

EFFECT OF MULCHES AND COVER CROPS ON WATER STATUS AND GAS EXCHANGE OF COCONUT (*Cocos nucifera* L.) PALMS IN GRAVELLY SOILS

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ABSTRACT

Two field experiments were conducted in gravelly soils (Andigama series) in Sri Lanka to investigate the effect of different mulches and cover crops, utilized to conserve soil moisture, on water status, gas exchange and related soil parameters of coconut palms (*Cocos nucifera* L. var *typica*). The results revealed that mulching only the manure circle was not effective in improving the palm water status, gas exchange and soil water status during dry periods in Andigama soil series (gravelly soils). The mulches tested were coconut husks, coir dust, straw, black polythene and dried coconut fronds. The palms were equally sensitive to soil water depletion and responded to the water deficit by increasing the stomatal resistance irrespective of the mulch treatment. When the manure circle was mulched with dried coconut fronds, and the rest of the land was also mulched with a five cm thick layer of coir dust, the palms showed an improved gas exchange ability than palms growing in bare land or with cover crops during the dry period.

Key words: *Cocos nucifera*, mulching, cover crops, leaf water relations, soil temperature, soil water relations, coir dust, black polythene

INTRODUCTION

The coconut palm, a tree crop which exhibits continuous concurrent vegetative and reproductive phases of growth, requires a regular supply of water to realize and maintain its potential growth and nut production. As coconut is mostly cultivated under rain-fed conditions in Sri Lanka, soil moisture stress during the rain-free seasons is an acute problem, particularly in gravelly soils (eg. Andigama series), irrespective of the agro-ecological region (Somasiri *et al.*, 1994; Vidhana Arachchi, 1998). In the intermediate rainfall zone of Sri Lanka where coconut cultivation is most concentrated, the bimodal distribution of rainfall results in two distinct periods of water stress, sometimes extending for more than three months each year. During extended periods of soil moisture stress, the cells of the absorption zone of coconut roots become inactive by suberization and dehydration, adversely affecting the water and nutrient absorption processes (Vidhana Arachchi *et al.*, 1996; Vidhana Arachchi *et al.*, 2000).

Soil moisture stress is known to retard the growth of young palms, delay initiation of flowering, increase button nut shedding and immature nut fall and reduce the number and size of nuts (Abeywardena, 1971).

Transpiration through leaves is necessary for healthy growth of a palm as it lowers leaf temperature during hot weather. Transpiration aids the transport of water and nutrients to the canopy of the palm for the synthesis of organic food materials. In the dry season, if the absorption of the water is insufficient to balance the loss, the palm will close stomata to prevent dehydration. This will limit the CO₂ intake by the leaf, the movement of nutrients to the canopy and ultimately affect the nut yield (Taiz and Zeiger, 1991). To reduce these constraints and minimize the drought damage, a number of moisture conservation practices have been recommended by the Coconut Research Institute (Liyanage, 1999). The ability of different mulching material to conserve soil moisture in coconut has been investigated in sandy loam soils and, dead mulching was found to be the most efficient practice (Varadan *et al.*, 1990; Vidhana Arachchi, 1998). However, a detailed physiological study on the efficacy of these practices in improving water status of coconut palms has not been reported. Such information is vital in planning and implementing soil moisture conservation methods appropriate for different land suitability classes (Somasiri *et al.*, 1994). The aim of the present study was, therefore, to determine the effect of different soil moisture conservation practices utilizing mulches and cover crops, on water status and gas exchange of coconut palms in gravelly soils in the intermediate rainfall zone of Sri Lanka.

MATERIALS AND METHODS

Experimental site and planting material

The field experiments 1 and 2 described below were conducted at Ratmalagara Estate, Madampe, located in the intermediate rainfall zone of the low country of Sri Lanka (08° 02'N, 79°E; 35 m altitude). Soils at this site were gravelly and classified as the Andigama series belonging to the great soil group, Red Yellow Podzolic soils and moderately suitable land class for coconut (Somasiri *et al.*, 1994; Vidhana Arachchi *et al.*, 1996). The coconut palms (*Cocos nucifera* L var. *typica*) selected for the study were 16 years old and were subjected to the following soil moisture conservation treatments, for a period of three years and data collection on water status and gas exchange was done during the second and third years. The design of the experiments was a completely randomized single-tree plot with six replicates per treatment.

Treatments

Experiment 1

This experiment was conducted to study the effect of different soil moisture conservation treatments applied only to the manure circle. The manure circle (1.75 m radius from the bole) of coconut palms was mulched with the following material. The land surrounding the manure circle was treated uniformly (controlled grass cover).

- T₁ - Control (without mulch)
- T₂ - Husk mulch (250 husks)
- T₃ - Coir dust mulch (10 cm thick)
- T₄ - Straw mulch (5 cm thick)
- T₅ - Black polythene mulch (400 gauge black polythene cover with eight holes)
- T₆ - Dried coconut frond mulch (12-14 fronds per annum)

Experiment 2

The experiment was conducted to study the effect of different moisture conservation treatments applied to the entire land surrounding the manure circles. The manure circle of coconut palms (1.75 m radius from the bole) was mulched with 12-14 dried coconut fronds in all treatments. The surrounding ground area (total area excluding the manure circle) was subjected to following treatments.

- T₁ - Control – clean weeded at monthly intervals
- T₂ - *Brachiaria brizantha* – grass cover crop slashed every 6 months
- T₃ - *Brachiaria brizantha* - grass cover crop allowed to grow freely
- T₄ - *Pueraria* cover crop
- T₅ - Coir dust mulch (5 cm thick)

Collection of data

Experiment 1

Gas exchange (rate of transpiration, stomatal diffusive resistance) and water status (leaf water potential and relative water content) parameters were measured during wet (immediately after a good rainy season) and dry (after a 60 day period without rain) periods on the central leaflets from both sides of ninth frond (counting the youngest fully open leaf as one), between 9.00 a.m. and 1.00 p.m. with full sun. Soil water potential at 50 cm depth and soil temperature at 30 cm depth were measured in the manure circle (details are given below).

Gas exchange parameters

The rate of transpiration and stomatal diffusive resistance were measured using the LI-1600 Steady Porometer (LI-COR Inc, Lincoln, USA).

Water status parameters

Leaf water potential was measured using a Scholander type pressure chamber (Soil Moisture Equip. Corp, Santa Barbara, California, USA). Leaflets were detached from the adult palm, and they were sealed in the chamber as soon as possible to prevent evaporation of water from the leaf. Compressed air was used to determine the pressure necessary to produce incipient sap exudation, which corresponds to the balancing xylem sap negative pressure (Scholander *et al.*, 1965).

The Relative Water Content of the leaves was calculated using the following formula (Weatherley, 1950)

$$\begin{aligned} \text{RWC} &= (\text{FW} - \text{DW}) / (\text{TW} - \text{DW}) \times 100 \\ \text{FW} &= \text{Fresh weight of the sample} \\ \text{DW} &= \text{Dry weight of the sample} \\ \text{TW} &= \text{Fully turgid weight of the sample} \end{aligned}$$

Soil water potential (Ψ_{soil})

Water potential of the soil was measured by filter paper method (Hamblin, 1981). Soils at 50 cm depth in the manure circle were sampled and Whatman No. 42 filter papers were maintained in close contact with the soil for 4 days in airtight aluminium containers to allow the filter paper to equilibrate with the soil moisture. The wet and oven dried (105 ° C to a constant weight) weights of the filter paper were recorded to estimate soil water potential (Ψ_{soil}) using the following equation.

$$\ln (\Psi_{\text{soil}}) = -2.397 - 3.683 \ln F$$

F = fractional gravimetric water content of the filter paper

Soil temperature

Diurnal variation in soil temperature in the manure circle (under the mulch) of control (T1), coir dust (T3) and black polythene (T5) mulched palms at 30 cm depth was measured from 8.00 to 18.00 hours at two hourly intervals during dry period, using soil thermometers.

Experiment 2

Rate of transpiration, stomatal diffusive resistance and water potential of leaves of the palms were measured during wet and dry periods, on the central leaflets from both sides of ninth frond, between 9.00 a.m. and 1.00 p.m. with full sun (methods were described above).

RESULTS

Experiment 1

During the wet period there was no difference, between the treatments, in the transpiration rate of coconut palms. With the onset of drought, transpiration rate declined and there was no significant difference in transpiration between control (T_1) and mulched palms (T_2, T_3, T_4, T_5 and T_6). However, the highest rate of transpiration during the dry period was observed in coir dust mulched palms (T_3) and it was significantly higher than in palms mulched with other materials (T_2, T_4, T_5 and T_6). During the dry period, the lowest rate of transpiration was observed in palms mulched with black polythene (Table 1).

During both wet and dry periods there was no statistically significant difference in the stomatal diffusive resistance between control and mulched palms. However, the highest stomatal resistance was observed during the dry period, in palms mulched with black polythene. Furthermore, with the onset of drought there was a 12-25 fold increase in the stomatal resistance of all the palms compared to wet period (Table 1).

Table 1: Effect of mulching the manure circle with different materials on rate of transpiration and stomatal diffusive resistance of coconut palms during wet and dry periods of the year

Treatment	Rate of transpiration ($\mu\text{g cm}^{-2} \text{s}^{-1}$)		Stomatal diffusive resistance (cm s^{-1})	
	Wet period	Dry period	Wet period	Dry period
Control	4.96 ^a	0.89 ^{ab}	3.03 ^a	35.80 ^a
Husk mulch	4.71 ^a	0.64 ^b	3.18 ^a	49.77 ^a
Coir dust mulch	5.45 ^a	1.55 ^a	2.93 ^a	50.68 ^a
Straw mulch	4.99 ^a	0.48 ^b	2.62 ^a	59.62 ^a
Black polythene mulch	4.77 ^a	0.38 ^b	3.02 ^a	78.43 ^a
Dried coconut frond mulch	4.67 ^a	0.48 ^b	3.39 ^a	69.17 ^a

Values are means and means with the same letters are not statistically significant within a column at $p \leq 0.05$)

Leaf water potential of the palms was unaffected by mulching during wet period and was approximately -1 MPa in both control and mulched palms. During dry period the leaf water potential of all the palms was increased compared to wet period and husk mulched palms showed a significantly lower water potential than in other palms (Table 2).

Relative water content of the leaves was also unaffected by mulching during both wet and dry periods. However, relative water content was less during the dry period than in the wet period in all treatments (Table 2).

Table 2: Effect of mulching the manure circle with different materials on leaf water potential and relative water content of leaves of coconut palms during wet and dry periods of the year.

Treatment	Leaf water potential (MPa)		Relative water content (leaf) (%)	
	Wet period	Dry period	Wet period	Dry period
Control	-1.19 ^a	-0.58 ^b	93.96 ^a	91.47 ^a
Husk mulch	-1.06 ^a	-0.73 ^a	94.59 ^a	92.13 ^a
Coir dust mulch	-1.23 ^a	-0.53 ^b	94.28 ^a	91.56 ^a
Straw mulch	-1.24 ^a	-0.59 ^b	95.31 ^a	90.21 ^a
Black polythene mulch	-0.97 ^a	-0.52 ^b	95.41 ^a	92.78 ^a
Dried coconut frond mulch	-1.23 ^a	-0.57 ^b	95.13 ^a	93.65 ^a

Values are means and means with the same letters are not statistically significant within a column at $p \leq 0.05$)

The soil water potential in the manure circle of control palms was similar to that of mulched palms during both wet and dry periods. However, the lowest soil water potential was under the polythene mulch irrespective of the season (wet or dry) and the highest soil water potential was under the coir dust mulch during the dry period although the effects were not significant. With the onset of drought the soil water potential in all treatments declined compared to wet period (Table 3).

Table 3: Effect of different mulches on the soil water potential (MPa) in the manure circle during wet and dry periods of the year.

Treatment	Wet period	Dry period
Control	-0.41 ^a	-2.05 ^a
Husk mulch	-0.40 ^a	-2.32 ^a
Coir dust mulch	-0.36 ^a	-1.58 ^a
Straw mulch	-0.33 ^a	-2.12 ^a
Black polythene mulch	-0.56 ^a	-2.90 ^a
Dried coconut frond mulch	-0.30 ^a	-2.21 ^a

Values are means and means with the same letters are not statistically significant within a column at $p \leq 0.05$)

The soil temperature under black polythene mulch was significantly higher, and under coir dust mulch was significantly lower than in the control throughout the day, during the dry period. The mean temperature increase by black polythene mulch was 1.1 °C and decrease by coir dust mulch was 1.3 °C compared to the control (no mulch) (Table 4).

Table 4: Effect of different mulches on diurnal soil temperature in the manure circle, 30 cm below the mulch.

Treatment	Time (h)					
	8:00	10:00	12:00	14:00	16:00	18:00
Control	29.0 ^b	29.3 ^b	29.4 ^b	29.7 ^b	30.3 ^b	30.6 ^b
Black polythene	30.0 ^a	30.4 ^a	30.4 ^a	30.8 ^a	31.3 ^a	31.6 ^a
Coir dust	28.4 ^c	28.4 ^c	28.5 ^c	28.6 ^c	27.7 ^c	29.0 ^c

Values are means and means with the same letters are not statistically significant within a column at $p \leq 0.05$

Experiment 2:

During wet periods, the treatments did not affect rate of transpiration, stomatal diffusive resistance and leaf water potential of coconut palms. With the onset of drought transpiration rate decreased and stomatal resistance increased in all the palms irrespective of the treatment. However, in the palms mulched with coir dust, the transpiration rate was significantly higher and stomatal diffusive resistance was significantly lower than those in other treatments, during dry periods. The leaf water potential of palms in all treatments was about -1 MPa during both wet and dry periods. The leaf water potential of palms in the *Brachiaria* grass cover slashed every six months (T2) showed significantly lower water potential than control palms, during dry period (Table 5).