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# GAS EXCHANGE CHARACTERISTICS OF COCOA GROWN UNDER ARECANUT IN RESPONSE TO DRIP IRRIGATION

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## ABSTRACT

This study describe the effects of different levels of drip irrigaion on the gas exchange characteristics of cocoa under arecanut palms. The irrigation levels were 10 liters/day (I1), 20 liters/day (I2) and 30 liters/day (I3). Higher soil water content was measured in I3 level. Stomatal resistance was higher in I1 level, which reduced photosynthesis and transpiration in both crops. Photosynthesis was closely related to stomatal conductance in cocoa, but there was no mesophyll limitation due to water deficit as encountered in I1 level.

## INTRODUCTION:

Cocoa is cultivated as a mixed crop with arecanut in Southern India. During summer months the weather is dry for 5-6 months resulting in soil and atmospheric drought. Water stress reduced leaf area (Sale, 1970), decreased photosynthesis (Joly and Hahn 1989, Balasimha et al., 1991) and affected yield (Hutcheon et al. 1973) of cocoa plants. Arecanut is raised as an irrigated crop and the environmental conditions in these areas are favourable for cocoa growth (Shama Bhat, 1988). Significant yield increase in arecanut with drip irrigation has been reported (Abdul Khader, 1983). Various methods of drip irrigation have been tried in cocoa earlier (Jadin et al. 1976; Khan et al. 1988). The objective of this study was to determine the effect of supplemental water applied through drip irrigation during dry weather on the gas exchange characteristics of cocoa and arecanut.

## MATERIAL AND METHODS :

A mixed garden planted with a spacing of 2.7 x 2.7 m for arecanut *(Areca Catechu L)* and 2.7 x 5.4 m for cocoa *(Theobroma cacao L)* was used for the study. Cocoa was planted in 1988 under 26 year old arecanut in a split plot design with three levels of irrigation in main plots and four levels of fertilizers in sub plots having five replicates. Irrigations were given through drippers during the dry season i.e. from December to May at the rate of 10 liter/day (I1), 20 liter/day (I2) and

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30 liter/day (I3). Under treatment I1, two emitters of 2 lph capacity were used. In treatement I2, two emitters of 2 lph and one of 4 lph capacities were used, while I3 had three emitters of 4 lph capacity. The drippers were placed in the basins of arecanut and cocoa plants. For this experiment only treatments with recommended dose of fertilizers viz. 100 g N, 40 g $P_2O_5$ and 140 g $K_2O$ per year were considered. Quantitative estimations of soil moisture was carried out gravimetrically in soil cores collected during March. Measurements of stomatal conductance (gs), transpiration (E), net photosynthesis (Pn) were made in the leaves of five cocoa trees (one each from replicates) using LI-6200 portable photosynthesis system (Li-Cor Inc., Nebraska, USA). Microclimatic parameters viz. light (PAR), vapour pressure deficit (VPD), air (Tair) and leaf (Tleaf) temperatures were also recorded. In each case, fully expanded healthy third or fourth leaf from the distal portion of most recently hardened flush (about one month old) was used. Six measurements were taken for each tree from around the canopy. This was done with a one liter chamber enclosing upto 25 $cm^2$ leaf area and equlibrated for 1-2 min. Two observations were logged for each leaf at 8 seconds intervals (Balasimha et al., 1991). Leaflets from third leaf from top of arecanut were excised and measurements made immediately using same instrument (Chowdappa and Balasimha 1992). Leaf water potential ($\psi$) was measured with Scholander pressure chamber (Soil Moisture Equipment Corpn. Santa Barbara, USA). The studies were conducted during 1990 to 1995 for cocoa and 1990 to 1993 for arecanut and all measurements were made in March between 10.00 to 12.00 h for five days. The data were analysed statistically using MSTATC package.

## RESULTS AND DISCUSSION :

The period without rainfall can be as long as 5-6 months (December to May) in these regions. This increases atmospheric drought also. When microclimatic parameters were measured between 10.00 and 12.00 h, there were no significant variations in PAR, Tair and relative humdity (RH) in relation to irrigation levels. The VPD was slightly higher in I1 level (Table 1). However, there were no significant variations in most of these parameters due to irrigation levels or years except in RH at different years. Moisture contents at the horizontal and vertical distances in the plant basins are given in Fig. 1. Moisture percentage was higher closer to the point source in I3 level. Vertical movement of water was highter than lateral movement (Phillip, 1968, Bresler et al., 1971, Raats, 1971). Gas exchange characteristics were measured in March and data presented in Tables 2 and 3. Significantly lower gas was recorded in I1 level as compared to I3 for both cocoa and arecanut. The values also varied significantly among the years. Due to this stomatal closure, transpiration was reduced in I1, resulting in retention of leaf turgidity. Therefore no significant differences in water potential were discernible. Stomatal normally close in response to reduced soil moisture and increased VPD (Schulze et al., 1972, Jarvis 1980, Kasturibai et al., 1988, Balasimha and Rajagopal, 1988). Similar results in soil water deficits and water relations have been reported in relation to different frequencies of irrigation in coconut (Rajagopal et al. 1989).

The efficient stomatal closure though advantageous in terms of reducing water loss might hamper carbon assimilation (Jones 1979). It is evident from the data that due to lower gs, Pn was significantly reduced at I1 in cocoa (Table 2). These results showed a remarkable lack of response to internal $CO_2$ to stress levels as encountered in I1, even though both gs and Pn were adversely affected. Further relatively small variations in water use efficiency, (Pn/E), ratios of Pn/Ci and Pn/gs were recorded in cocoa (data not shown). Thus mesophyll factors are not affected under the experimental conditions. Stomatal play a major role in the gas exchange of cocoa (Balasimha et al., 1991 and Balasimha and Rajagopal, 1988). Another interesting feature noticed is the sensitivity of leaf termperature to VPD in cocoa. The results suggest that I2 (20 liter/day) was sufficient to sustain the physiology. This was also supported by the yield of cocoa beans which was highest in I2 level (Table 4). However, arecanut showed increasing trend in these parameters and maximum yield was recorded in I3 level (Table 5).

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**Table 1 :** Microclimatic variables in leaf chamber for cocoa

| Treatment | PAR (µmol/m2/s) | Tair (°C) | RH (%) | VPD (kPa) |
|---|---|---|---|---|
| Irrigation | | | | |
| I1 | 723 | 35.68 | 46.24 | 3.36 |
| I2 | 694 | 34.74 | 49.72 | 2.99 |
| I3 | 839 | 35.04 | 48.92 | 3.20 |
| LSD (p<0.05) | NS | NS | NS | NS |
| Years | | | | |
| 1990 | 712 | 35.39 | 51.37 | 2.94 |
| 1991 | 794 | 35.11 | 50.09 | 3.11 |
| 1992 | 795 | 35.86 | 46.92 | 3.49 |
| 1993 | 761 | 34.21 | 46.06 | 3.10 |
| 1994 | 667 | 34.77 | 45.86 | 3.30 |
| 1995 | 785 | 35.57 | 49.49 | 3.14 |
| LSD (p<0.05) | NS | NS | 3.99 | NS |

**Table 2 :** Effect of irrigation levels on photosynthetic characteristics and leaf water potential in cocoa

| Treatment | Pn (µmol/m2/s) | E (mmol/m2/s) | gs (mol/m2/s) | Ci (ppm) | ψ (MPa) |
|---|---|---|---|---|---|
| Irrigation | | | | | |
| I1 | 3.11 | 2.94 | 0.102 | 265 | -0.97 |
| I2 | 3.86 | 3.47 | 0.136 | 268 | -0.88 |
| I3 | 4.14 | 3.85 | 0.148 | 266 | -0.89 |
| LSD (p<0.05) | 0.80 | 0.25 | 0.042 | NS | NS |
| Years | | | | | |
| 1990 | 3.90 | 3.30 | 0.133 | 249 | -0.93 |
| 1991 | 2.91 | 3.14 | 0.113 | 273 | -0.57 |
| 1992 | 3.42 | 3.48 | 0.112 | 263 | -0.97 |
| 1993 | 4.51 | 3.62 | 0.154 | 263 | -0.96 |
| 1994 | 3.49 | 3.06 | 0.114 | 271 | -0.92 |
| 1995 | 3.99 | 3.92 | 0.145 | 278 | -1.14 |
| LSD (p<0.05) | 0.60 | 0.52 | 0.025 | 9.8 | 0.01 |

**Table 3 :** Effect of irrigation levels on photosynthetic characteristics and leaf water potential in arecanut

| Treatment | Pn (µmol/m2/s) | E (mmol/m2/s) | gs (mol/m2/s) | Ci (ppm) | ψ (MPa) |
|---|---|---|---|---|---|
| Irrigation | | | | | |
| I1 | 3.98 | 3.46 | 0.105 | 255 | -1.23 |
| I2 | 3.62 | 3.68 | 0.122 | 269 | -1.19 |
| I3 | 4.48 | 4.75 | 0.168 | 270 | -1.17 |
| LSD (p<0.05) | NS | 0.96 | 0.041 | NS | NS |
| Years | | | | | |
| 1990 | 4.25 | 3.44 | 0.113 | 248 | -1.32 |
| 1991 | 1.79 | 3.40 | 0.101 | 298 | -1.08 |
| 1992 | 4.02 | 4.78 | 0.146 | 256 | -1.20 |
| 1993 | 5.26 | 4.22 | 0.167 | 257 | -1.19 |
| LSD (p<0.05) | 0.89 | 0.97 | NS | 17.9 | 0.01 |

**Table 4 :** Cocoa bean yield (Kg/ha) in relation to irrigation levels.

| Years | Treatments I1 | I2 | I3 | LSD (P<0.05) |
|---|---|---|---|---|
| 1990-91 | 141.70 | 162.37 | 139.10 | NS |
| 1991-92 | 465.35 | 509.15 | 472.03 | NS |
| 1992-93 | 524.03 | 799.14 | 554.78 | 212.93 |
| 1993-94 | 702.68 | 1028.18 | 929.76 | NS |
| 1994-95 | 806.03 | 1148.94 | 897.39 | 247.97 |

**Table 5 :** Arecanut yield (Kg/ha) in relation to irrigation levels (mean of 4 years 1989-90 to 1992-93).

| Treatment | Yield (Chali) |
|---|---|
| I1 | 1804 |
| I2 | 1958 |
| I3 | 2007 |
| LSD (P<0.05) | NS |

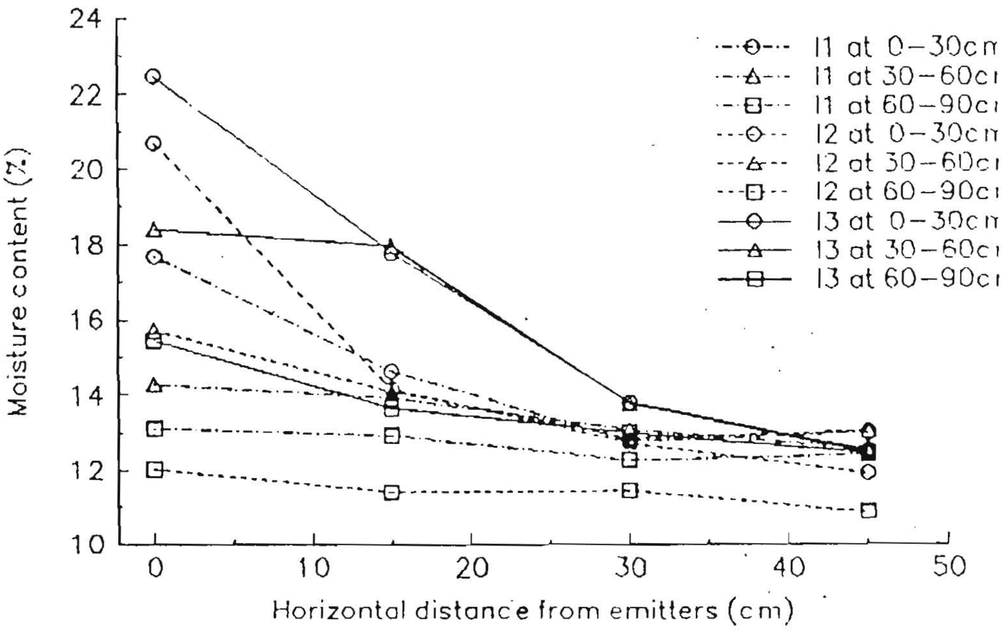


**Fig.1. Soil moisture profiles in I1, I2, and I3 levels at 0-30cm, 30-60 cm and 60-90 cm depth**