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PHOTOSYNTHETIC CHARACTERISTICS AND WATER RELATIONS IN COCONUT PALMS UNDER DRIP IRRIGATION ON SANDY AND LATERITE SOILS

S. Naresh Kumar, V. Rajagopal, R.H. Laxman, R.D. Dhanapal and H.P. Maheswarappa

Plant Physiology and Biochemistry Section,1Agronomy Section,
Central Plantation Crops Research Institute, Kasaragod, Kerala, 671 124

ABSTRACT

Plant's response to irrigation depends on various internal and external factors. The leaf moisture status and its photosynthetic efficiencies are interrelated and largely influence the final economic yield. To assess the extent of this influence on yield, coconut (*Cocos nucifera* L.) palms, grown on sandy and laterite soils were given different levels of irrigation through drip {sandy-66, 100 and 133% of open pan evaporation (Eo); laterite - 33, 66 and 100% of Eo} and basin (100% of Eo). Control palms without irrigation were maintained. The data on source parameters (photosynthetic and chlorophyll fluorescence (PSII) characteristics, besides water relations) were recorded during 1995-96 and 1996-97. Sink parameters such as female flower production, nut yield and nut retention were recorded during the experimental period. Photosynthetic rate, Ψ leaflet and PS II efficiency varied with the irrigation level and soil type. Instantaneous WUE increased markedly with irrigation and time. Palms receiving irrigation also showed marked improvement in female flower production and their retention to produce higher nut yields. Three types of physiological conditions in source and sink were observed in the palms based on the type of irrigation treatment they were subjected to. Results indicated that the drip irrigation provided conditions for better physiological efficiency of source and sink for high WUE and yield. They also indicated that the drip irrigation increased WUE at field and at plant and leaflet level.

INTRODUCTION

Plantations of coconut (*Cocos nucifera* L.) generally are maintained under rain fed conditions. Such plantations undergo water stress periods for at least 4 months annually. Ideally palms should receive water every week for good yields. Since the irrigated plantations give higher nut yield compared to rainfed ones, it is desirable to provide irrigation to palms at optimum levels. As the availability of water for irrigation is becoming scarce, it is important to manage the available water resources to the optimum utilization by employing the correct method and dose of application.

Water requirement of a crop depends not only on the crop and climate but on soil factors also (Keller *et al.,* 1992). In the West coast of India coconut is grown mainly on littoral sandy soils and laterite soils. The physical, chemical and water holding capacities of these soils vary considerably. It is obvious that the amount of water required to be applied to the soil for optimum availability to the palms vary in these two types of soils.

Plant's response to irrigation depends on various external and internal factors. The leaf moisture status and its photosynthetic efficiencies are interrelated and largely influence the final economic yield. Since the physiological status of the leaf is a major indicator of the plant efficiency under given conditions, the relationship of source physiological parameters viz., photosynthetic parameters and water relations with the major sink components of coconut i.e.,

number of female flowers produced, nut retention and nut yield as influenced by the type and dose of irrigation and type of soil was studied. Such studies are expected to provide the information for scientific management of irrigation practices.

MATERIAL AND METHODS

The experiment was conducted in WCT coconut gardens planted on littoral sandy and laterite soils of the research farm of CPCRI, Kasaragod. The palms were of comparable age and were planted during 1972-73 period. The irrigation treatments in laterite soils included 33% of Eo, 66% of Eo and 100% of Eo through drip, and 100 of Eo as basin irrigation. In littoral sandy soils the treatments were 66% of Eo, 100% of Eo and 133% of Eo through drip, and 100 of Eo as basin irrigation. Besides, control palms were maintained under rainfed conditions. Under drip irrigation, the water requirement was based on the monthly mean of Eo, worked out on previous 20 years data from December to May. In drip irrigation, emitters (six/palm in sandy soil and four/palm in laterite soil) were placed at 1m from bole at equal distance between the emitters.

The physical properties of littoral sandy soil include a mechanical composition of 95.8% coarse sand, 3.3% fine sand, 0.7% clay and 0.2 % silt with a bulk density of 1.66g/cc. Field capacity of this soil was 4.2% and wilting point was 0.44%. Laterite soil has a mechanical composition of 45% sand, 35% clay and 9.95% silt with a bulk density of 1.32g/cc. Field capacity of laterite soils was 12% and permanent wilting point was at 6%.

Data on physiological parameters were recorded during 1995-96 and 1996-97 in April month. The meteorological data during the experimentation period are given in Table 1. Leaflet water potential (Pressure chamber, Soil Moisture Equipments, USA), gas exchange characteristics (LCA-4, ADC, UK) and chlorophyll fluorescence parameters (Morgan, USA) were recorded on the middle leaflets of sixth leaf from top as described earlier (Rajagopal *et al.*, 2000). All the physiological observations were recorded in four replications (three palms/replication) in each treatment.

Data on number of female flowers and nuts produced per bunch were recorded periodically during the experimentation period. Data was statistically analysed in RBD separately for sandy and laterite soils and CD was used to compare the means at P=0.05 (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Source parameters: The net photosynthetic rates were higher in the palms grown on laterite soils compared to those grown on sandy soils. Irrigation significantly increased the Pn rates and stomatal conductance (Figure 1 a & b). Plants receiving basin irrigation had higher Pn and gs rates followed by those receiving drip irrigation at 66% of Eo in laterite soils. However in sandy soils the Pn rates among the drip irrigated palms did not differ significantly. Stomatal conductance did not differ significantly among the drip irrigated palms. The chlorophyll fluorescence parameter (Fv/Fm; Figure 1 c) is an indicator of extent of physiological stress on leaflet under stress conditions. This ratio declines under stress conditions. In the present study it remained almost similar in all irrigated palms and they

Table 1. Weather parameters during the observations on physiological parameters.

Weather parameter		Years		
		April 1995	April 1996	April 1997
PAR		1363	1391	1086
Temperature	Max.	33.2	23.2	32.4
	Min.	23.8	32.9	24
RH	max	79	61	89
	Min	62	85	60
Rainfall	(mm)	26.4	99.2	4.8
Evaporation (mm) /day		5.8	5.1	6.3

maintained higher ratio compared to the rainfed palms indicating that the rainfed palms were under stress.

The type of irrigation and soil influenced the water relations of the palm leaflets. Transpiration rates were higher in palms receiving irrigation, particularly basal irrigation (Figure 1 d). In general the transpiration rates were higher in palms grown on sandy soils compared to those on laterite soils. Consequently, the leaflet water potentials were lower in sandy soils (Figure 1 e). The leaflet water potentials were maintained at higher levels in drip irrigated palms, possibly due to better regulation of stomatal conductance under mild stress conditions. This condition of regulating stomatal conductance in such a way that the transpirational rates were checked with out affecting much the Pn rates led to higher WUE under drip irrigated conditions (Table 2). This may be possible as in drip irrigated conditions, part of root zone does not receive the water. Roots in this dry zone send root-shoot signals in the form of ABA or electro-kinetic signals to make stomata partially close (Hartung and Radin, 1989; Davis and Zhang, 1991), simulating the mild stress conditions. These conditions are favorable for high WUE (both intrinsic and instantaneous). No such signals were available in fully wet root zone under basal irrigation, leading to a situation where the stomata remained open to have higher transpirational rates under these conditions. Consequently the leaflet water potentials were low in basin irrigated palms compared to the drip irrigated ones.

Irrigation increased the instantaneous WUE. The intrinsic WUE was higher in rainfed and drip irrigated palms. Our earlier studies also indicated higher WUE and predominance of non-stomatal inhibition of Pn in rain fed coconut palms (Rajagopal *et al.*, 2000). Earlier studies established high correlation of instantaneous WUE with WUE at field level (Kasturi Bai *et al.*, 1996).

Sink parameters

The female flower production increased with irrigation and the % increase over rainfed palms in general was higher in sandy soils (Figure 2 a). The annual nut yield was higher in irrigated palms. Palms grown on laterite soil yielded higher (~90 - 100 nut/palm/year) compared to those grown on sandy soil (~60-70 nuts/palm/year). The palms receiving basin irrigation and 66% of Eo through drip yielded similarly on laterite soils (~90 nuts). In sandy soils drip irrigation at 66% of Eo, 100% of Eo produced higher yields compared to basin irrigated palms. Less soil moisture holding capacity and capillary movement of water towards root zone in sandy soils may be the causes for such trend. The evaporation loss and loss of water due to percolation in basin irrigation may also were important contributors for less WUE in sandy soils. Percent increase in nut yield over rainfed palms was higher in sandy soils compared to laterite soils (Figure 2 b). The % increase was more at100% of Eo in sandy soils.

The percentage of nut retention is an indicator of efficiency of conversion of female flowers into mature nuts (Figure 2 c). Irrigation

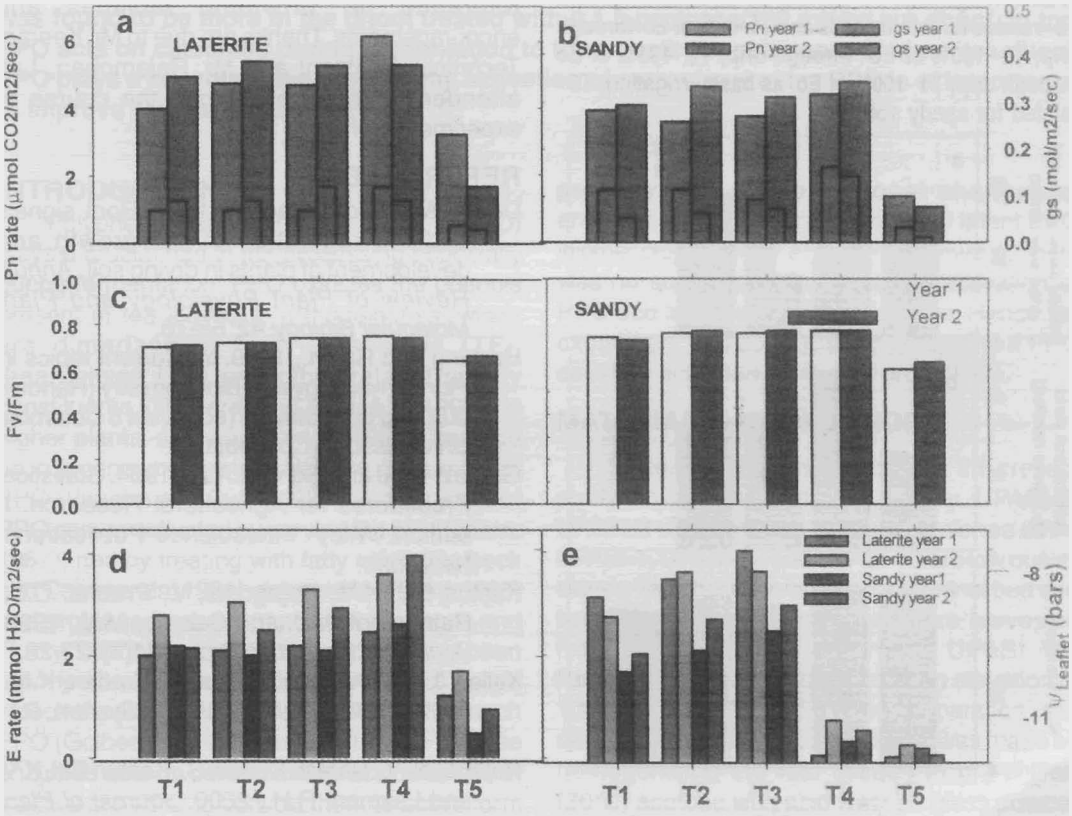
Table 2. Instantaneous and intrinsic WUE in the leaflet of coconut palm under different systems of irrigation.

Treatment	WUE (Pn/E)		WUE (Pn/gs)	
	Laterite	Sandy	Laterite	Sandy
Drip Irrigation				
33% of Eo	2.28	-	60.7	-
66% of Eo	2.45	1.98	70.3	63.2
100% of Eo	2.44	2.25	61.4	59.0
133% of Eo				
Basin Irrigation 200L once in 4 days	2.06	1.51	57.0	32.3
Rainfed	1.86	1.57	75.2	66.8
CD at P=0.05%	0.25	0.25	5.01	5.01

Table 3. Summary of physiological conditions of source and sink as influence by the type of irrigation.

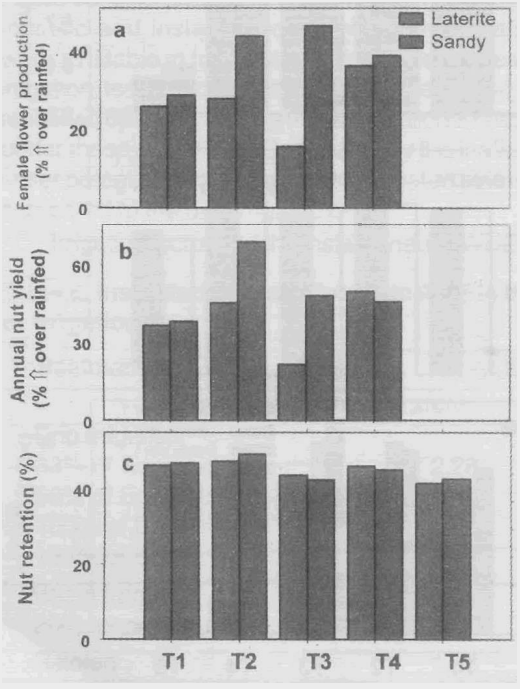
Source	Sink	Condition	Yield/WUE (instantaneous)	Remarks
Low Y_{leaf}, E, gs and Pn	Less female flower production, nut retention	Rainfed	Low/Low	Less available waterin root zone
Low Y leaf, high E, gs and Pn	More female flower production, nut retention	Basin irrigation	High/Low	Adequate availability of water; no dry pockets in root zone
High Y_{leaf}, medium e and gs and high Pn	More female flower production, nut retention	Drip irrigation	High/High	Availability of water in optimum; dry pockets in root zone

Fig. 1. a) Net photosynthetic rates (*Pn*), b) Stomatal conductance (*gs*), c) Photosystem II efficiency (Fv/Fm) d) Transpiration (E) rates and e) water potentials (Y leaflet) in leaflets of coconut palms grown under different types of irrigation in laterite and sandy soils. (T1- 33% of Eo through drip; T2- 66% of Eo through drip; T3 - 100% of Eo through drip; T4 -100% of Eo as basin irrigation; T5 - rainfed for laterite soils and T1- 66% of Eo through drip; T2- 100% of Eo through drip; T3 -133% of Eo through drip; T4 -100% of Eo as basin irrigation; T5 - rainfed for sandy soils).



increased the nut retention % indicating that the additional supply of water is a pre requisite for higher yields. Interestingly, higher dose of water did not further increase the nut retention. The increase in yield due to irrigation predominantly is a result of increases in source (the Pn rates) and sink (female flower production) efficiency. In such a situation the final nut yield is directly proportional to the number of female flowers produced with translocation of photosynthates is not a limiting factor as indicated by the increased nut retention. The female flower production was higher in plants grown on laterite soils compared to those grown on sandy soils. Under rainfed conditions, the palms grown on sandy soil produced less number of female flowers compared to those grown on laterite soils. The experiment revealed three physiological conditions of source and sink in palms grown under different systems of irrigation (Table 3).

Fig. 2: a) Annual female flower production, b) Annual nut yield (% increase over control) and c) Nut retention (%) in coconut palms grown under different types of irrigation in laterite and sandy soils. (T1- 33% of Eo through drip; T2- 66% of Eo through drip; T3 -100% of Eo through drip; T4 -100% of Eo as basin irrigation; T5 - rainfed for laterite soils and T1- 66% of Eo through drip; T2- 100% of Eo through drip; T3 -133% of Eo through drip; T4 -100% of Eo as basin irrigation; T5 - rainfed for sandy soils)



In conclusion, the drip irrigation is a system where not only the available water is used to the optimum with negligible losses, but also because of presence of dry zones in root system possibly act as the stomatal regulation system to provide optimal physiological efficiency for higher WUE and better yields. Drip irrigation increases the WUE at not only field level but at plant and leaf level also. From the study it is indicated that even in basin irrigation, by applying water in such a way that the dry pockets are created in root system, it may be possible to increase WUE with high yields. However, experimental evidences are required for any such recommendation.

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