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Effect of conserved soil moisture on the source-sink relationship in coconut (*Cocos nucifera*) under different agroclimatic conditions in India

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ABSTRACT

A long-term multi-location experiment was conducted during 1997-98 to 2002-2003 at different agroclimatic zones (five centers) representing the major coconut (*Cocos nucifera* L.) growing areas in India. Different moisture conservation practices in coconut palm basins, viz husk burial, leaf mulching, application of farmyard manure and farm waste, composted coir pith, application of synthetic polymer and increased potassium dose were evaluated for soil moisture conservation (SMC) at root zone during dry season. The soil moisture conservation practices resulted in the availability of soil moisture in the root zone for extended period. The 'source' parameters like net photosynthesis (Pn), water-use efficiency (WUE) and number of physiologically functional leaves in the crown increased due to irrigation and moisture conservation practices. 'Sink' parameters like, number of pistillate flowers and nut retention efficiency were increased with water conservation and irrigation. The irrigated palms produced more pistillate flowers with higher retention capacity even during summer. The results clearly demonstrated that the prolonged soil moisture availability due to soil moisture conservation treatments helped to increase the photosynthetic source number and efficiency as also the sink capacity and efficiency.

Key words: Coconut husk, Soil moisture conservation, Yield, Source-sink relationship, Photosynthesis, Agroclimatic zones, Mulching

Coconut (*Cocos nucifera* L.) palms are mainly grown as rainfed crop in many parts of India. They are exposed not only to frequent drought years of different intensities and durations, but also to annual summer months. This lead to significant reduction in yields thereby resulting in considerable economic loss to the growers. During summer period the soil moisture deficits coupled with the changes in atmospheric parameters aggravate the situation leading to soil as well as atmospheric drought. Generally, this is the time when they should receive adequate water supply to get better yields. The intricate relationship between dry spell and stages of nut development right from inflorescence initiation to the nut maturity, which takes 44 months, indicated that coconut production under rainfed condition is influenced by the length of dry spells at critical stages such as primordial initiation, ovary development and button size nut (Rajagopal *et al.* 1996) and also annual nut yield in different agroclimatic zones (Rajagopal *et al.* 2000b). As these sensitive stages are present in a palm at any given time, water stress affects the nut yield not only in the current year but also for next 4 years (Rajagopal *et al.* 1996, 2000b, Rajagopal and Naresh Kumar 2003). Thus it is important to identify the location specific soil moisture conservation practice and to evolve management strategies for conserving available water sources to mitigate adverse effects of drought and summer dry spells. Present experiment was carried out with objective to study the impact of soil moisture conservation on source and sink parameters in coconut under different agroclimatic conditions.

MATERIALS AND METHODS

The experiment was conducted during 1997-98 to 2002-2003, at the experimental sites in different agroclimatic zones representing major coconut growing areas, viz Western coastal area – hot sub-humid per-humid (Ratnagiri , Maharastra), Western Ghats – hot sub-humid per-humid (Kidu , Karnataka), hot semi=arid (Arsikere, Karnataka) and eastern coastal plains – hot sub=humid (Veppankulam , Tamil Nadu ; Ambajipeta, Andhra Pradesh). The experimental fields were selected at each representative centre based on uniformity of palms in age and morphological status and uniformity of the field. Due to non-availability of a single cultivar with comparable age grown at different centers, local tall cultivars ('West Coast Tall' at Kidu; 'Benaulim' at Ratnagiri; 'East Coast Tall' at

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Table 1 Number of leaves on crown as influenced by the soil moisture conservation at different agroclimatic centers

Treatments	Centers														
	Kidu			Arsikere			Ratnagiri			Veppankulum			Ambajipeta		
	Season			Season			Season			Season			Season		
	Dry	Wet	Mean	Dry	Wet	Mean	Dry	Wet	Mean	Dry	Wet	Mean	Dry	Wet	Mean
Rainfed	29	27	28	32	31	31	29	30	29	30	24	27	36	35	34
SMC treated	29	27	28	30	30	30	30	30	30	30	25	28	35	35	35
Irrigated	30	28	29	31	31	31	31	29	30	32	32	32	34	34	36
CD		2.41*			NS			NS			1.95**			1.87*	

SMC, Soil moisture conservation

Ambajipeta and Veppankulum; 'Arsikere Tall' at Arsikere), maintained under rainfed conditions, were selected for imposition of soil moisture conservation treatments. In addition to the experimental sites in the research farms, a trial was also laid out in the farmer's field at one of the centers, viz Ambajipeta. Soil types of experimental sites are laterite in Kidu and black loam in Arsikere, whereas Ratnagiri (sandy loam), Veppankulam (sandy loam) and Ambajipeta (coastal sandy) have different types of sandy soils. All the centers have acidic soil (pH~5 to 6) except Arsikere where it is alkaline (pH ~8). The analysis of available soil NPK was done as per the standard procedures and the levels of available NPK were: at Kidu 151:3.9:48 ppm; at Arsikere 91:7.9:150 ppm; at Ratnagiri 84: 2.5: 144 ppm; at Veppankulum 87: 2: 26 ppm and at Ambajipeta 56: 6.9: 78 ppm. The soil organic carbon content also varied from 1.57 % at Kidu to 0.88% at Arsikere; 0.23% at Ratnagiri; 0.4% at Veppankulum and 0.2% at Ambajipeta. Based on the available soil nutrients, each of these palms received the NPK @ 500 g N, 320g P_2O_5 and 1200g K_2O /palm/year.

The experimental treatments included: Control (fully rainfed, normal management practices);soil moisture conservation treatments–rainfed palms with burial of coconut husk in the basin, mulching palm basins with dry coconut leaves, application of double dose of potassium than the recommended (~2000 g K_2O /palm/year), soil amendment with a water absorbing polymer, local practices like weed heaping, burial of Casurina leaves, farm waste, burial of composted coir pith and absolute control (fully irrigated at 200 l/palm once in 4 days as recommended).

All these treatments were imposed in complete randomized design with 9 palms /treatment. Thus 81 palms (9 treatments × 9 palms) at each center and a total of 405 palms (81 × 5 centres) were used for the experiment. For the estimation of soil moisture, soil samples were taken from two opposite spots in each of the basins (1.8 m radius from palm base) of experimental palms. Sampling was done using augur and hammer at 25 and 50 cm depths as the active root zone falls in this layer. Soil moisture (%) was estimated uniformly at 15 days interval at all locations, however, during rainy season, the sampling was done at 1 month interval by the gravimetric method.

Gas exchange characters of experimental palms were recorded from all centers during Nov-Dec; Jan-Feb and April-May using Infra Red Gas Analyser (ADC-LCA4). All necessary calibrations were carried out before taking observations. Leaf chamber parameters were maintained uniformly throughout the experimentation period. Observations were recorded between 9.00 and 11.00 AM. Set gas flow rate in the leaf chamber was 200 mL/ min and boundary layer resistance was 0.08 m^2s /mol. CO_2 mode was put at ambient. Instrument calibrations were done for CO_2 and H_2O before actual measurements. From the gas exchange data, instantaneous water use efficiency (net photosynthetic rate / transpiration rate -P_n/E) was calculated.

Morphological data on date of new leaf emergence, inflorescence emergence and number of pistillate flowers in just opened bunches were collected by tagging the respective plant parts. Data on number of leaves in the crown and nut yield were also collected on the experimental palms once in 3 months. Using the above data leaf production rate, inflorescence production rate and nut retention percentage were calculated.

All these data were collected for 5 years. Data were pooled and statistically analysed for comparing the means. The nut yield (for 6 years; every two years data was pooled to overcome the variations due to biennial bearing) was analysed using covariance analysis to counter the pre-treatment variations among the palm population.

RESULTS AND DISCUSSION

The soil moisture conservation treatments helped in retaining the soil moisture for longer duration during the dry spell as compared to the control palm basins without treatment, where depletion of soil moisture was faster. Soil type played a crucial role in determining the efficiency of treatment mainly owing to the soil water- holding capacity.

Source parameters of coconut

Number of leaves on crown and annual leaf production

In general, the number of physiologically functional leaves on crown did not vary between seasons except at Veppankulam and Kidu, where palms had more number of leaves during dry (summer) season (Table 1). This is mainly because of the carry-over effect of more production and

Table 2 Annual leaf and inflorescence production rates in palms under soil moisture conservation, rainfed and irrigated treatments at different agroclimatic centers

Centers	Treatment			Mean	CD (P=0.05)
	Rainfed	SMC treated	Irrigated		
Annual leaf production rate (no. of leaves/year/palm)					
Kidu	10	11	11	11	0.56
Arsikere	12	12	12	12	NS
Ratnagiri	13	14	14	14	0.52
Veppankulam	13	13	14	13	0.61
Ambajipeta	11	13	13	12	0.82
Annual inflorescence production (no. of bunches/year/palm)					
Kidu	11	11	12	11	0.42
Arsikere	11	12	12	12	NS
Ratnagiri	12	12	12	12	NS
Veppankulam	12	13	14	13	0.76
Ambajipeta	11	12	13	12	0.69

* SMC, Soil moisture conservation

retention of leaves during wet season. Palms with soil moisture conservation treatments and irrigated palms had more number of functional leaves. Among centers, palms grown at Ambajipeta had more number of leaves on crown, whereas those grown at Kidu had less number. The annual leaf production was higher at Ratnagiri and lower at Kidu (Table 2). Irrigation and soil moisture conservation treatments increased the rate of leaf production as well.

Gas exchange parameters

The net photosynthetic rates (Pn), stomatal conductance (gs), transpiration rates (E) were high during post-monsoon period. However, they declined during summer. Palms receiving irrigation and those with soil moisture conservation treatments maintained relatively high Pn and E rates compared to those in rainfed palms, even during summer period. Further, in irrigated and treated palms, apart from improved Pn rates, the overall canopy Pn rates may be significantly high thus contributing towards higher yields in these palms. Low stomatal conductance during summer also led to reduced Pn. rates in rainfed and soil moisture conservation treated palms. However, providing irrigation led to maintenance of Pn rates almost equal to post=monsoon period.

Physiological water use efficiency

In general, the physiological WUE -Pn/E was low during post-monsoon period, whereas it increased during summer. However, in Kidu and Veppankulam the trends were reverse. Palms receiving irrigation and those with soil moisture conservation treatments maintained relatively high water-use efficiency (Pn/E) compared to those in rainfed palms during summer. Palms at Veppankulam maintained water-use efficiency (Pn/E) at similar levels from post monsoon till summer. Overall observations indicate three types of responses by palms in terms of water-use efficiency of palms: (1) high water-use efficiency during post monsoon and low during summer (in Kidu) due to reduction in Pn rates during summer while maintaining same transpirational rates. (2) Low water-use efficiency during post-monsoon and high water-use efficiency during summer (in Ratnagiri and Ambajipeta) because the Pn rates were maintained high even during summer period with a slight decrease in transpiration resulting in increased water-use efficiency during summer. (3) Maintenance of water-use efficiency during post monsoon and summer (as in Veppankulam) because of the reduction in both Pn and E during summer. This indicates that the water-use efficiency of palms is dependent on the intensity of stress. In coconut, during the moderate water deficit periods, the water-use efficiency is maintained high as the decrease in E was more than the decrease in Pn. However, when LAVPD increased further, the stomata started closing, decreasing Pn rates and increasing E thus the water-use efficiency reduced drastically under such situations (Rajagopal *et al.* 2000a) before the stomata is closed. The instantaneous water-use efficiency increased during summer at Arsikere, Ratnagiri and Ambajipeta, whereas it declined at Kidu. The soil moisture conservation led to the maintenance of higher Pn rates for longer duration even during summer thus improving the source efficiency. More importantly, the physiological water-use efficiency was high in palms under conservation treatments. This implies that the soil moisture conservation practices not only improve the water-use efficiency at field level but at physiological level also. Drip irrigated palms also had shown improved physiological water-use efficiency (Naresh Kumar *et al.* 2002).

Sink parameters and yield

Annual inflorescence production

The annual inflorescence production in palms varied with treatment and center. In general, irrigated palms had higher rate of inflorescence production (Table 2). Soil moisture conservation practices also led to increase in annual inflorescence production. Among the centers, rate of inflorescence production was more at Veppankulam and less at Kidu, indicating rate of leaf production and bunch production are related. High annual leaf and inflorescence production at Ratnagiri may be due to high day/ night temperature regimes (36/28 °C) particularly during summer, whereas Kidu is having annual low temperature regimes particularly low night temperatures (10 to 20 °C).

Number of pistillate flowers

In general, palms under soil moisture conservation treatments and irrigated palms had more number of pistillate flowers/inflorescence, particularly during dry periods, at all centers. Pistillate flower production in rainfed palms was low particularly during summer. Palms at Arsikere had more number of pistillate flowers/inflorescence and least number was found in palms at Ambajipeta. The pistillate flower production was

Table 3 Co- variance table of pre- and post-treatment nut yield in palms with rainfed, SMC treatments and irrigation at different agroclimatic centres

Centre/ treatment		Number of nuts/palm/year			CD
		Pre-treatment	Post-treatment	Post-treatment (adjusted)	
Arsikere	Rainfed	48	50	75	8.4
	SMC treated	55	66	76	
	Irrigated	119	127	89	
Kidu	Rainfed	60	62	67	12.0
	SMC treated	62	69	73	
	Irrigated	92	105	91	
Veppankulum	Rainfed	52	70	69	11.2
	SMC treated	51	89	89	
	Irrigated	116	130	131	
Ratnagiri	Rainfed	68	68	78	6.4
	SMC treated	78	89	93	
	Irrigated	112	115	95	
Ambajipeta	Rainfed	100	97	96	20.9
	SMC treated	105	117	116	
	Irrigated	140	152	154	

SMC, Soil moisture conservation

more during post-monsoon season compared with summer at Arsikere and Veppankulum, whereas at Kidu reverse trends were observed. However, at Ambajipeta and Ratnagiri, the number of pistillate flowers//inflorescence did not vary significantly between seasons. Peak production pistillate flowers also varied with agroclimatic zone.

Nut retention

In general, nut retention (%) was more during wet season than in dry season. During dry season, nut retention was more in palms receiving soil moisture conservation treatment and irrigation than in rainfed palms. Overall mean nut retention was higher at Ambajipeta, where number of pistillate flowers/ bunch is low. But at Veppankulum nut retention (%) was the least. The irrigation and soil moisture conservation treatments increased pistillate flower production and nut retention thus improving the sink number and capacity.

Nut yield

To overcome the possible influence of alternate bearing nature of palms, mean of 2 successive years was used for analysis in a cycle of 6 years data. The data indicate that soil moisture conservation practices significantly increased nut yields compared to rainfed palms at all centers (Table 3). However, degree of increase differed among treatments and centers. Increase in nut yield was highest at Veppankulum with ~75% increase over rainfed palm yield. Percent increase at Arsikere, Kidu and Ratnagiri was up to the tune of ~ 40%, 20% and 20%, respectively over rainfed yields at respective places. This indicates that the efficiency of soil moisture conservation varies with soil type and climatic condition. In general, burial of husk or composted coir pith in the basin, mulching with coconut leaves or other farm waste also gave encouraging results in soil moisture retention and increased nut yield.

The influence of drought on the nut yield was seen in the subsequent years (Rajagopal *et al.* 1996, 2000b; Rajagopal and Naresh Kumar 2001, 2003). As the frequency and amount of irrigation influences the water relations and dry matter production of coconut palm (Kasturi Bai *et al.* 1997) an increase in yield is predominantly due to the result of increase in source (the Pn rates) and sink (female flower production) efficiency (Naresh Kumar *et al.* 2002). This implies that by giving life saving irrigation during summer months, the adverse effects of dry spells on the development of inflorescence and nuts can be reduced. The importance goes further up in view of the fact that once affected, palms will take at least 3 years to revive. This emphasizes the importance of soil moisture conservation not only for providing the water to palms for extended period but also, more importantly, to maintain the physiological efficiency of palms for sustaining the productivity levels.

In conclusion, the results clearly demonstrated that the prolonged moisture availability due to soil moisture conservation treatments helped to increase the source number (number of leaves and annual leaf production) and efficiency (increased Pn even during summer for longer periods and improved WUE). The sink number (number of pistillate flower production) and efficiency (nut retention) also increased. This overall improvement in source-sink efficiency and relationship due to soil moisture conservation is reflected in improved coconut yields (Table 4). It is also advisable to conserve the summer rainfall water in similar way. Soil moisture conservation methods reduce number of summer irrigations. Apart from this, available water may be supplied economically to all palms so as to maintain the physiological efficiency of palms for sustained coconut yields even during drought years.

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