PHYSIOLOGICAL AND BIOCHEMICAL BASES OF COCONUT PRODUCTION

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ABSTRACT

The relevance of the physiological arid biochemical investigations on coconut production has been amply proved. The physiological data on the seedling characters arid the equations developed for leaf area arid dry matter production proved to be valuable tools for application in the nursery selections. The experimental evidence provided by the biochemical studies opened up new vistas for utilising some of the biochemical markers related to the processes of growth arid yield in coconut palms. The rapid screening technique developed for drought tolerance offers a good scope for evaluating the germplasm collections. That the scientific management practices could substantially enhance the yield potential of root (wilt) diseased palms has been convincingly delineated.

INTRODUCTION

The coconut palm exhibits wide variability in the production of nuts ranging from 30 nuts, 200 nuts palm-1 year-1, with elite (super) palms yielding even upto 400 nuts (Iyer *et el*. 1979). This variability may be attributed to genotypes arid their responses to the agronomic operations like water management arid fertilizer levels, soil factors such as sandy, laterite or clay soils arid to the prophylactic measures adopted against the disease arid pests. Weather factors namely sunshine hours, light intensity, ambient temperature, arid relative humidity and rainfall also contribute to the fluctuation in the yield of nuts (Murray, 1977). The ultimate yield of any crop depends on the efficiency of dry matter production arid its partitioning into economic produce. This can be assessed with an understanding of the physiological arid biochemical processes involved in the production of nuts in coconut palm, such as leaf area, photosynthesis, dry matter, carbohydrate levels, chlorophylls, enzymes arid nut characters.

Physiological characters

The selection of planting material is one of the important methods of crop improvement. In coconut, selection is made at two stages namely mother palm selection and seedling selection. Harland (1957) reported a wide variability in the transmittance of high yielding capacity to the progenies among the West Coast Tall (WCT) palms. The length of stem and number of leaves in the crown are significantly correlated with annual yield (Patel 1938). A higher rate of leaf production has been noticed in the bearing than in the non-bearing palms (Femond and Brunin 1966, Ramadasan and Mathew 1977). The seedlings which produce more number of leaves in the first two years of growth are found to be the early yielders.

The leaf area and shoot dry mass are the two important parameters which determine the production potential of crop plants (Watson 1952). However, partitioning of the total biological yield is an essential inherent character that determines the economic yield. Extensive work as been carried out in the case of oilpalm to study the growth related aspects (Rees and Tinker 1963, Hardon *et al* 1969, Corley *et al* 1976), while only limited reports are available on coconut (Pillai and Davis 1963, Ramadasan *et al* 1980, Ramadasan and Jacob Mathew 1987). The latter workers, who developed the

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regression equation for the estimation of leaf area and dry matter production observed that once the leaf is completely expanded no differences in the leaf area are noticed among the leaves. From the leaf area of a single leaf the total canopy area has been computed. The leaf area of the hybrids (Tall x Dwarf and Dwarf x Tall) ranges from 5.0 M^2 to 6.8 M^2 as against 4.5 M^2 to 5.5 m^2 exhibited by the tall/dwarf parent. The dry weight of individual leaf ranges between 1.2 to 2.0 kg.

The coconut palm with a single meristem at the shoot apex exhibits growth in terms of the emergence of leaves in succession. Only the newly emerged leaf shows active growth, before it is fully expanded and this rate of increase in leaf area and dry weight during a certain interval should provide an index for the efficiency of dry matter production. Since the amount of assimilate translocated from the leaf is not taken into consideration during the sampling interval as in the case of net assimilation rate determinations of annual crops, the values obtained would give only the relative efficiencies of dry matter production. This rate of increase in leaf area and dry weight of the growing leaf per unit time has been termed as relative assimilation rate (RAR). Ramadasan *et al* (1984) reported higher RAR in the hybrids than in the parents, and highly correlated with yield.

The coconut palm grows to a height of 10 to 24 meters with rough pitted fallen leaf scars, which encircle the whole stern. Roughly 12 to 14 such successive leaf scars correspond to the growth of the tree for one year. Ramadasan and Mathew (1987) developed regression equations for the non-destructive estimation of annual stern dry mass by using the parameters namely annual growth of the trunk and the number of leaf scars. The annual dry matter production of adult WCT palms, adopting the above method, ranged from 65 to 85 kg palm-1.

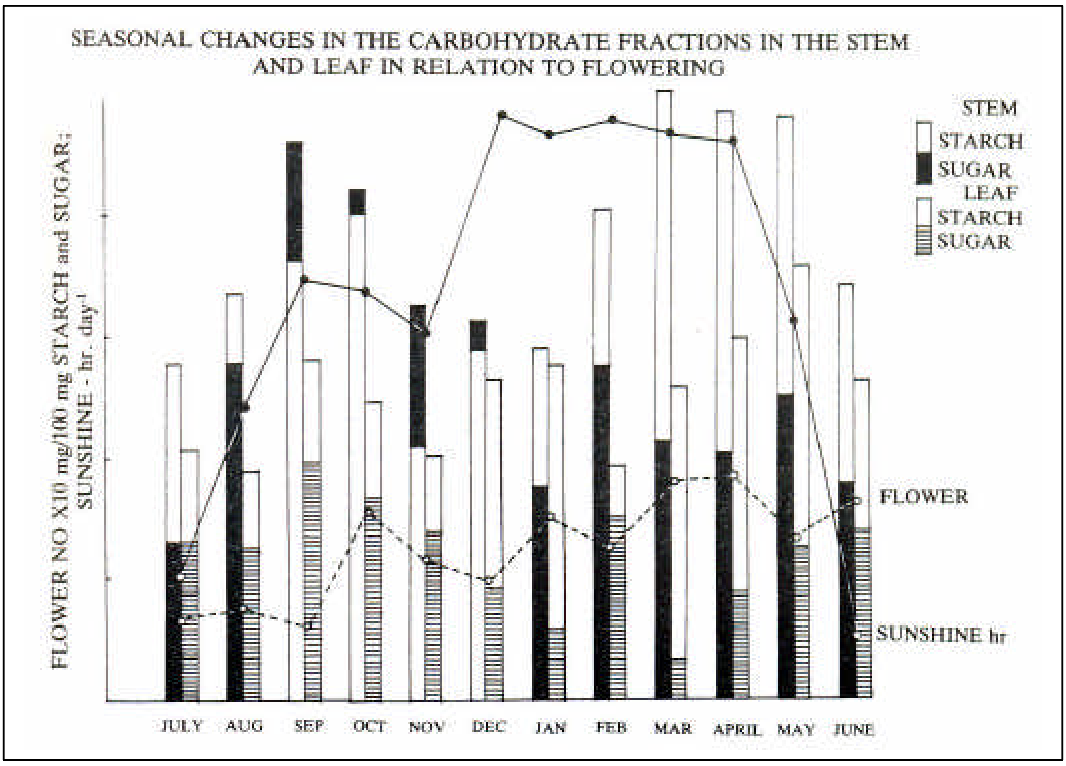
Shivashankar *et al* (1982) observed a higher leaf area coupled with higher rate of photosynthesis and lower dark respiration in tall x dwarf hybrid (WCT x COD) than the respective parents. The low yields among the dwarfs has been attributed to high rates of dark respiration in proportion to photosynthetic rates (Table 1). A similar trend was reported in the East Coast Tall (Raveendran *et al* 1989).

Table l : Rate of Apparent Photosynthesis Dark Respiration, Relative Assimilation Rate and Other Characters in Three Coconut Genotypes

Parameters	WCT		COD		T x D	
	Mean	CV%	Mean	CV%	Mean	CV%
Rate of apparent Photosynthesis (LO_2 evolved cm $^{-2}$h^{-l})	28.11	22.0	32.82	30.2	33.98*	14.0
Dark respiration (lo_2, consumed Cm^{-2} h^{-1})	4.23	24.4	6.31	11.8	5.02**	21.5
Relative assimilation Rate (g. m^{-2}, week^{-1})	2.83	44.1	2.63	38.8	4.7**	23.4
Total Chlorophyll (mg. cm^{-2})	0.05	30.0	0.04	15.0	0.06**	16.0
Total carotenoids (mg cm^{-2})	0.02	36.0	0.02	20.0	0.03**	17.0
Stomatal frequency (NO. mm^{-2})	199.06	10.3	189.5	19.3	203.59	14.0
Leaf area (m^2 leaf^{-1})	4.5	-	3.6	-	6.8**	-
Mean yield (No: of nuts palm-$^{-1}$ year^{-1})	58.3	26.4	48.6	33.3	93.1	51.5

**Significant at 1% level.
* Significant at 5% level.

Another important area in the production physiology of coconut is the development of inflorescence and fruit set. Although the number of female flowers produced vary depending on the genotypes, the percentage of fruitset is normally 35 to 40% but under abnormal conditions, the shedding of buttons/immature fruit increases leading to poor nut yield (Menon and Pandalai, 1958). Kasturibai and Ramadasan (l 982, 1983) have shown the importance of assured level of carbohydrate fractions from the source (stem) to the sink (inflorescence) for the initiation and development of the inflorescence. Their work also revealed the influence of environmental variables on the carbohydrate levels and inflorescence development (Fig. 1). This is in support of earlier report on the adequate build up of carbohydrates in the stem as a pre-requisite for the commencement of first flowering (Ramadasan and Mathew, 1977)



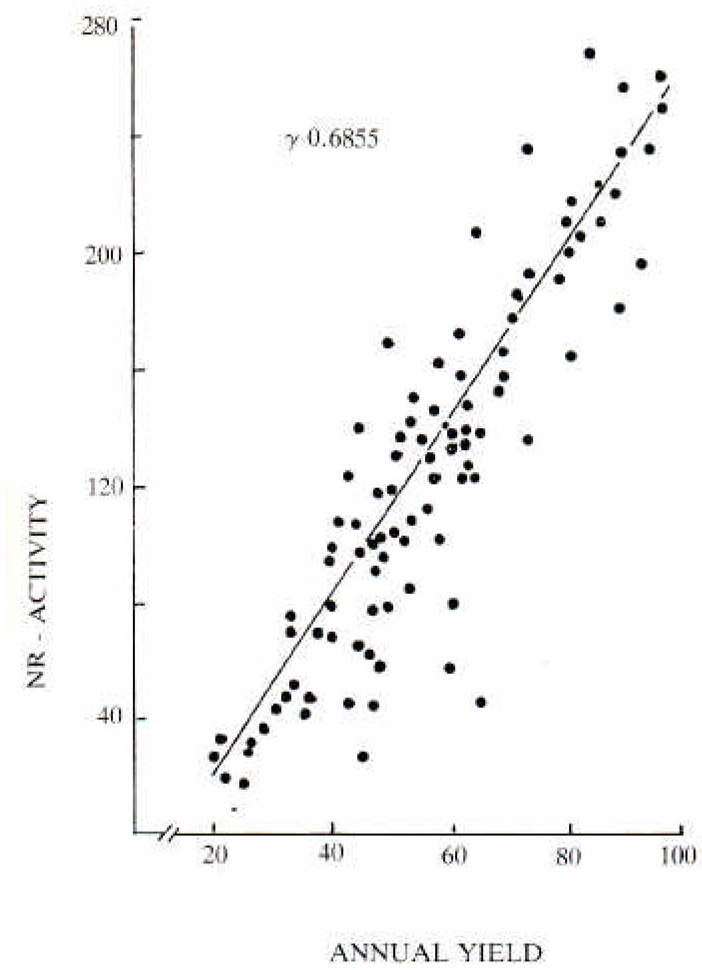
Since the harvest index is an important criteria in determining the genetic variability in biological and economic yields, attempts have been made to work out the index in coconut. By determining the partitioning of dry matter to the annual production of nuts from the annual, biological yield, the annual productivity index (API) has been worked out. The API thus estimated ranged from 0.4 to 0.5 in a group of palms in which the annual yield of nuts ranged from 45 to 91 nuts palm-1 year-1. The ratio showed a good relationship with annual yield of nuts and is a good index for determining the production efficiency of coconut palm (Ramadasan and Rajagopal 1987). According to Ramadasan *et al* 1985, the efficiency of dry matter production in coconut is a heritable character.

Biochemical characters

As plant growth and yield are also the manifestation of biochemical pathways, linked with the physiological processes explained in the earlier section, an attempt has been made to assess the relevant aspects in coconut. One of the limiting factors associated with the growth and productivity is the uptake and assimilation of nitrogen, the first among the major nutrients. The utilization of this important nutrient is determined by the activity of nitrate reductase (NR) enzyme which catalyzes the rate-limiting step namely the reduction of nitrate to nitrite in the sequence of reactions leading to the production of aminoacids. The in vivo activity of this enzyme has been positively correlated with the yield and protein content of several cereal crops (Hagemen, 1970; Eck *et al* 1975) and yield of tea (Wickremasinghe *et al*, 1980).

Experiments in our laboratory indicated that NR activity in coconut leaves measured after substrate induction was significantly related to yield of nuts in a population of 150 palms belonging to low, medium and high yield groups (Fig. 2) (Shivashankar and Ramadasan 1983). Subsequent work on the inducibility of NR in low and high yielding palms subjected to a range of nitrate levels showed that in the high yielders the enzyme activity was two-fold higher than in the low yielders at the optimal substrate level. Further more, the nitrate concentration required for maximum induction was much less in high yielders (80 mm) than that for low yielders (140 mm) (Fig. 3), implying thereby the better utilization of the available nitrate by the high yielders than the low yielders (Shivashankar and Kasturibai 1989).

Figure 2. RELATIONSHIP OF INDUCIBLE NR ACTIVITY WITH ANNUAL YIELD [? = 0.6855]



Further investigations centered around the assay of the enzyme in certain varieties and hybrids of genetically dissimilar nature, with the objective of relating the enzyme activity with growth parameters at nursery level itself. The F, progeny of Chowghat Orange (COD) and West Coast Tall (WCT) cross trend to be highly heterozygous with respect to the colour of the petiole and seedling vigour. From the Table (2) it is clear that the greenish brown coloured vigorous plants (heterotic hybrids) has higher content of chlorophylls (a+b) and nitrate reductase activity as compared to the orange coloured vigorous plants (intermediate hybrids) and the dwarf segregants (dwarf hybrids). The shoot dry mass, an important index of vigour, was significantly and positively correlated with NR activity (r = 0.55), reflecting the central role played by NR in the growth process. These results indicated that NR activity at the juvenile stage could serve as a sensitive predictor of the seedling vigour (Shivashankar *et al*, 1985). Further confirmation was obtained with the seedlings of three hybrid crosses, which revealed the superiority of MYDxWCT in growth attributes as compared to MOD x WCT and COD x WCT (Shivashankar and Kasturibai 1988). The hybrid MYD x WCT displayed a higher nitrogen use efficiency than the other two hybrids, which implies the better utilization of applied nitrogen by MYD x WCT (Table 3). The growth parameters followed over a period of five years have established the superiority of MYD x WCT which also showed early bearing habit (Shivashankar *et al*, unpublished).

Figure 3. Nitrate Reductase activity

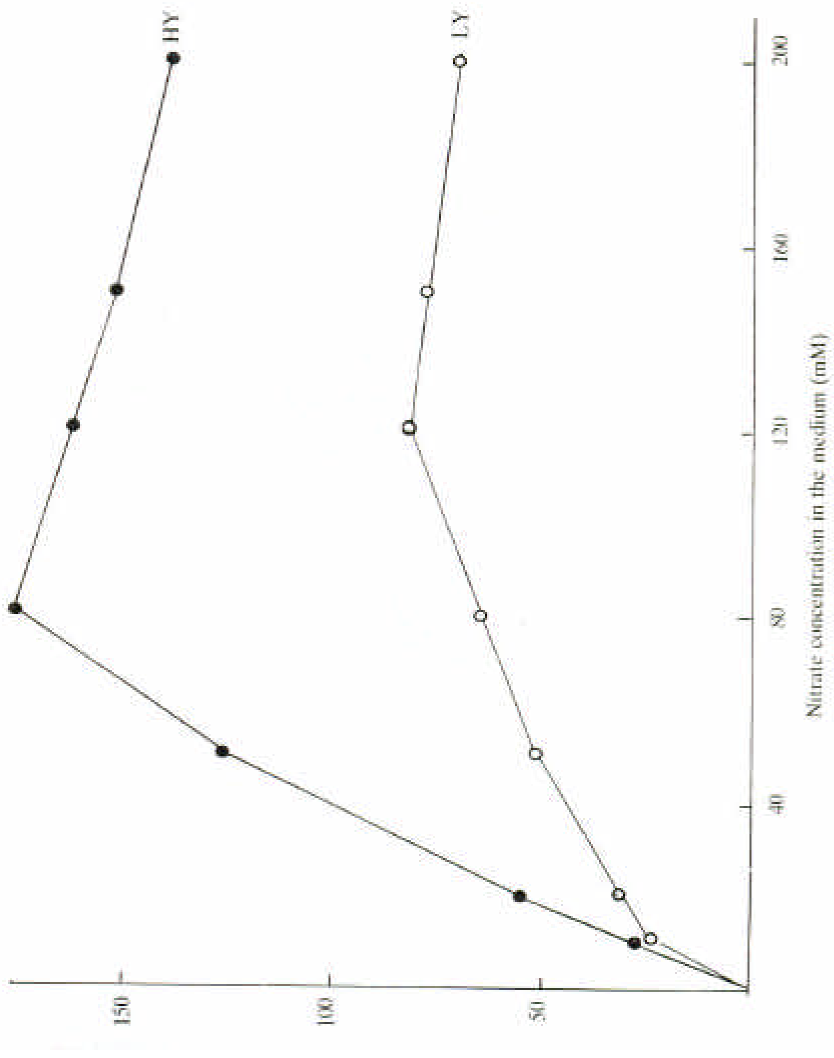


Table 2: Photosynthetic Pigments, Nitrate Reduction, Leaf area and Shoot dry in F_1 Hybrid Coconut Seedlings

Type	Chlorophylls (a+b)	Carotenoids (mg/dm^2)	NR activity nimoles	Reduced N (mg/g)	Shoot dry mass (g)	Leaf area (m^2)
Heterotic hybrid	3.57	1.59	457.4	18.5	221.3	0.84
Intermediate hybrid	3.09	1.37	183.4	18.5	148.1	0.53
Dwarf hybrid	2.70	1.23	119.0	15.3	47.6	0.30

Table 3: Nitrate Reduced and Nitrogen Accumulated by the Seedling Shoots in One Months After N - Application

Hybrid	Total shoot N (g)	Nitrate reduced by shoot (m moles)	N contributed Via. nitrate reduction (mg)	%N by shoot NR activity	Nitrogen uptake efficiency
COD x WCT	0.70	3.39	46.1	6.13	0.014
MOD x WCT	1.24	8.81	123.3	10.00	0.25
MYD x WCT	1.90	27.1	379.1	20.00	0.40

** Significant at 1% level.

Production Constraints

The production of coconuts is hampered by factors such as drought, diseases or disorders. While yield decline is attributed to drought in some of the coconut growing countries, diseases like lethal yellowing in Jamaica, Cadang Cadang in Philippines and root (wilt) disease in India are reported to result in low production of nuts. A case study on the physiological approaches made on drought tolerance in coconut genotypes and root (wilt) disease is presented below.

Drought: As a rainfed crop coconut is exposed to vagaries of weather in countries like India. Rainfall has greater influence on the production of nuts. The differential response of yield by coconut to the monthly and seasonal rainfall was observed at Kasaragod and Pilicode (Balasubramanian 1956). Lakshmanachar (1953) reported the correlation between rainfall and nut yield. The important factor for the highest production of nuts is the better distribution of rainfall (Abeywardena 1969). A comparative study of the data on the climatic chahges and nut yield from four African countries indicated that water deficit plays an important role in yield fluctuations under non-limiting conditions of sunshine and temperature (Coomans 1975).

Frequent occurrence of drought even in heavy rainfall areas as in North Kerala, results in poor nut yield, emphasizing thereby the significance of effective rainfall in nut production. Rajagopal *et al* (1986) reported the response of two genotypes (WCT and COD x WCT) to low and high drought intensities (South and North Kerala respectively) on leaf characters and yield attributes. The impact of moisture stress on yield related processes like stomatal regulation dry matter partitioning has been investigated (Rajagopal *et al* 1989a). A soil water deficit of 110 mm was found to be the critical level at which coconut suffered most due to moisture stress in sandy loarn soil, is indicated by stomatal closure a sensitive indicator of plant stress. Exposure of palms to field stress for 16 or 24 days during summer led to a reduction in the vegetative dry matter by 15% and 18% respectively whereas the reproductive dry matter was reduced by 20% and 22% respectively, as compared to nonstressed i.e. irrigated palms. The number of days taken for unfolding of spindle leaf and the spathe was more during 'dry' than during 'wet' season both in WCT and COD x WCT palms, which reflects on the role of soil moisture availability on these important processes. During summer, atmospheric drought further aggravates the water relations of coconut palms (Kasturibai *et al*. 1989b).

When three genotypes namely WCT, WCT x COD and COD x WCT were compared under irrigated and rainfed conditions, the partitioning of dry matter into husk, shell and copra was affected due to stress (rainfed) more in COD x WCT than in the other two genotype, revealing thereby the drought susceptible nature of COD x WCT (Anonymous, 1987).

Prasada Rao (1985) worked out the aridity index based on which drought classification was made to assess the extent of damage to coconut palms. Accordingly, an aridity index of 85% that occurred during March 1983 was associated with drying of leaves, preceded by drooping sympton. Varietal differences exist among coconut palms in the number of dry and broken leaves (Pomier and de Taffin 1982, Rajagopal *et al* 1990b). Besides leaf characters, poor spathe development and shedding of unfertilized female-flowers (buttons) and immature nuts are characteristic features of drought affected palms. Ramadasan *et al* (1991) reported the response of ten coconut genotypes to the severe drought of 1982-1983 (Table 4). When ail the three characters recorded, namely leaf and bunch conditions and nut fall were compared, WCT x MOD appeared to be more affected, followed by COD x WCT while other genotypes exhibited the impact on one or two characters only. In general, WCT x COD, LO x COD, WCT x GB, WCT x FIJI, WCT x Kappadam, besides WCT are relatively tolerant to drought. The screening techniques adopted in the authors' laboratory also indicated the drought tolerant nature of some of the above genotypes (Rajagopal *et al* 1990a). The better yield performance of the drought tolerant LO x GB, LO x COD, WCT x COD than the other genotypes, further confirmed the efficacy of screening techniques (Rajagopal *et al* 1990 c). Further evidence on drought tolerance was obtained through biochemical characterization of the genotypes (Shivashankar 1988, Shivashankar *et al* 1991, Shivashankar 1990).

Table 4: Effect of Drought on Coconut Leaves, Bunches and Nuts

Cultivars	Leaves		Drought index*	Bunches			Nuts		
	Dry/ broken	Total		Affected	Total	%	Fallen	Total	%
WCT x COD	6.4	29	22.1	7.6	14.3	53.1	39	135	28.9
COD x WCT	10.2	20	51.0	9.2	14.6	63.0	40	103	38.8
LO x COD	5.5	23	23.9	6.0	12.5	48.0	21	66	31.8
WCT x GB	2.5	21	11.9	9.0	13.5	66.7	33	105	31.4
WCT x Fiji	5.0	29	17.2	2.0	15.0	13.3	39	142	27.5
WCT x SSG	8.0	24	33.3	11.0	14.0	78.6	43	127	33.8
WCT x Philiord.	0	24	0	12.0	17.0	70.6	40	134	29.8
WCT x Kappadam	7.0	23	30.4	10.0	15.0	66.7	12	77	15.7
WCT x MOD	11.0	17	64.7	10.0	11.0	90.9	18	50	36.0
WCT	6.8	23	29.5	6.0	13.0	46.1	23	101	22.8
WCT (Irrigated)	0	28	0	0	13.5	-	5	108	4.6

* Method of Pomier and Taffin, 1982.

Disease: Among the coconut diseases in India, root (wilt) disease of mycoplasmal etiology, in Kerala state ranks high in terms of the spread and decline in nut yield. It is estimated that 968 million nuts are lost from the affected palms (Anonymous 1985). The disease is characterized by flaccidity, yellowing and necrosis of leaves of different intensities, which in physiological terms would amount to reduction in effective photosynthetic area. Reduction in nut yield in the disease affected palms was found to be proportionate to the intensity of the disease (Anonymous 1976). From a comprehensive field experiment on the response of diseased palms to management practices involving summer irrigation, fertilizer application and prophylactic measures, Rajagopal *et al* 1987, 1989b) reported a marked decline in the number of yellow leaves, senescent leaves and rotten leaves between the pre and post treatment stages. This means that the greenness of leaves increased in well managed palms, resulting in higher photosynthetic area than those palms, which were poorly managed (Table 5). These resulted in significant improvement in the production and quality of nuts of palms subjected to management practices.

Table 5: Effective Photosynthetic Area in Root (wilt) Diseased Coconut Palms Under Different Management Practices. Leaf area, m^2 $palm^{-1}$

Treatment	Stage	Yellowing	Rot	Senscence	Average
1_1F_1	Pre-treatment	69.5	29.4	25.8	41.6
	Post-treatment	28.6	17.4	10.2	18.6
	%	59.4	40.9	60.5	44.7
I_0F_1	Pre-treatment	51.5	27.0	22.2	33.6
	Post-treatment	55.7	17.4	18.6	30.6
	%	108.6	35.6	16.2	91.1
I_0F_0	Pre-treatment	73.7	34.1	30.6	46.1
	Post-treatment	76.1	31.8	34.1	47.3
	%	103.3	106.7	111.4	102.6

Thrust Areas of Research:

Major areas of activity for future research could be broadly outlined based on the results presented :

(i) Relationship between the seedling characters and nut yield of adult palms.

(ii) Photosynthesis and nitrogen metabolism in relation to productivity.

(iii) Biochemical markers as indicators of yield potential, drought tolerance etc.

(iv) Mechanism of drought tolerance and future strategies for breeding programme.

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