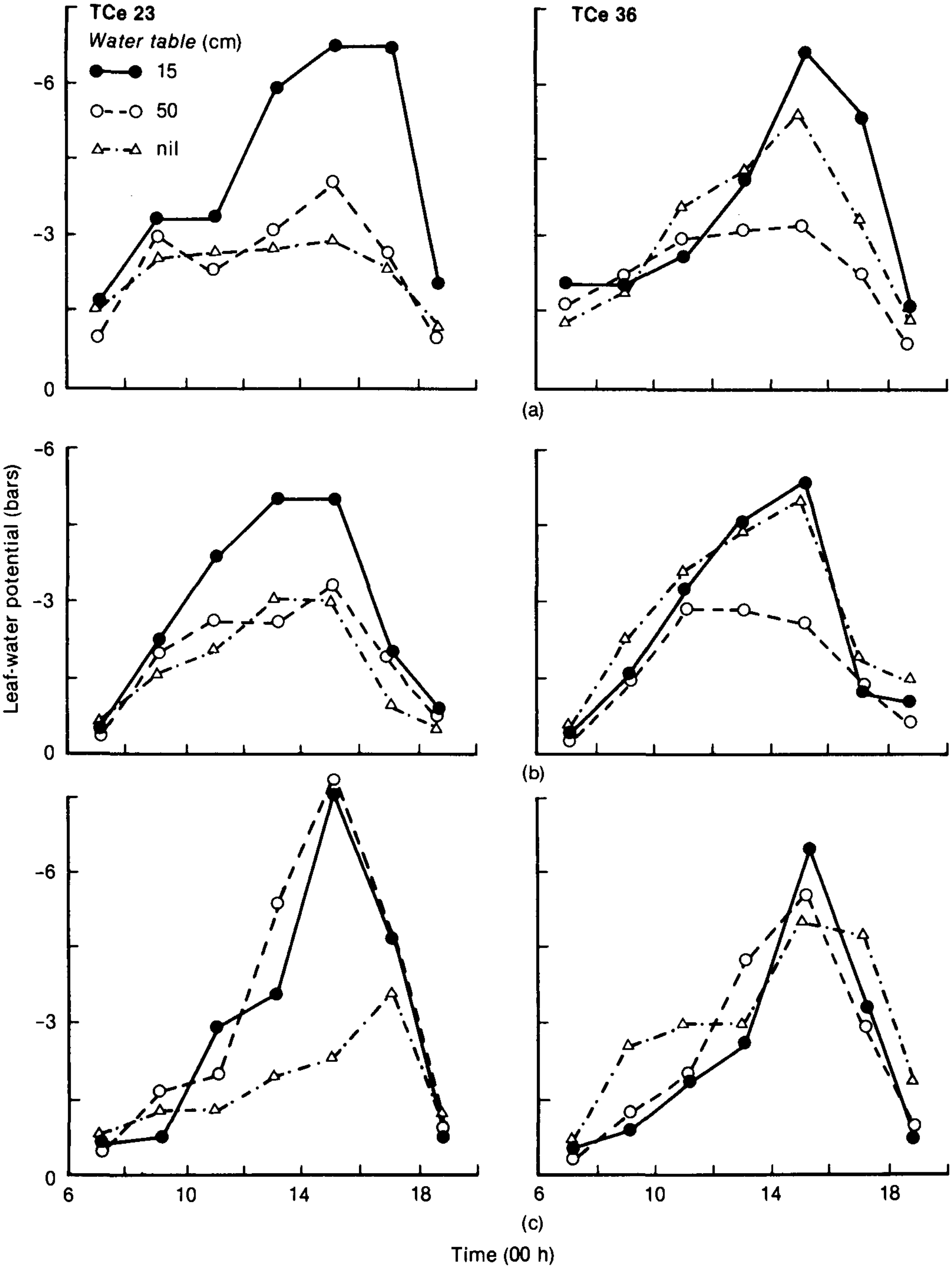

Fig. 3. *Leaf-water potential, on (a) 9 February, (b) 12 February, and (c) 9 March 1982, of TCe 23 and TCe 36 grown in lysimeters.*

of *C. esculenta* between 3.6 and 8.6 seconds/cm during daytime for irrigated and stressed treatments. Our values lie well within this range. However, our observations indicated relatively less variation in the daytime stomatal resistance (4–6 seconds/cm) over a range of soil-water contents (6–23% by weight at 5 cm deep depending on water table). Therefore, we suggest that leaf-diffusion resistance should be used with some caution as an indicator of soil-water and plant-water status.

On 9 February, the morning values of relative humidity as estimated from wet- and dry-bulb readings were incredibly low, 35–40%, which, coupled with increasing air temperature at 1045 h, probably increased the evaporative demand of the atmosphere. This change, in turn, probably brought about the closure of the stomata and resulted in high resistance values. After a few hours, when the plants were adjusted to the environment, the stomatal resistance would fall almost to the morning values. The plants in which the water table was maintained at 15 cm below the surface did not indicate stomatal closure, probably because of nonlimiting water supply.

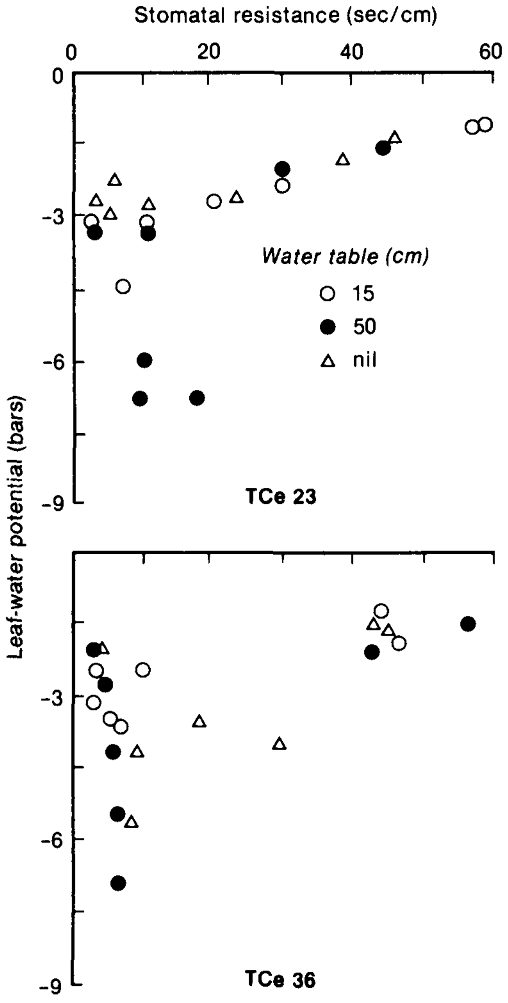

Fig. 4. *Leaf-water potential at different levels of stomatal resistance.*

Leaf-water potential fell rapidly during the day. The minimum was observed about 1515 h (Fig. 3) and was affected by water-table depth. On 9 and 12 February, leaf-water potential was between −5.1 and −6.8 bars at 1515 h for TCe 23 with the water table at 15 cm; with TCe 36, leaf-water potential ranged between −5.4 and −6.8 bars. At a water table of 50 cm below the surface, water potential was about −3 bars for both cultivars. In contrast, on 9 March, a day with high energy load (Fig. 1), the figures at 15-cm and 50-cm water tables were −7.8 and −8.2 bars for TCe 23 and −6.8 bars and −5.8 bars for TCe 36. In the control, water potential at 1515 h was about −3 bars for TCe 23 and −5 bars for TCe 36 cultivar, irrespective of the energy load and evaporative demand. At these minimal values, wilting of the leaves was not observed in any of the treatments. Recovery of leaf turgidity as indicated by the rise of leaf-water potential in both cultivars for all treatments began toward evening because of increasing relative humidity and decreasing solar radiation and ambient temperature (Fig. 1).

The high stomatal resistance values corresponding to high water potentials occurred just before sunrise and after sunset (Fig. 4). There seemed to be no direct relationship between stomatal resistance and leaf-water potential. However, the results indicate that, for cocoyam, leaf-water potential values up to −7.8 bars did not limit the leaf-diffusion resistance and hence could not bring about midday closure of the stomata of either cultivar.

Daytime stomatal resistance did not vary appreciably in response to changes in air temperature (17–38°C), relative humidity (22–95%), or per-minute solar radiation (0.3–1.12 Gcal/cm^2) for the days that diffusive resistance was monitored.

Leaf-water potential decreased with increasing air temperature, the decrease being most in the highest water table followed by the control and then the water table at 50 cm — relationships indicated by the slope of the respective regression equation (Table 1). Similarly, the leaf-

Table 1. Regression equations between leaf-water potential (−bars) and air temperature, AT (°C), relative humidity, RH (%), or solar radiation, SR ($Gcal/cm^2/min$), for cocoyam cv. TCe 36.

Environmental variable	Treatment		
	WT_{15}	WT_{50}	WT_{no}
Air temperature	−3.76 + 0.22 AT r = 0.63	−2.02 + 0.14 AT r = 0.61	−2.96 + 0.19 AT r = 0.74
Relative humidity	0.28 − 0.05 RH r = −0.64	4.10 − 0.04 RH r = −0.55	5.31 − 0.04 RH r = −0.69
Solar radiation	1.23 + 3.46 SR r = 0.68	0.85 + 3.06 SR r = 0.89	1.49 + 3.18 SR r = 0.81

water potential decreased with increasing solar radiation and decreasing relative humidity. Leaf-water potential showed a hysteresis phenomenon, i.e., the values before minima (that occurred at 1515 h) were different from values after minima, in response to environmental variables. Water potential versus air temperature followed a clockwise direction and when plotted against the relative humidity and radiation levels followed a counterclockwise path. Further, the correlation coefficients (r) reveal that the solar radiation was the most important environmental variable influencing leaf-water potential, followed by ambient temperature and atmospheric humidity.

Evapotranspiration rate of cocoyam for

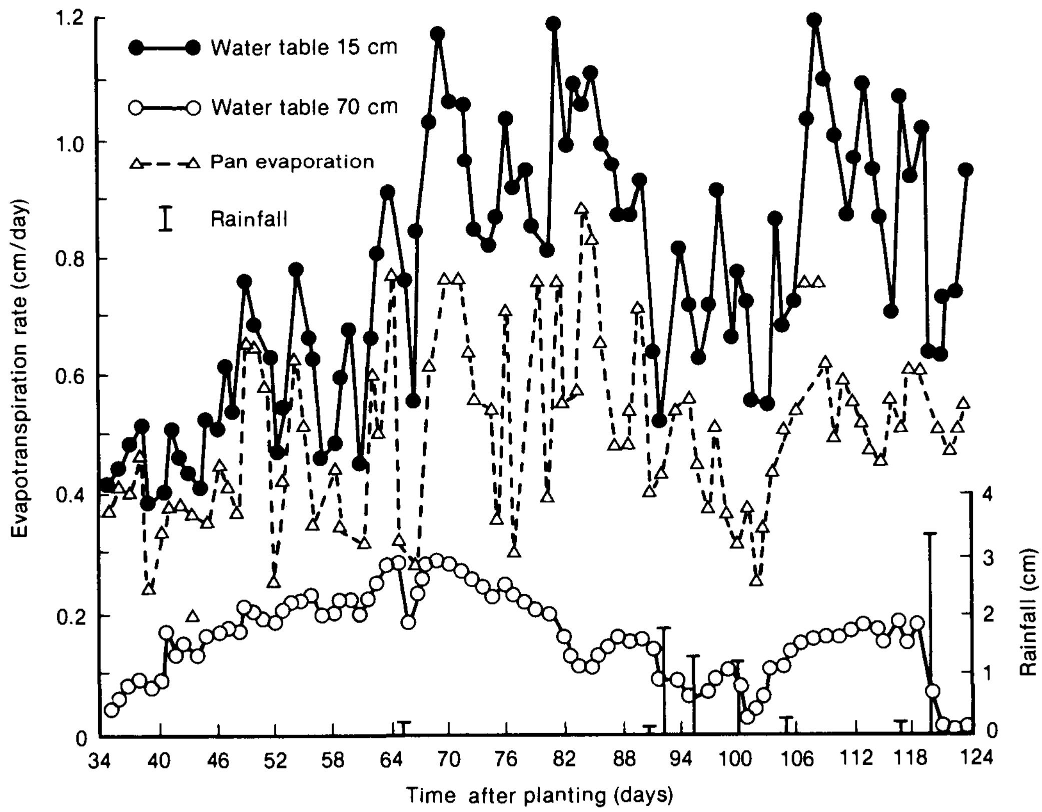

Fig. 5. *Comparison of evapotranspiration rates in lysimeters with water tables at 70 and 15 cm.*

89 days (21 December 1981–20 March 1982) from planting to harvest varied according to open pan evaporation (E_0) (Fig. 5). Following a rain, it abruptly declined; compared with E_0, it was always high in the treatment with the highest water table and low for the treatment with the lowest water table. The average evapotranspiration rates for the period were 0.77, 0.52, 0.34, and 0.17 cm/day for the four treatments (highest to lowest water table, respectively). The average potential evaporation rate was 0.51 cm/day. For summer in Japan, an evapotranspiration rate of 0.5–0.7 cm/day was reported for well-watered cocoyam (Kato et al. 1969). During 89 days of measurements, the treatments (highest to lowest water table) utilized 68.8, 46.0, 30.5, and 14.9 cm of water, respectively, in comparison with 45.3 cm measured by class-A pan evaporimeter. Leaf area per two plants at harvest for the corresponding treatments was 4122, 3373, 2642, and 1594 cm^2 respectively. The highest evapotranspiration was found in the treatment with the shallowest water table and the greatest leaf area. Kato et al. (1969) and Naito (1969) reported that transpiration rate of taro plants increased with increased leaf area and rise in temperature.

The weekly averages of evapotranspiration (ET) and potential evaporation (E_0) rates were computed and subjected to multiple regression analysis: $ET = 0.50 + 0.76 E_0 - 0.01 WT$; $R = 0.92$ where ET and E_0 are weekly means expressed in cm/day and WT (water table) in cm. The relation shows that weekly evapotranspiration rate is related positively to pan evaporation and negatively to water-table depth, and these variables (E_0 and WT) accounted for 84% of the variation in the measurements of ET.

Conclusions

The stomatal resistance of the cultivars studied was not affected by the water-table treatments. The afternoon leaf-water potential of both cultivars increased with the lowering of the water table. In the control, leaf-water potential of TCe 23 was higher, −3 bars, than that of TCe 36, which was about −5 bars. Under conditions of this study, stomatal resistance did not show any relation to leaf-water potential and the environmental variables studied. However, leaf-water potential was influenced by the environmental parameters that affect evaporative demand.

We wish to thank Dr T.L. Lawson for permitting us to use pan-evaporation and relative humidity data and Dr M.N. Alvarez for supplying the planting material.