SIX DECADES OF COCONUT RESEARCH

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FOREWORD

India faces today, a deficit of 12 million tonnes of vegetable oils. Out of the total production of 3.3 million tonnes in the country, the share of coconut oil is seven per cent. At the present rate of consumption, India will have to produce coconut oil to the equivalent of 12,172 million nuts by the turn of the century, an increase of 5688 million nuts from the present level of production. The task of bridging this gap is enormous, but it could be achieved if technologies already evolved through years of experimentation are understood and adopted by the farmers at large.

Coconut research in India commenced in the year 1916 with the establishment of research stations at Pilicode, Nileshwar and Kasaragod by the erstwhile Government of Madras Presidency. Later, a few more stations came into existence in different parts of the country with the mandate for solving location specific problems. The first attempt on controlled cross breeding in coconut was made at Kasaragod. The world's first hybrid plantation was established in the year 1936 at Nileshwar. Thanks to the concerted efforts of the researchers in these stations, Kerala state has now a sound package of technologies for coconut production. However, a great body of knowledge that has emanated from research remains unpublished due to various reasons. There is a dire need to compile all the valuable information and make it available. The present title 'Six Decades of Coconut Research' is an attempt in this direction. It provides a digest of information on coconut production and management gathered from the research institutions presently under the Kerala Agricultural University.

I am sure that this publication will serve scientists, students and farmers alike.

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PREFACE

Coconut research has a long history in India dating back to 1916, the year in which the first coconut research centre in the world was established at Nileshwar, Kerala. The early work on coconut has been mostly with limited objectives understandably due to lack of proper and sound methodologies in experimentation. The research work on coconut in the country picked up momentum in the 1940s with the establishment of more centres. As a result of these developments, voluminous literature on several aspects of coconut culture, both of basic and applied nature, has been accumulating over the years. This compendium is an attempt to present all the work on coconut so far carried out during the past six decades at the various research centres which are presently under the Kerala Agricultural University. We do not, however, claim that we have been able to do the job to our best satisfaction. Flaws and omissions may be found but those are bound to occur while tracing and compiling the oldest literature in any field.

A great deal of effort had gone into the preparation of this manuscript. We are grateful to all our colleagues who have contributed to this volume.

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CHAPTER 1

Coconut Production in Kerala : Problems and Prospects

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Coconut is a crop of great antiquity in Kerala. It has always been an object of reverence in the local tradition. The very name 'Kerala' is derived from its association with the coconut palm, called *Kera Vriksha* in Sanskrit. To the Keralite, the coconut palm is 'Kalpavruksha' or the tree of divine life because it is a primary source of food, drink and shelter. No other tree crop grown in the state can match coconut in its versatality. It provides nutritious food and refreshing drink, oil for edible and nonedible uses, fibre, timber and shell of commercial value, thatch, alcoholic beverages and a variety of products for use as domestic fuel.

Coconut is the most important cash crop grown in Kerala, its contribution to the state's income being 9.3 per cent. The share of the crop to the agricultural income of the state is 34.9 per cent. The coconut-based industries provide direct employment to about one million people. The contribution of the crop to the country's export earnings is Rs. 264 million.

Among the different coconut growing states in the Indian Union, Kerala ranks first with a share of 57.7 per cent (6.89 lakh ha) of the area and 49.3 per cent (3395 million nuts) of the total production of coconut. Kerala, Tamil Nadu, Karnataka and Andhra Pradesh together account for 90 per cent of the area under coconut in India (Table 1.1).

Although Kerala is known as the land of coconut, the performance of the crop in the state since the year 1974-75 has been dismal. Both area as well as production of the crop have registered a fall over the past decade. The negative growth rate recorded was 7.9 per cent for area and 8.7 per cent for production. Kerala state which accounted for more than 67.0 per cent of the area and 61.0 per cent of the production of coconut in the country during the year 1974-75 has slided down the scale in its contribution to the present levels of 57.7 per cent and 49.3 per cent, respectively.

Even the increased production level of 339 million nuts achieved in the year 1984-85 was much less than the production levels recorded in the beginning of the decade. In contrast to this, the neighbouring states, Tamil Nadu and Karnataka, have achieved significant increases both in area and production over the

Table 1.1. Coconut in India: Area and production (1984-85)

	State	Area ('000 ha)	Share (%)	Production of nut (million)	Share (%)
1	Kerala	689.3	57.74	3395.0	49.28
2	Tamil Nadu	152.8	12.80	1627.5	23.63
3	Karnataka	193.9	16.24	1011.1	14.68
4	Andhra Pradesh	47.0	3.94	194.5	2.82
5	Orissa	26.2	2.20	98.3	1.43
6	Maharashtra	10.6	0.89	99.3	1.44
7	Assam	6.5	0.54	46.4	0.67
8	West Bengal	15.3	1.28	169.7	2.46
9	Goa, Daman and Diu	22.3	1.87	106.0	1.54
10	Andaman and Nicobar Islands	20.8	1.74	96.6	1.40
11	Lakshadweep	2.8	0.23	23.5	0.34
12	Pondicherry	1.6	0.13	15.7	0.23
13	Tripura	2.7	0.23	2.1	0.03
14	Others (Gujarat, Bihar and Madhya Pradesh	1.0	0.08	1.7	0.02
	India	1192.8	100	6887.2	100

last decade. In area, Karnataka registered an increase of 34.1 per cent as against 40.7 per cent by Tamil Nadu. The production improvement recorded was 40.3 per cent and 49.1 per cent, respectively, by these two states (Table 1.2).

Wide variations do exist in the productivity of coconut in the different states in India. In Kerala, the unit productivity of the crop is as low as 5023 nuts per ha as against 10987 nuts per ha in Tamil Nadu and 5173 nuts per ha in Karnataka (1984-85). This reflects on the per palm productivity also. The nut production per palm is 33 in Kerala, 44 in Tamil Nadu and 54 in Karnataka (Table 1.3). Lack of irrigation facilities, severe incidence of diseases like root (wilt), high plant density, senility of the existing palms and sub-optimal management levels are undoubtedly the factors responsible for the poor performance of the crop in the state of Kerala. A comprehensive survey to estimate the crop losses due to the root (wilt) disease conducted during 1984 covering eight districts of Kerala revealed that about 30 million palms were under the grip of the disease. This is roughly 19.6 per cent of the total number of palms (154 million) in the state.

Despite the incidence of root (wilt) disease in the southern districts—Quilon, Alleppey, Kottayam, Ernakulam, Idukki and Trichur—the per palm productivity is on par with that of the districts where the crop is relatively free of the disease (Table 1.4). In the northern tract of the state the factor responsible for low yield is the prolonged drought that occurs almost every year from December to May.

Table 1.2. Trend in the area and production of coconut in Kerala, Tamil Nadu and Karnataka

Year	Kerala		Karnataka		Tamil Nadu		All India	
	Area (lakh ha)	Production of nut (crore)	Area (lakh ha)	Production of nut (crore)	Area (lakh ha)	Production of nut (crore)	Area (lakh ha)	Production of nut (crore)
1974–75	7.48	371.9	1.45	72.0	1.09	109.1	11.16	603.1
1975–76	6.93	344.0	1.51	76.7	1.10	109.9	10.70	582.9
1976–77	6.95	334.8	1.54	80.3	1.09	109.5	10.74	576.5
1977–78	6.73	305.3	1.56	81.0	1.10	103.9	10.56	541.3
1978–79	6.61	323.7	1.64	85.5	1.09	112.3	10.55	573.0
1979–80	6.64	303.2	1.68	87.3	1.15	118.0	10.76	566.2
1980–81	6.66	303.6	1.71	89.0	1.16	135.4	10.83	594.2
1981–82	6.67	300.6	1.76	91.8	1.16	138.6	10.91	594.0
1982–83	6.74	318.4	1.83	95.0	1.44	143.5	11.49	635.6
1983–84	6.82	260.2	1.90	99.1	1.37	136.8	11.66	580.8
1984–85	6.89	339.5	1.94	101.1	1.53	162.7	11.93	688.7
Growth over the period 1974-75 to 1984-85 (%)	-7.9	8.7	34.1	40.3	40.7	49.1	6.9	14.2

Table 1.3. Coconut in India: Production of nut per ha in the major coconut growing states

Year	Kerala	Tamil Nadu	Karnataka	India
1974–75	4970	10488	4983	5401
1975–76	4964	9996	5073	5448
1976–77	4817	10054	5227	5366
1977–78	4533	9462	5204	5123
1978–79	4900	10258	5215	5431
1979–80	4563	10235	5198	5263
1980–81	4558	11676	5190	5485
1981–82	4509	11925	5202	5445
1982–83	4721	9969	5204	5531
1983–84	3814	9979	5207	4983
1984–85	5023	10987	5173	5774

Poor crop management and high plant density aggravates the problem. On the other hand, the rainfall in the disease affected districts is fairly well distributed and the management levels are more intensive than in the disease free northern tracts. This indicates that root (wilt) is a debilitating disease and

Table 1.4. Trend in the productivity of coconut in Kerala (nut yield per palm per annum)

District	1977-78	1979-80	1981-82	1983-84	1984-85	1985-86
Trivandrum	38	38	36	27	45	35
Quilon	30	31	34	23	38	30
Pathanamthitta	—	—	—	18	31	39
Alleppey	32	34	29	26	40	40
Kottayam	26	21	23	18	23	26
Idukki	30	20	23	19	23	33
Ernakulam	32	39	40	28	41	37
Trichur	43	36	44	36	33	44
Palghat	39	28	27	23	28	38
Malappuram	37	35	30	20	29	29
Calicut	33	34	29	33	39	33
Wynad	—	—	19	10	12	22
Cannanore	25	32	26	24	35	33
Kasaragod	—	—	—	—	—	18
Mean	33	31	30	23	32	33

satisfactory yield could be obtained if the crop is properly managed. This also points out the necessity of streamlining definite strategies for increasing coconut production in root (wilt) disease affected areas and for other regions, especially, the northern tracts.

Though the productivity of coconut in Kerala is far from satisfactory, it has potential for further improvement. A comparative analysis of the coconut production under irrigation in Kerala with that of Karnataka or Tamil Nadu makes interesting indications. The experiments conducted in Kerala have conclusively proved that irrigation alone increases the average nut production per palm to 73 from the state average of 33. Thus the yield per tree under irrigation in Kerala is higher than that of Tamil Nadu or Karnataka. This would suggest that if irrigation facilities could be assured in the coconut growing tracts of Kerala, the state will attain the top most position in productivity in the country. There is, therefore, every justification to invest in building up irrigation facilities to cater to the needs of small and marginal farmers of Kerala. The necessity for concerted efforts in this direction has been relegated to the background probably due to major concentration on root (wilt) disease. Improving management practices, replacing systemetically the senile palms and adopting proper plant protection measures are the other areas which should go a long way in furthering the productivity.

Coconut research in Kerala

Coconut research in Kerala commenced in the year 1916 with the establishment of four research stations in the erstwhile Malabar at Pilicode (Nileswar I, Nileswar II, Nileswar III and Kasaragod by the then Government of Madras. In these stations, research was initiated to study the genetics of the palm and agronomic and cultural requirement of the crop in relation to three soil types-laterite (Pilicode) red sandy loam (Nileswar II and Kasaragod) and littoral sand (Nileswar III). The research activities gained further momentum since 1945 with establishment of the Indian Central Coconut Committee. The Committee took over the research station at Kasaragod in 1947. One year later, another research station was set up at Kayamkulam to intensify research on pests and diseases affecting coconut palm. The Committee also funded the establishment of the coconut research stations at Kumarakom and Balaramapuram under the Department of Agriculture in the same year.

With the abolition of the Indian Central Coconut Committee in the year 1966, the research stations at Kasaragod and Kayamkulam were brought under the Indian Council of Agricultural Research in 1970 and thus came into existance the Central Plantation Crops Research Institute (CPCRI) at Kasaragod. The coconut research stations at Nileswar, Pilicode, Balaramapuram and Kumarakom functioned under the Department of Agriculture till 1972. These stations were transferred to the Kerala Agricultural University in 1972.

The year 1980 witnessed a further fillip in coconut and coconut based farming research when the Kerala Agricultural University came within the fold of the National Agricultural Research Project (NARP). The coconut research stations at Pilicode and Kumarakom were elevated to the status of Regional Research Stations with the mandate for research on coconut and coconut based farming systems and integrated coconut-livestock-fishery systems, respectively. The improvement of infrastructural facilities and manpower and additional resources have helped these regional stations to initiate research on a more scientific footing. A major breakthrough in coconut research with the establishment of regional stations was in identifying location specific problems in coconut production and initiating projects to tackle these identified problems. Based on the results of such studies, the University has now made a beginning to make specific recommendations for coconut in the different agroclimatic zones.

Thrusts on research and development

The disturbing trend of declining productivity in coconut in the state of Kerala should not discourage our efforts in research or development activities. The technologies that have been evolved through years of concerted efforts have convincingly proved that the challenge could be met with success. In the present context of limited scope for expansion of area, our strategy should be to maximise production in the traditional tracts through intensive management practices. Irrigation and manuring of the existing gardens alone have been found to double the present production. The irrigation needs of the small and marginal farmers could only be met through small scale irrigation schemes. The impact of prolonged dry spell has been considerable which could be alleviated through assured water supply or through moisture conservation methods. Water, being a precious commodity, has to be economically utilized, which calls for intensified research on water use efficiency.

Replacing the senile palms is a continuous process in coconut culture, which calls for supply of elite planting materials with proven efficiency. There is, thus, sufficient justification for enhancing the production of hybrids since they have a higher production potential. The production of hybrids or stable varieties suited to specific needs has to be intensified to make sure that every coconut newly planted will ultimately fall within the high yielding category.

In the root (wilt) disease affected areas, a two-pronged strategy has to be worked out. Trees which are in the early stages of the disease could be improved by adopting intensive management practices while those which are in the advanced stages should be eliminated and replaced with good planting material. Replacing of severely affected palms could be taken up on an area basis rather than on isolated single tree basis.

The research on root (wilt) disease still eludes all our efforts. The situation all the more calls for further intensification of research in this field.

Intercropping in coconut gardens with perennial and annual crops has given encouraging results in the root (wilt) affected as well as disease-free zones. Research work has to be further intensified to evolve suitable cropping system models which will ensure additional income besides sustaining soil productivity.

The acceptance of technological innovations and their adoption on a wider scale are influenced to a major extent by the remunerative prices for the produce. The diversified use of products will help the farmer to obtain better prices for his produce.

The challenges before the scientists, developmental agencies, planners and policy makers to stabilize and increase coconut production in Kerala state are multi-faced and the success depends upon co-ordinated and more concerted efforts.

CHAPTER 2

Coconut Improvement

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Two distinct varieties have been distinguished in coconut, the Tall and the Dwarf. In the Tall, wide variations occur within the same type due to cross pollination. For instance, in the West Coast Tall (WCT), the popular cultivar of Kerala, green and brown types occur. There are three colour types in the Dwarfs, orange, yellow and green. Variation within a type in the Dwarfs is practically absent since they are, in general, self pollinated. A key for the identification of varieties was developed at the Coconut Research Station, Nileshwar as early as in 1939 (Fig 1).

Morphological studies

The morphological studies conducted at the Coconut Research Station Nileshwar in the early 1930s indicated that the rate of growth of the stem and the leaves varied with the varieties and management practices. A correlation study on length of leaf and yield of nut revealed that the high yielding palms had significantly more number of leaves than the low yielding ones and that the longer the leaf, the higher was the yield. The adult palms of WCT generally possessed 30 to 40 fully opened leaves. Under favourable conditions, the leaves of good yielders had a life span of 36 to 42 months. The life span of leaves was shorter in the poor yielders as compared to those of the medium and heavy bearers. The leaves opened at shorter intervals during the North East monsoon (September–November) compared to South West monsoon (June–August) and summer (March-May) months. The correlation between the mean period of the opening of successive leaves and nut yield was found to be nonlinear. This relationship suggested that the rate of production of leaves alone could not be indicatory of the bearing capacity of the palm. On an average, a West Coast Tall palm produced 10.8 leaves in a year at an interval of 34.7 days. These studies also established the direct relationship between the number of fully opened leaves and the number of roots.

Floral biology

The studies conducted simultaneously at Nileshwar and Pilicode revealed that the varieties differed significantly in their flowering behaviour. Normally, the Dwarf types came to flowering in 36 to 42 months and the Tall in 7 to 8 years. However, it was also observed, that the Tall types under ideal conditions, flowered in 5 years.

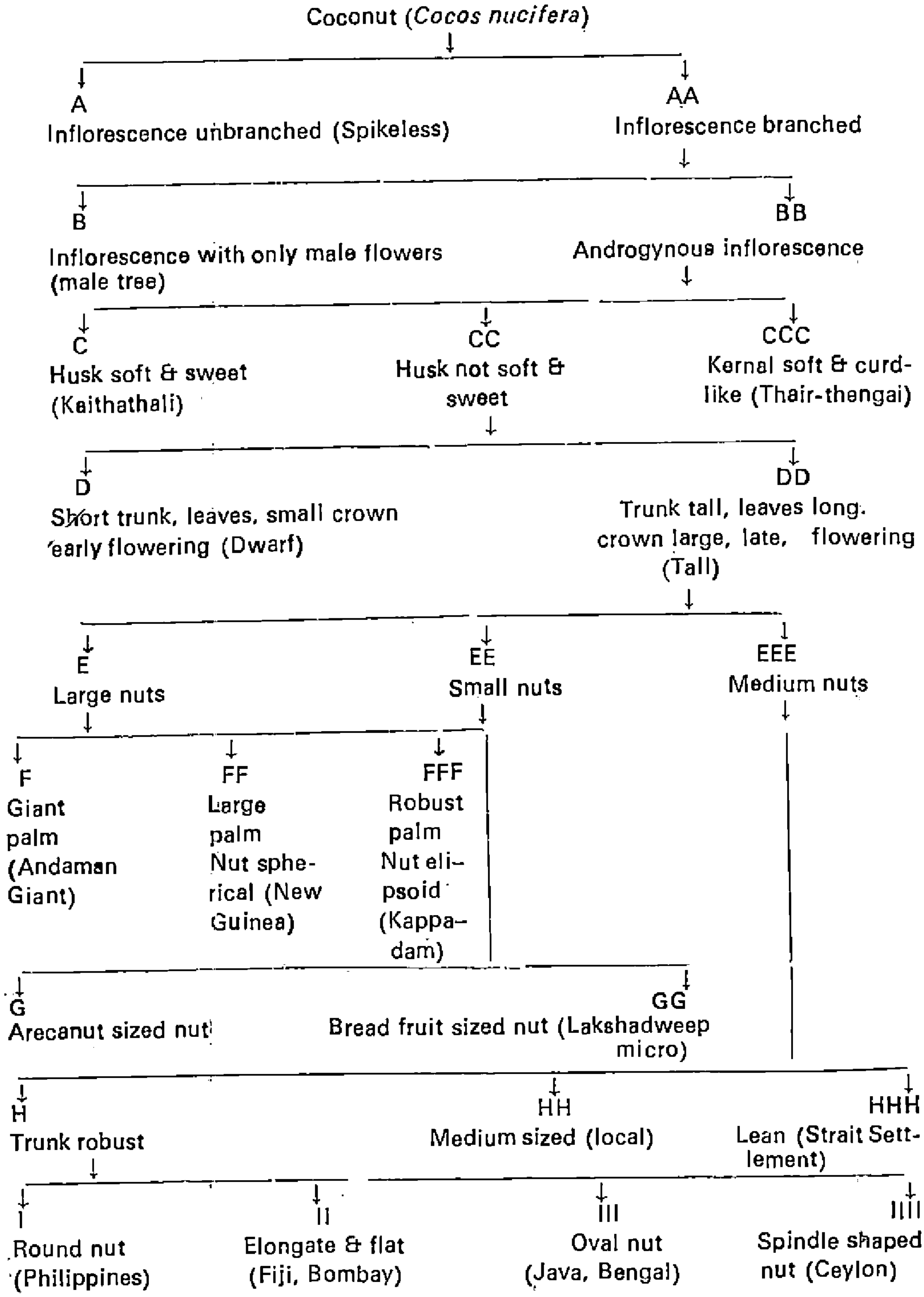

Fig.1 Key for identification of coconut varieties

The coconut palm has the inherent ability to produce one inflorescence in every leaf axil. When every leaf produces an inflorescence in its axil, the palm is considered to be a regular bearer. This phenomenon is hampered in the irregular bearers. As early as in 1930, the scientists at Pilicode observed that only 34 percent of the West Coast Tall palms had the inherent ability to produce inflorescence in every leaf axil. The test palms, produced, on an average, 7 inflorescences per annum. These observations, although may appear as elementary in the present day, however, brought to light the irregular bearing tendency of the West Coast Tall palms.

The seasonal variations in inflorescence production in West Coast Tall palms was also a subject of study in the earlier experiments at Pilicode. It was found that the percentage emergence of inflorescence was the highest (16.9) in the month of March and the lowest (3.0) in the month of December (Table 2.1). The intervals between the emergence of successive inflorescences were relatively longer in January and February (55.9 and 54.3 days, respectively) and shorter in April (21.5 days) and May (24.3 days). The rate of production of female flowers was higher during the summer months of March, April and May as compared to the other months. The lowest rate (1.2%) was found in the month of December. The male flowers were observed to outnumber the female flowers invariably in all the test varieties. The number of female flowers varied with the inflorescence and the palms in a given type. The studies conducted at Pilicode indicated that the production of female flowers could be increased by 6.5 per cent in good yielders, 19.9 per cent in medium bearers and 33.3 per cent in poor bearers. It was also found that the female flower became receptive 19·8 days after the opening of the spathe. The last male flower was shed 17.9 days after the opening of the inflorescence. The opening of the first female flower took place 3.2 days after the shedding of the last male flower. This mitigated the chances of self-pollination in the Tall types. Further these studies indicated that abortion of inflorescences was highly influenced by the season (Table 2.1) and relatively more abortions took place in the months of August (24.0%) and September (27.%).

Pollination

In an investigation conducted at Pilicode to estimate the extent of self pollination in coconut cv. West Coast Tall under natural conditions, twenty five inflorescences were bagged to prevent cross pollination and the nut development monitored. It was found that nuts developed in four inflorescences at an average rate of six per inflorescence in spite of bagging. When all the male flowers were removed before the female flowers became receptive, one nut each developed in two inflorescences, but they were barren. It was concluded from this study that self pollination was a rare phenomenon in the Tall varieties of coconut.

Further studies on pollination revealed that wind as well as insects acted as pollinating agents. The major insects involved were, bees, flies and ants. The ants played a prominent role in the transporting of pollen from one inflorescence to another in the same palm when the emergence of inflorencences overlapped. It

Table 2.1. Emergence of inflorescence and production of female flowers in West Coast Tall palms (mean of 1934 and 1935)

Month	Emergence of inflorescence in a year (%)	Interval between the emergence of successive inflorescences (days)	Female flower production in a year (%)	Abortion of inflorescence (%)
January	4.6	55.9	3.8	0.7
February	10.0	54.3	10.3	0.7
March	16.9	28.9	16 1	3.0
April	13.1	21.5	14.9	3.0
May	11.7	24.3	16.8	5 3
June	6.5	27.9	9.2	8.3
July	6.6	37.7	7.6	14.2
August	8.2	48.4	6.7	24.1
September	7.2	38.3	6.0	27.0
October	5 8	32.9	4.5	11.3
November	6.1	34.6	3.3	3.8
December	3 0	41 3	1.2	1.5

was found that the ants, on an average, carried 40 pollen grains at a time. The production of a large quantity of pollen, distinct exposure of anthers and stigma to the wind designed to scatter pollen rapidly, complete separation of sex with staminate and pistillate flowers in the same inflorescence and an interphase between the male and female phases in the same inflorescence were identified as the factors facilitating cross pollination in coconut.

In order to see whether setting percentage and nut yield could be increased by artificial pollination, the alternate inflorescences of twenty two West Coast Tall palms were hand pollinated leaving the rest to natural pollination. The study was conducted at Pilicode. It was found that neither the setting percentage nor the nut yield was affected by artificial pollination. Similar results were also obtained when artificial pollination was attempted on West Coast Tall palms which had consistently produced a large number of barren nuts every year. From this investigation, it was concluded that the production of barren nuts was not due to lack of fertilization but owing to genetic and environmental factors.

The observations on the fertilization of female flowers (buttons) in West Coast Tall palms indicated that a large number of buttons failed to develop into nuts due to lack of fertilization. As a result of this, many of the buttons were finally shed by the palms. Lack of pollination and fertilization, defects in the flower, physiological disorders, genetic nature of the variety, pest and diseases and unfavourable environmental conditions were identified as the factors responsible for button shedding in coconut. The cultivars differed in the extent of button shedding, the range in variation being 49 to 94.4 per cent (Table 2.2). The extent of shedding was as high as 95.7 per cent in the cultivar Fiji. Button shedding also was seen to vary within a year which indicated that season had a profound influence.

The subsequent studies on button shedding at Pilicode led to the following conclusions:

1. Button shedding occured in all the varieties of coconut
2. The shedding of buttons seldom took place before they had attained stigmatic receptivity.
3. The majority of the shed buttons were the non-fertilized ones
4. Most of the buttons were shed within a period of two months after the opening of the inflorescence
5. Invariably, there was no button shedding two months after the opening of the inflorescence.

Table 2.2. Button shedding in coconut : Varietal variations (per cent)

Variety	1943	1944	Mean
Andaman Dwarf	87.69	65.17	76.43
Andaman Giant	86.65	80.80	83.72
Andaman Ordinary	94.17	76.74	85.46
Bengai	91.59	68.20	79.90
Ceylon	76.88	61.10	68.90
Cochin China	97.86	75.15	86.50
Fiji	97.07	94.43	95.75
Java	84.47	49.16	66.82
Lakshadweep Ordinary	81.02	76.48	78.75
Lakshadweep Small	65.98	75.93	70.95
New Guinea	94.87	85.65	90.26
Philippines	89.32	60.69	75.00
Siam	85.67	82.26	83.97
Straight Settlement	90.38	66.42	78.40
West Coast Tall	79.20	73.72	76.46

Nut characters

The coconut cultivars are usually identified based on the colour, shape and size of nuts, and the stature of the palms. The colour varied from dark green to orange red in the cultivars maintained at Pilicode. San Ramon had the biggest nuts among the cultivars and Lakshadweep Micro, the smallest.

In order to study the influence of season on the size of nuts, one in every lot of 50 nuts of each harvest from January to December was separately husked and measurements recorded at Pilicode. The test variety was West Coast Tall. The data indicated that the nuts harvested during April/May were the biggest and those harvested during December/January, the smallest. The thickness of the kernal ranged from 11.4 cm to 12.4 cm. In another study, it was found that the nuts harvested in the month of October were the smallest in volume. The specific gravity of copra was observed to range between 0.979 and 1.145 and it varied from palm to palm.

In copra recovery, the nuts harvested in the hot summer (March-April) were superior to those of the other months. They yielded more copra per nut. The copra weight tended to increase from February onwards, reached a peak during March/April and began to fall from May. During the next 7 months the weight of copra remained more of less stationery. The nuts harvested in the cold winter months of December and January yielded more oil.

Production of planting material

Coconut being a perennial crop with its economic life span lasting for 60 years or more, it is important that only genetically superior seedlings are planted in the field. The agronomic traits of coconut seedlings leading to high yield have been identified at Nileshwar and Pilicode based on a series of investigations conducted as early as in the 1930s. The seed nuts collected from consistantly high yielding mother palms were found to be equally productive. The nuts gathered from the palms of varying age groups were compared and they were observed to behave similarly in total germination. Nevertheless, the middle-aged palms should be preferred as mother palms so as to make sure their yielding ability. The palms with spherical or semi-spherical crowns having 30 to 40 fully opened leaves and 12 to 15 bunches were found to be ideal for seed nut collection. It was also observed that the progenies of high setting mother palms were superior to the others in respect of early germination of nut.

A study was conducted at the College of Agriculture, Vellayani in the year 1982 to identify prepotent mother palms through seedling progeny analysis among the two important varieties of coconut in the state of Kerala viz., West Coast Tall and Komadan. Forty Komadan mother palms available at Vellayani and fifty West Coast Tall palms of identical age group and yield range available at the Coconut Research Station, Balaramapuram formed the material for the study. The results indicated conclusively that Komadan mother palms were significantly superior to the West Coast Tall in respect of all the characters studied (Table 2.3).

Table 2.3. Agronomic traits and yield potential of Komadan and West Coast Tall types of coconut

Trait	WCT	Komadan	Value
Girth of stem (cm)	77.10	75.00	6.05
Number of fronds per palm	28.58	32.00	11.25
Number of inflorescences per palm	13.58	17.00	3.85
Number of female flowers per bunch	25.06	30.00	2.41
Setting percentage	32.12	39.50	19.47
Nut yield per palm per annum	83.10	126 00	81.87
Difference in nut yield between the peak and lean harvests	22.58	23.00	1.08

In another study at the College of Agriculture, Vellayani in 1982, ten super palms (WCT) were evaluated for their pre-potency to produce quality seedlings. The 'super palms' were selected from five different locations (T_1 to T_{10}) in the Trivandrum and Quiion districts of Kerala state. Five groups of control palms (T_{11} to T_{15}) each consisting of five trees representing a location from where a super palm was selected formed the control. The data on biometric observations showed that the super palms were really superior to the control palms in number of bunches per palm and number of nuts per bunch but the weight of husked nut and weight of meat showed an erratic trend (Table 2.4).

Table 2.4. Evaluation of super palms of cv. West Coast Tall for their yield attributes

Super palm Tree-No.	Leaves per bunch	Inflore-scence per palm	Bunches per palm	Nuts per bunch	Weight of husked nut (g)	Weight of meat (g)
T_1	26.0	2.0	18.0	22.0	476	261
T_2	38.0	3.0	20.0	28.0	258	155
T_3	32.0	3.0	13.0	27.0	392	222
T_4	52.0	3.0	22.0	26.0	777	551
T_5	38.0	2.0	15.0	48.0	147	86
T_6	33.0	3.0	17.0	25.0	384	248
T_7	28.0	3 0	16.0	38.0	153	82
T_8	67.0	7.0	19.0	26.0	295	155
T_9	38.0	3.0	17.0	27.0	262	155
T_{10}	63.0	7.0	21.0	25.7	421	269
Control palm (mean of 5 palms)						
T_{11}	33.2	2.8	15.6	10.0	392	203
T_{12}	29.4	2.8	12.8	10.6	243	123
T_{13}	19.5	2.7	16.5	8.7	310	177
T_{14}	40.0	3.8	14.2	16.2	412	177
T_{15}	30.1	3.0	11.2	10.2	415	251

Collection of seed nut

When the nuts attain full maturity, the bunches are harvested by cutting the stalk-end with a sharp knife by which process the bunches fall on the ground. There existed a belief in the early 1930s that dropping of nuts led to delayed germination due to disturbance of the embryo. A study was, therefore, conducted at Nileshwar on the differential behaviour of 'dropped' and 'lowered' nuts in germination. In the former practice, the seed nuts were harvested as usual and allowed to fall on the loamy soil, but in the latter, the bunches were lowered from the crown of the palm (about 27 m height) by means of a rope. Each treatment had a population of 100 nuts of the variety West Coast Tall. The nursery was raised and the germination count recorded periodically. The results revealed that the nuts in both the groups ('dropped' and 'lowered') behaved similarly in respect of early and total germination.

In another experiment conducted at Nileshwar, it was found that germination as well as vigour of seedlings depended to a great extent on the quantity and quality of the kernal (meat) in the nut which in turn depended on maturity. The maximum development of the kernal took place when the nut attained full maturity. This was studied by sowing 13, 12 and 11-month-old seed nuts of the variety West Coast Tall in the nursery and recording their germination periodically. The data of germination showed that 12-month-old seed nuts were relatively more superior to the other age groups in total germination although the differences among these three groups did not touch the level of statistical significance. The seed nuts of both 11 and 12-month-age groups therefore, were considered suitable fer nursery purposes.

Table 2.5. Effect of age of seed nut at harvest on germination

Age of nut (month)	Germination (%)
13	82.60
12	91.60
11	90.60
F (0.05)	N S

The influence of time of harvest on the germination of seed nut was the objective of another study. Two hundred seed nuts of the variety West Coast Tall harvested every month (January-December) from the same fifty palms were sown in the nursery a month after harvest and the germination recorded periodically. The results revealed that the best time for the collection of seed nuts was February to May which coincided with the summer season in Kerala state (Table 2.6). The seed nuts harvested in the rainy months of June, July, August, September and October were found to be quite unsuitable for nursery purposes. The nuts harvested in the months of November and December, although recorded good germination, were rated as unsuitable as they were invariably smaller in size.

Table 2.6 Effect of time of harvest on seed nut germination

Month of harvest	Germination (%	Month of harvest	Germination (%)	Month of harvest	Germintion (%)
January	83.3	May	92.9	September	71.9
February	92.7	June	61.4	October	81.6
March	91.0	July	74.4	November	88.5
April	100.0	August	55.3	December	96.5
		C D (0.05)	18.6		

In another investigation, it was observed that seed nuts which were "too small" or "too big" in volume failed to germinate or germinated very late. Similarly the percentage of ungerminated nuts was found to be higher in 'light bunches' than in the 'medium' or 'heavy bunches'. The nuts from the heavy bunches germinated earlier. The seed nuts with thin husk (1.4 cm–2.1 cm) gave a higher percentage of germination as compared to those having very thin (less than 1.4 cm) and very thick (more than 2.1 cm) husk. In a study on the influence of shape of seed nut on germination, it was observed that spherical nuts germinated earlier. These nuts had more uniform distribution of fibrous tissues in the husk and a higher kernal content.

A germination study conducted with the nuts collected from top, bottom and middle portions of the bunch revealed that the nuts from the middle and bottom portions germinated earlier than those from the top and top most positions. However' in total germination, the nuts from middle, bottom, top most and bottom most positions of the bunch were statistically on a par (Table 2.7)

It was concluded from the study that nuts from the middle and bottom positions of the bunch should be preferred for seed purposes as there existed a positive correlation between early germination and seedling vigour

Table 2.7. Effect of position of nut in a bunch on germination (variety: West Coast Tall)

Nut position in the bunch	Nut weight (g)	Germination percentage			Total
		Early (below 127 days)	Medium (128–152 days)	Late (above 152 days)	
Top	695	—	40	30	70
Middle	766	16	67	17	100
Bottom	806	23	69	—	92
Top most	715	—	33	67	100
Bottom most	843	—	100	—	100

Another investigation indicated that heavy seed nuts (variety: West Coast Tall) with good copra content floated vertically with stalk-end up when put in water (Table 2.8). The seedlings from such nuts were more vigorous than those raised from obliquely or horizontally floating nuts.

Usually, the seed nuts are sown in the nursery before the nut water dries up. In order to elucidate more information on this aspect, an experiment was conducted at Nileshwar using seed nuts of the variety West Coast Tall, having

Table 2.8. Influence of kernal weight on the floating habit of nut in water

Position of nut when floated in water	Kernal (copra) weight (g)	Z test
Vertical	181.8	
Oblique	173.0	Sig.
Horizontal	139.7	

varying amounts of water, namely, "good amount of water". "small amount of water" and "no water". The seed nuts were sown under identical conditions and germination recorded periodically. Each treatment had a population of twenty five nuts. The data indicated that, the nuts with good amount of water 'and' small amount of water gave significantly higher percentages of germination (97.2% and 95.6%, respectively) over those without water (85.2%). These results indicated the need for preservation of seed nuts without dessication till they were sown in the nursery. Therefore, a study was conducted at Nileshwar during 1938. One hundred seed nuts of the variety West Coast Tall harvested in the month of February 1938 were burried in sand under shade and another lot of hundred nuts kept in the open. The physical condition of the nuts and their weight were monitored periodically The results showed that (Table 2.9) the nuts left in the open became unfit for sowing by the end of the nineth month due to complete dessication of nut water. The study also indicated that seednuts could be preserved in sand without loss in viability up to 9 months from harvest.

Table 2.9 Loss in weight of seed nuts as influenced by the method of preservation

Date of observation (1938)	Method of preservation					
	Burried in sand			Left in the open (control)		
	Nut weight (kg)	Loss in weight (%)	No. of dry nuts	Nut weight (kg)	Loss in weight (%)	No. of dry nuts
March 26	1.11	—		1.13	—	—
April 26	0.96	13.8	1	0.82	28.0	5
May 26	0.92	17.9		0.77	31.6	5
June 26	0:92	17.9		0.96	32.8	17
August 26	0.77	30.5	1	0.76	32.8	38
December 9	0.82	26.4	9	0.63	44 0	100

A few correlation studies were also conducted at Nileshwar on the agronomic traits of the mother palms and the germination percentage of seed nuts. The results are summerised in Table 2.10.

Table 2.10. Correlation between the agronomic traits of mother palms and percentage germination of seed nuts

Correlation between	Correlation coefficient	Probable error	Significance
1. Setting percentage and germination	—0.632	±0.0390	Sig.
2. Nut yield of parents and germination	+0 0730	—	N. S.
3. Copra content per nut and germination	+0.3488	±0.0577	Sig·
4. Oil content of kernal and germination	—0.0982	—	N. S.
5. Kernal content of nut and volume of nut water	+0.7253	—	Sig.

Sig. Significance N. S. Not significant

Nursery technique

Raising seedlings in the nursery facilitates selection of quality seedlings for planting in the field. A number of studies have been conducted at Nileshwar and Pilicode on nursery techniques and selection criteria for seedlings.

Positioning of seednut in the seed bed

The nuts are sown in the nursery beds either vertically with the stalk-end up or horizontally. Vertical planting is the rule in Kerala at present. In order to find out the influence of positioning of the nuts in the seed bed, vertical or horizontal, an experiment was conducted at Nileshwar adopting the paired plot technique with two treatments, namely, A, horizontal position and B, vertical position. The dates of germination of individual nuts were recorded and the data pertaining to percentage of germination under the two methods analysed statistically. The results revealed no significant difference between the two treatments, the percentages of germination being 95.0 and 94.7, respectively for the horizontal and vertical sowings. In most of the coconut producing countries in the world, horizontal positioning is practised in the seed bed. However, in Kerala, vertical planting is preferred in view of the economy of space and greater convenience in transportation of seedlings.

A series of changes take place in the nut as its embryo germinates and develops into a seedling. The studies on these aspects led to the following conclusions:

1) The nut water disappeared in the sixth month after sowing
2) The seednut started to germinate 12 weeks after sowing under normal conditions. The maximum percentage of germination was attained between 17 and 18 weeks after sowing. No germination occurred 23 weeks after sowing
3) The first leaf appeared in the second month after germination
4) The production of root commenced in the first month after sowing
5) The increase in girth at collar and the height of seedling was gradual
6) There was a gradual fall in the thickness of the kernal as the seedling developed
7) The apple filled the whole cavity of the nut in the fifth month, losts its sweetness thereafter and became papery as the seedling developed. These studies also indicated that the cultivars differed significantly in the time taken for germination (Table 2.11).

It was generally believed that the late-germinated seedlings were inferior to the early-germinated ones in growth performance. In order to throw more light on this assumption, the growth habit of early and late germinated seedlings (variety: West Coast Tall) were compared at Nileshwar. Each treatment consisted of fifteen nine-month-old seedlings. The results indicated that the early-germinated seedlings were significantly superior to the late-germinated ones in respect of plant height and and girth at collar (Table 2.12). There was no marked variation between these two groups in leaf production. It was also found that the mortality of seedlings was high among the late-germinated seedlings.

Table 2.11. Varietal variation in the time taken for germination

Cultivar/type	Nut size	Duration of germination (days)	Germination percentage
Andaman Giant	Large	94.1	100.0
Andaman Ordinary	Large	135.0	61.4
Ceylon	Large	115.5	86.1
Cochin China	Large	102 0	67.7
Fiji	Small	106 0	78.7
Java	Large	109.9	73.5
Lakshadweep Small	Small	161 8	69.4
New Guinea	Large	84.5	64.8
Philippines	Large	97.4	64.0
Siam	Large	171.0	100 0
Straight Settlement	Small	66.7	74.2
West Coast Tall (WCT)	Large	134 0	75.0
Mean	—	112.9	77.3
S D	—	30.9	13.1

Table 2.12. Growth performance of early and late-germinated seedlings

Germination (early or late)	Plant height (cm)	Girth at collar (cm)	Leaf production (no./seedling)
Early	82.00	12.09	6.00
Late	54.10	9 78	5.30
F (0.05)	Sig.	Sig.	N. S.
S E	6.1	0.51	0.3

Sig: Significant NS: Not significant

The nursery studies conducted at Nileswar during 1932-33 showed that the girth at collar and early splitting of leaf were the most important traits of a quality seedling. A significant negative correlation was also established between the time taken for germination and leaf production. The seedlings with early leaf splitting habit had longer leaf blades. These studies also showed significant positive correlations between (1) the height of seedling and the total length of roots; (2) the girth of seedling and the weight of roots; (3) the weight of roots and the length of roots and (4) the early splitting of leaves and the number of roots. No correlation, however, could be observed between the number of roots and the surface area of the nuts. The seedlings characterised by yellowish brown or light brown colour, narrow leaves and stunted growth were found to be inferior and unfit for planting.

The nursery studies with the F_1 progenies of T x D hybrids conducted at the College of Horticulture, Vellanikkara during 1979-80 produced almost similar results indicating that the selection criteria fixed for West Coast Tall seedlings earlier could be utilised for the selection of seedlings of the Tall x Dwarf progenies also. The important conclusions from these studies were:

1) The polar circumference, equitorial circumference, weight and volume of seed nuts were positively correlated with the girth of seedlings at collar (Table 2.13)
2) The girth of seedling had significant relation with height and the total number of leaves produced
3) The early germinated nuts produced seedlings having more collar girth and vigour
4) The number of days taken for germination and girth at collar were negatively correlated

Table 2.13. Correlation between nut characters and morphological traits of seedlings of Tall x Dwarf progenies (r values)

Nut character	Seedling character		
	Girth	Height	Leaf number
Polar circumference	0.393*	0.100	0.116
Equitorial circumference	0.472*	0.302	0.044
Weight	0.436*	0.210	0.081
Volume	0.533*	0.297	0.046
Days taken for germination	0.429	0.276	0.261

*Sig. at 5% level

An experiment was conducted at Nileswar during 1985-86 to study the effect of partial removal of husk from the stalk-end portion of nut prior to sowing on germination end seedling vigour. The seed nuts were sown in conventional seed beds as well as in poly bags filled with soil and the germination monitored periodically.

The results revealed that partial removal of husk hastened the process of germination, and increased the girth at collar (Table 2.14). The polybag seedlings were superior to the seedlings raised in conventional seed beds in respect of early germination, girth at collar, plant height and leaf production.

BREEDING

Introduction

The introduction of coconut types for yield evaluation was started as early as in 1923 at Pilicode with the ultimate objective of identifying elite types with high yield. The collection of types was restricted to the erst-while Madras Presidency in the beginning probably due to administrative reasons. None of the

Table 2.14. Effect of partial removal of husk from the stalk-end of the seed nuts on germination and seedling characters

Treatment	Germination percentage 3 months after sowing	Germination percentage 5 months after sowing	Girth of seedling (cm)	Leaves per seedling (No.)	Plant height (cm)
Sowing in conventional nursery without husk removal	28.0	84.0	11.1	5.8	102.3
Sowing in conventional nursery after removing the husk partially	54.0	88.0	12.3	6.1	90.2
Sowing in polybags without husk removal	30.0	82.0	11.8	6.5	111.0
Sowing in polybags after removing the husk partially	66.0	98.0	13 2	6.3	98.7
C D (0.05)	5.1	—	1.0	0.5	13.0

types available in the central and southern parts of the present Kerala state were, therefore, included in the collection of types. The first collection comprised:

1) Kasaragod (from red loam soil)
2) Kasaragod (irregularly bearing palms from red loam soil)
3) Kasaragod (regularly bearing palms from red loam soil)
4) Badagara (from heavy back water soil)
5) Tikkodi (from coastal sandy soil)
6) Pollachi
7) Kumarapalayan
8) Tanjore
9) Chingelpet—Edakarad
10) Gudiatham (North Arcot)
11) Malrosapuram
12) Omalur
13) Kulithalai—Tiruchirappally
14) Godavary—Kodiripady
15) Indupali
16) Godavary (from black loam soil)

In the same year, seed nuts from the following places were obtained and sown in the nursery at Nileswar:

1. Bengal—Barissal
2. Strait Settlement
3. Laccadives—Apricot, Green and Ivory
4. Port Blair
5. Fiji Islands
6. Ceylon
7. Dwarf types from Malabar and Chowghat

During the year 1924-25, 122 seedlings of Fiji, Strait Settlement, Lakshadweeps, Andamans and Bengal-Barissal were planted at Pilicode. The introduction continued during the years 1925-26, 1926-27, 1938-39, 1953-54, 1975-76 and 1984-85. As a result, the Regional Agricultural Research Station' Pilicode has now a unique collection of coconut germplasm of 31 exotic and 36 indigenous types as detailed below.

Exotic cultivars

1. Borneo
2. British Solomon Island
3. Cochin China
4. Ceylon
5. Fiji
6. Gon Thembili
7. Guam
8. Java
9. Jamaica
10. Kalpawangi
11. Karkar Tall
12. Kenya
13. Kudat
14. Lifaou Tall
15. Malayan Dwarf Yellow
16. Malayan Dwarf Green
17. Malayan Dwarf Orange
18. Markar Tall
19. Navasi
20. New Guinea
21. Philippines Lono
22. Philippines Kalibahim
23. Philippines Laguna
24. Philippines Ordinary
25. San Ramon
26. Seychelles
27. Siam
28. Strait Settlement Apricot
29. Strait Settlement Green
30. St. Vincent
31. Thembili

Indigenous types

1. Andaman Dwarf
2. Andaman Giant
3. Andaman Ordinary
4. Ayiramkachi
5. Baboor
6. Bansa hybrid
7. Basanda
8. Bengal
9. Bombay
10. Chingalpet
11. Chowghat Dwarf Green
12. Chowghat Dwarf Orange
13. Chowghat Dwarf Yellow
14. Gangabondam
15. Godavery
16. Gudiathum
17. Indupali
18. Kaithathali
19. Kappadam
20. Kodiripadu
21. Kulithali
22. Lakshadweep Dwarf
23. Lakshadweep Micro
24. Lakshadweep Ordinary
25. Lakshadweep Small
26. Malrosapuram
27. Mysore
28. Omalur
29. Pollachi
30. Rangoon Kobbary
31. Selam
32. Spicata
33. Tanjore
34. Thiruthirapundy
35. Verry Kobbari
36. West Coast Tall

Earlier studies on the performance of the introduced types revealed that Lakshadweep Ordinary, Lakshadweep Small, Andaman Ordinary, Philippines and Cochin China were promising. Among the exotic varieties, Cochin China and Philippines were outstanding in quality for their tender nuts.

Out of the sixty seven cultivars maintained at Pilicode fifty one have reached the steady bearing stage and they have been studied in detail for the number of nuts, mean copra content and copra out turn (Table 2.15).

Table 2.15. Yield performance of cultivars in the germplasm collection at Pilicode

Sl. No.	Cultivar	No. of nuts per palm	Copra content per palm (g)	Copra out-turn per palm per year (kg)
(1)	(2)	(3)	(4)	(5)
1.	Andaman Dwarf	30.71	176.11	5.41
2.	Andaman Giant	71.67	189.26	14.89
3.	Andaman Ordinary	69.17	186.50	12.90
4.	Baboor	71.92	199.00	14.31
5.	Bensa Hybrid	84.57	191.00	16.15
6.	Basanda	100.71	172.94	17.42
7.	Bengal	59.79	261.00	15.61
8.	Bombay	69.58	236.00	16.42
9.	Ceylon	66.08	186.67	12.34
10.	Chingalpet	46.17	135.83	6.27
11.	Chowghat Dwarf Green	40.67	125.00	5.08
12.	Chowghat Dwarf Orange	47.53	163.00	7.75
13.	Chowghat Dwarf Yellow	64.33	165.00	10.61
14.	Cochin China	67.29	234.98	15.81
15.	Fiji	59.21	201.25	11.92
16.	Gangabondam	60.40	189.50	11.45
17.	Godavery	69.71	151.25	10.54
18.	Gon Thembili	70.28	161.50	11.35
19.	Gudiathum	72.60	173.16	12.57
20.	Indupali	52.29	207.00	10.82
21.	Jamaica	65.28	229.50	14.98
22.	Java	66.08	236.26	15.61
23.	Kappadam	48.17	233.13	11.23
24.	Kodiripadu	63.54	165.00	10.48
25.	Kulithalai	71.29	212.11	15.12
26.	Lakshadweep Dwarf	46.28	130.00	6.02
27.	Lakshadweep Ordinary	93.13	193.70	18.04
28.	Lakshadweep Small	115.42	108.50	12.52
29.	Malayan Dwarf Green	57.67	126.00	7.27

(1)	(2)	(3)	(4)	(5)
30.	Malayan Dwarf Orange	50.67	152.50	7.73
31.	Malayan Dwarf Yellow	68.67	130.00	8.93
32.	Malrosapuram	48.33	169.77	8.20
33.	Mysore	55.46	187.78	10.41
34.	Navasi	63.67	239.50	15.25
35.	New Guinea	75.21	247.25	18.60
36.	Omullur	59.66	225.00	13.42
37.	Philippines Kalibahim	77.00	218.00	16.79
38.	Philippines Laguna	74.00	216.50	16.02
39.	Philippines Ordinary	79.33	236.50	18.76
40.	Pollachi	52.17	160.75	8.39
41.	San Ramon	51.29	346.00	17.75
42.	Selam	54.67	185.50	10.14
43.	Seychelles	36.33	163.67	5.94
44.	Siam	78 83	189.00	14.90
45.	Spicata	116.17	175.00	20.33
46.	S. S. Apricot	26.04	167.50	4.36
47.	S. S. Green	62.71	184.75	11.59
48.	Tanjore	49.17	155.75	7.66
49.	Thembili	65.37	182.86	11.96
50.	Thiruthirapundy	50.08	112.33	5.63
51.	West Coast Tall	67.53	180.00	12.16

The cultivars with an annual yield of 70 nut and above included Baboor (71.9), Basanda (100.7), Bansa hybrid (71.9), Andaman giant (78.7), Goan Thembili (70.3), Gudiatham (72.6), Kulithalai (71.3), Lakshadweep Ordinary (93.1) Lakshadweep Small (115.4), New Guinea (75.2), Philippines Kalibahim (77.0), Philippines Laguna (74.0), Philippines Ordinary (79.3), Siam (78.8) and Spicata (116.2). The popular cultivar, West Coast Tall yielded 67.5 nuts per palm. However, in copra out turn per palm per year Spicata topped the list with an yield of 20.3 kg. The cultivars Philippines Ordinary (18.76 kg), New Guinea (18.60kg) and Lakshadweep Ordinary (18.04kg), ranked the second, third and fourth positions, respectively. Against this, the West Coast Tall registered a copra out turn of 12.16 kg per palm only.

Fifteen types of coconut in the germplasm] collection were also evaluated for their toddy yield (Table 2.16). Two palms from each type were tapped continuously for 6 months and yield of sweet toddy recorded daily. The best yielder was Lakshadweep Ordinary recording 1.66 litres per day.

The next best best type was Andaman Ordinary with a toddy yield of 1.51 litres per day. The popular variety West Coast Tall yielded only 0.65 litre per day. Siam and Spicata did not yield any toddy at all.

Table 2.16. Evaluation of coconut types for toddy yield

Type	No. of days yielding toddy (out of 180 days)	Toddy yield (litre per palm per year)	Yield per palm per litre/day	Mean yield per spadix litre/year
Andaman Dwarf	11	3.4	0.321	3.49
Andaman Ordinary	164	247.4	1.510	33.74
Andaman Giant	3	0.1	0.042	0.12
Bengal	7	0.9	0.134	0.94
Bombay	10	1.5	0.155	1.50
Cochin China	166	138.0	0.831	17.25
Fiji	129	63.6	0.493	9.09
Java	121	61.0	0.502	12.20
Lakshadweep Dwarf	10	0.6	0.06	0.63
Lakshadweep Ordinary	138	224.7	1.66	40.85
Lakshadweep Small	112	78.0	0.70	19.50
New Guinea	89	54.6	0.61	12.12
Philippines	85	61.5	0.72	12.31
Straight Settlement	163	75.7	0.49	9.09
West Coast Tall	133	87.0	0.65	19.33

Hybridization and selection

Selfing and crossing in coconut

In the dwarf varieties, self pollination occurs due to the overlapping of the male and female phases in the same inflorescence. However, self pollination is not uncommon in the Tall varieties in certain seasons, especially when the production of inflorescences overlaps. At Kasaragod, eight high yielders and three poor yielders were selected for selfing in 1923-24 with a view to study the inheritance behaviour. For artificial selfing, the pollen was collected from the same inflorescence or from the next one according to availability. Selfing was done in eight high yielders and three poor yielders. A total of 958 flowers were pollinated out of which 196 developed into nuts. Crossing was also done between palms having green round nuts and those having red round nuts. The palms with green round nuts were crossed with those having green long nuts. Trees with long flower stalks were crossed with those having short flower stalk and vice versa. Besides these, one was artificially selfed. Thus, a beginning was made in selfing and crossing of coconut with the ultimate objective of evolving high yielding varieties.

The studies on the performance of the progenies of natural, selfs and crosses were continued in the subsequent years. The observations made on the number of leaves and height of the progenies indicated that out of the twenty nine comparisons in six instances, crosses were superior to naturals while in two instances crosses were superior to selfs and in ten cases naturals were better than the selfs. Selfs, thus appeared to be poorer than crosses and naturals.

Controlled cross pollination between thick meated and thin meated parents to assess the influence of male parent on the endosperm of the nut of the female parent was done at Nileshwar. The trial was conducted with thick meated and thin meated parents. Two thick meated parents (female) were cross pollinated with thin meated male parent and vice versa. The selfed bunches of the respective parent trees served as control. The nuts were converted into copra and the weight of copra of individual nuts recorded (Table 2.17).

Table 2.17. Thickness of meat and weight of copra of different cross combinations

Treatment	Thickness of meat (mm)	Weight of copra/nut (g)
Thick meat (Self)	13.97	186 88
Thick meat x Thin meat	13.10	187.23
Thin meat (Self)	11.68	154.94
Thin meat x Thick meat	12.06	167 44

There was a general indication that the thickness of meat tended to increase when a thick meated male was used for hybridization.

The exploitation of hybrid vigour by crossing distantly related parents was thought of during the early 1930s. The main objective of this work was to spot out parental combinations that would give vigorous seedlings and better types for further multiplication and distribution.

Crossing was first attempted between high yielding ecotypes possessing desirable economic characters. Later, the work was extended to ecotypes and prominent varieties and over 2000 progenies were raised in the year 1932 for evaluation.

Hybridization

Systematic hybridization studies were taken up in the year 1932-33 under the following schemes.

Scheme 1: Very high bearers (Yielding, on an average, 100 nuts per year and above)

Five trees were selected each one to represent any of the following quantitative characters.

1) High yield of nut
2) Large number of female flowers
3) High setting percentage
4) Very thick meat
5) Big sized nuts

One bunch was selfed in all the palms. All possible combinations of crosses were made. Another group of five trees of the second best formed the duplicate.

Scheme 2: Selfing and crossing of trees having the maximum setting and trees producing very large number of female flowers.

Scheme 3: Crossing of female flowers of a few ordinary trees with the pollen from a dwarf type to see whether the age at first flowering could be reduced.

Scheme 4: Crossing between regularly bearing and irregularly bearing parents with the objective of finding out whether the high yielding nature of irregular bearers could be combined with the regular bearers.

The hybrid nuts produced as per these schemes in 1932-33 were sown in the nursery keeping all the combinations of individual mother palms side by side. The germination of nuts started 76 days after sowing and continued upto the 195th day. The progress of germination became rapid from the 15th week after sowing and continued to be so for another eight weeks. The total germination obtained was 90.38 per cent. These studies also revealed that, though good germination might be due to certain inherent characters of the mother palms the percentage germination in any particular year was likely to vary.

The hybrid seedlings raised from the crosses done at Kasaragod were planted at Nileswar. Altogether 516 seedlings were planted—280 seedlings under scheme 1, 120 under scheme 2, 76 under scheme 3 and 40 under scheme 4. Thus, the first ever planted coconut hybrid plantation came into existance at Nileshwar in the year 1936-37.

The following observations were recorded on the seedlings raised by artificial pollination from the above schemes. The rate of emergence of leaves in the hybrids involving dwarf parent either as female or as male was markedly above that of the rest. As regards height of seedlings, it was noted that the seedlings from parents which were high producers of female flowers were generally superior to the others.

The important conclusions drawn from the study are:

1) The selfed progenies were inferior to the hybrids
2) The crossed progenies of the Dwarf females and Tall males confined to a Dwarf type
3) The progenies of the Dwarf males and Tall females showed good girth measurements
4) The inclusion of dwarf element in hybridization hastened the early expression of the leaf splitting nature of the seedlings.

The progeny studies conducted on heterosis in coconut hybrids revealed interesting results. The age at first flowering, the rate of production of spadices, length of stem, girth of the stem near the crown and number of leaves on the crown were the characters studied. The materials for the studies were eight year-old natural and selfed progenies of the age group 9 to 11 years. The naturals had more vigour than the selfed ones. The rate of production of spadices and the leaves was expected to be faster in the selfed group as the trees were older. But that was not the case. It indicated that heterosis was involved and that with self fertilization, there was reduction in vigour.

Flowering in hybrids

The tall types usually came to flowering after 7 to 8 years after planting and the dwarfs after 3 to 3½ years. The F_1 progenies of the cross between the two types flowered at the age of 4½ years. The inheritance of age at first flowering thus appeared to be intermediate in character between those of the parents (Table 2.18).

Table 2.18. Performance of hybrid coconut palms (Percentage of palms flowered)

Material	4th year (1975)	5th year (1976)	6th year (1977)
Tall x Dwarf	20	50	100
Tall x Gangabondam	10	30	80
Tall x Tall	0	0	0
West Coast Tall	0	0	10

A comparative study of F_1 hybrids obtained by crossing selected high yiedling Tall palms with Dwarf green male parents revealed that these progenies possessed hybrid vigour. The early bearing habit of the dwarf parent was inherited by the hybrid. It attained the steady bearing period much earlier than the Tall type though irregular bearing was exhibited by certain trees. The lean harvests were compensated by the very high yields in the subsequent years. The annual yield of copra per palm in Tall x Dwarf hybrid was much higher than that of West Coast Tall (Table 2.19). Based on these observations the hybrid Tall x Dwarf was popularized among farmers.

A large scale programme for breeding coconut was taken up based on the consistently good performance of Tall x Dwarf progenies for over 15 years. The Tall x Dwarf palms had the economic characters of early bearing, high yield, and good quality (copra and oil).

In a study for testing the suitability of Tall x Dwarf hybrids for further propagation by selection from the natural progeny, observations on the vegetative characters were made at Pilicode in the progenies of Tall x Dwarf and the natural progenies of West Coast Tall. The results are given in Table 2.20.

The natural progenies of Tall x Dwarf were found to be significantly superior to West Coast Tall in the rate of leaf production.

The studies conducted during the year 1952–53 on copra and oil content of the nuts of the Tall x Dwarf progenies revealed that the quantity and quality of copra compared favourably with those of West Coast Tall. The observations on the intra and inter varietal crosses were continued during the subsequent years. The F_2 progenies of these crosses were also found to be quite vigorous. The crosses involving Lakshadweep Ordinary x Chowghat Dwarf and Strait Settlement x Andaman Dwarf were also found to be promising.

Table 2.19. Yield and yield attributes of Tall x Dwarf hybrids evolved at Nileshwar (mean of 35 years)

Character	Tall x Dwarf	West Coast Tall	Dwarf (Chowghat) Dwarf Green)
Plant height (cm)	618.00	621.60	360.00
Stem girth (cm)	65.90	64.60	55.00
Total number of leaves/palm	390.00	349.00	415.00
Number of functional leaves/palm	28.50	29.60	22.00
Annual leaf production/palm	13.50	12.00	13.60
Annual nut yield/palm	75.30	54.00	11.30
Mean nut weight (kg)	1.20	1.90	0.40
Mean husked nut weight (kg)	0.90	0.60	0.10
Weight of kernal (kg)	0.24	0.22	0.05
Copra out turn per nut (kg)	0.19	0.17	0.04
Oil content (%)	70.10	71.70	65.60

Table 2.20. Growth performance of West Coast Tall and natural progenies of Tall x Dwarf

Material	No. of leaves produced per year	No. of leaves on the crown
West Coast Tall	11.45	19.41
Natural progenies of Tall x Dwarf	13.87	24.70
C. D. (0.05)	1.34	2.60
S E	0.48	0.96

The studies conducted on the seedling performance of Tall x Dwarf, Tall x Gangabondom, Tall x Tall and West Coast Tall at Kumarakom revealed that Tall x Dwarf and Tall x Gangabondam performed better than Tall x Tall and West Coast Tall in respect of girth at collar, average number of leaves, mean height and age at first flowering (Table 2.21)

Performance of Tall x Dwarf hybrids

In order to study the transmission of hybrid vigour to the progeny and to find out whether it would be advisable to use natural progenies of the hybrid for further propagation, a study was conducted at Nileshwar with the following treatments:

Table 2.21. Performance of hybrid varieties of coconut palm: morphological characters

Hybrid/ Variety	Girth at collar (cm)			Number of leaves/palm			Plant height (cm)		
	1971	1972	1973	1971	1972	1973	1971	1972	1973
Tall x Dwarf	12.4	26.1	73.9	5.9	12.7	22.4	143.7	205.2	396.6
Tall x Gangabondam	12.7	25.8	77.4	5.7	12.1	21.4	145.1	190.0	371.1
Tall x Tall	13.8	22.0	47.8	6.1	11.5	18.5	120.5	149.0	287.6
West Coast Tall	13.5	28.3	69.9	5.8	12.5	20.4	142.5	196.3	382.4
F' Test	N.S.	Sig.	Sig.	N.S.	N.S.	Sig.	Sig.	Sig.	Sig.
C.D. (0.05)	—	3.4	12.3	—	—	2.2	18.4	23.9	55.0

1) Natural progenies of ordinary Tall (WCT)
2) Tall x Dwarf
3) (Tall x Dwarf) x (Tall x Dwarf) of the same parent
4) (Tall x Dwarf) x (Tall x Dwarf) of different parents
5) Tall x (Tall x Dwarf)
6) (Tall x Dwarf) x Tall

Out of the 312 experimental seedlings planted in 1961, three seedlings of the following parental combinations flowered much earlier than the others.

1) (Tall x Dwarf) x (Tall x Dwarf) of the same parent
2) (Tall x Dwarf) x (Tall x Dwarf) of different parents
3) (Tall x Dwarf) x Tall

The (Tall x Dwarf) x (Tall x Dwarf) progenies showed high precocity. The natural progenies of Tall x Dwarf and back cross of Tall x Dwarf with West Coast Tall gave high yield and good quality nuts. The same parental cross of (Tall x Dwarf) x (Tall x Dwarf) showed very poor performance in respect of yield and nut characters.

Study of Spicata x Tall and reciprocal crosses

This study was taken up with the objective of finding out how far the economic characters of both Spicata and Typica varieties, namely, the high rate of female flower production of Spicata and the high setting percentage of Tall could be combined in their progenies. The work was started in the year 1956.

The results revealed that in the case of female flower production and yield, out of thirty eight palms flowered in the cross of Tall x Spicata, twenty eight had the spikeless character. In the reciprocal cross, out the twenty five flowered, fourteen showed typica character while eleven were spikeless.

Methods of pollination and vigour of seedlings

In order to find out whether method of pollination in coconut had any influence on the performance of progenies evolved through selfing and natural and artificial crossing, observations were made on palms planted in the year 1935-36. The progenies evolved by hybridisation were found to be better than natural and selfed ones, the latter being the least vigorous (Table 2.22).

Table 2.22. Effect of method of pollination on the performance of progenies

Parent Character	Cross			Natural			Selfed		
	Nuts	Female flower	Setting (%)	Nuts	Female flower	Setting (%)	Nuts	Female flower	Setting (%)
High yield High female	1.0	8.5	11.8	1.0	3.0	33.3	—	—	—
flower production	10.0	36.7	27.3	4.5	26 5	17.0	3.0	23.0	13.0
High setting	8.3	28.6	29.0	21.0	96.0	21.9	—	—	—
Thick meat	7.8	29.8	26.2	—	—	—	—	—	—
Large sized nuts	9.1	32.5	28.0	9.0	31.0	29.0	4.0	13.0	22.2

Inbreeding depression

With the objective of finding out whether inbreeding depression existed in coconut, breeding programmes were taken up in 1924. Eighteen West Coast Tall palms in the Coconut Research Station, Kasaragode were selfed in the years 1924, 1925 and 1926 and the first generation selfed progenies were planted at Pilicode during the year 1926, 1927 and 1928.

During 1959 and 1960 selfing was done in the S_1 progenies to produce the second generation selfs. Crossing was also done between progenies of the same parent to produce sibs. These were planted in the station in the year 1961, in a split plot design in compact family blocks, allocating six groups of progenies to six main plots. Each main plot contained two rows of five seedlings each and each row was a sub plot. There were four replications. Planting was done by selecting the seedlings strictly at random. The yield performance of selfs, sibmates and grand parents is given in Table 2.23. The data indicated conspicuous inbreeding depression due to selfing. Hybrid vigour was met with when crossing was done between the progenies of the same parent. Work is in progress at Pilicode for raising the S_3 generation.

In the earlier studies, the inter varietal crosses involving Gangabondam as the male parent proved better than the other dwarfs like Chowghat Dwarf Green or Chowghat Dwarf Orange. Therefore, to acsertain the combining ability of Gangabondam with Tall female parents, concerted efforts were made in 1946-47 by crossing it with cultivars like Lakshadweep Ordinary, Lakshadweep Small, Andaman Ordinary, Cochin China, West Coast Tall and Jawa. The seedlings of all these crosses were planted at Pilicode for a comparative yield study in the year 1949 under rainfed conditions.

These studies ultimately culminated in the release of three varieties by the Kerala Agricultural University.

The yield performance of Lakshadweep Ordinary x Gangabondam (Pilicode Hybrid Coconut 1) in relation to its parents and the popular variety West Coast Tall under rainfed conditions at Pilicode (soil type : lateritic loam) is summarised in Table 2.25.

Table 2.25. Yield performance of the hybrid Lakshadweep Ordinary x Gangabondam (PHC 1) as compared to its parents and West Coast Tall

Variety	Mean nut yield palm/ year	Mean copra content per nut (g)	Copra yield/ ha/ year (kg)	Oil content %	Oil yield per ha (kg)/ year
Lakshadweep Ordinary x Gangabondam	108.3	194.5	3748.7	73.1	2740
Lakshadweep Ordinary	86.7	193.7	2988.6	68.6	2051
Gangabondam	42.4	159.5	1203.3	62.8	756
West Coast Tall	64.3	180.0	2059.5	68.2	1404

The hybrid registered an average yield of 108.0 nuts per palm per year as against 86.7 by Lakshadweep Ordinary, 42.4 by Gangabondam (b) and 64.3 by West Coast Tall. It yielded 3749 kg of copra per hectare annually as against 2989 kg by Lakshadweep Ordinary 1203 kg by Gangabondam and 2059 kg by West Coast Tall. This trend was seen in oil production also. The magnitudes of increase in copra and oil yields by PHC 1 (Lakshadweep Ordinary x Gangabondam) over Lakshadweep Ordinary were, 25.4 per cent and 33.5 per cent, respectively. The year-wise yield performance of PHC 1 and its parents over a period of twenty three years (1963—1985) is given in Table 2.26.

The hybrid Lakshadweep Ordinary x Gangabondam was evaluated at the Gentral Plantation Crops Researeh Institute, Kasaragod (soil : red sandy loam) with Chowghat Dwarf Orange x West Coast Tall, West Coast Tall x Chowghat Dwarf Orange, West Coast Tall x Gangabondam, Lakshadweep Ordinary x Chowghat Dwarf Orange and West Coast Tall over a period of eighteen years under uniform fertility conditions. In this trial, the best yielder (nuts/palm) was Chowghat Dwarf Orange x West Coast Tall which recorded an increase of 42.2 per cent over West Coast Tall. The hybrid Lakshadweep Ordinary x Gangabondam with nut yield increase of 25.8 per cent over West Coast Tall ranked second (Table 2.27).

This hybrid was also observed to be fairly tolerant to moisture stress at Kasaragod. There was an unprecedented drought during the year 1983 badly affecting yield of all the varieties/hybrids in the following year. However, the

Table 2.26. Productivity (mean yield of nut per palm per year) of the hybrid Lakshadweep Ordinary x Gangabondam (PHC 1) as compared to its parents and the West Coast Tall

Year	Hybrid/Cultivar			
	Lakshadweep Ordinary x Gangabondam	Lakshadweep Ordinary	Gangabondam	West Coast Tall
1963	94.0	74.8	—	67.5
1964	89.6	68.6	—	91.5
1965	103.0	44.2	—	46.5
1966	129.6	107.6	—	76.4
1967	109.8	80.0	31.8	69.4
1968	124.0	85.6	9.8	64.6
1969	87.1	63.6	25.4	62.2
1970	94.3	68.4	9.8	32.6
1971	124.3	78.4	25.8	60.6
1972	151.6	84.8	20.6	63.2
1973	175.5	91.4	59.2	80.4
1974	145.5	90.0	31.4	43.0
1975	111.0	89.8	70.0	82.0
1976	111.8	97.8	21.4	55.8
1977	149.5	103.0	84.6	92.0
1978	92 3	113.2	30.6	68.0
1979	113 3	83.8	78.0	76.2
1980	92.5	83.2	54.0	67.8
1981	109.0	121.0	90.4	78.6
1982	65.8	78.6	11.6	63.4
1983	55.3	106.4	111.2	70.4
1984	59.8	86.4	17.2	48.8
1985	101.5	92.6	60.4	62.2
Mean	108.3	86.4	44.4	64.8

hybrids involving Lakshadweep Ordinary as the female Parent (Lakshadweep Ordinary x Gangabondam; Lakshadweep Ordinary x Chowghat Dwarf Orange) registered relatively more nut yields than Chowghat Dwarf Orange x West Coast Tall, West Coast Tall x Chowghat Dwarf Orange, West Coast Tall x Gangabondam and West Coast Tall during the year 1984 (Table 2.28).

Considering all these aspects, the All India Co-ordinated Coconut and Arecanut Improvement Project Workshop held at Trivandrum during November 6-9, 1985 recommended the release of the hybrid Lakshadweep Ordinary x Gangabondam (PHC 1) in Kerala. The VII Variety Evaluation Committee of the Kerala Agricultural University approved the recommendation on June 6, 1986 and decided

Table 2.27. Yield' performance of coconut hybrids at CPCRI Kasaragod (soil type: red sandy loam)

Hybrid	Age at bearing (year)	Cumulative yield (nuts per palm)			Increase over WCT(%)
		10th year	15th year	18th year	
Chowghat Dwarf Orange x West Coast Tall	6.6	154	503	816	42.2
WCT x Chowghat Dwarf Orange	7.1	109	308	688	19.7
WCT x Gangabondam	7.1	95	340	571	0.6
Lakshadweep Ordinary x Chowghat Dwarf Orange	8.6	47	374	686	19.4
Lakshadweep Ordinary x Gangabondam	7.4	124	422	723	25.8
West Coast Tall	6.9	93	336	574	—

Table 2.28. Yield performance of coconut hybrids during 1981-84 under stress condition, CPCRI, Kasaragod

Hybrid	Nut yield per palm					Increase over WCT(%)	Copra per nut(g)
	1981	1982	1983	1984	mean		
Chowghat Dwarf Orange x WCT	126.8	20.4	150.7	15.5	78.3	31.6	208
WCT x Chowghat Dwarf Orange	102.3	26.8	147.6	22.6	74.8	25.7	198
WCT x Gangabondam	92.8	21.5	105.6	11.5	57.8	2.8	189
Lakshadweep Ordinary x Chowghat Dwarf Orange	77.9	68.4	37.8	67.5	77.9	30.9	195
Lakshadweep Ordinary x Gangabondam	96.5	55.4	99.3	49.2	75.1	26.2	195
West Coast Tall	87.0	28.3	94.6	28.2	59.5	—	186

to release the hybrid as 'Laksha Ganga'. The State and Central Variety Release Committees officially approved the release in the year, 1988. A brief description of the variety in comparison to its parents is given in Table 2.29.

In the year 1988, the VIII Variety Evaluation Committee of the Kerala Agricultural University further recommended the release of two more hybrids—Andaman Ordinary x Gangabondam (PHC 2) and West Coast Tall x Gangabondam (PHC 3) taking into consideration their consistently good yield performance over a period of 23 years under rainfed conditions. These two hybrids registered potential nut yields of 95.2 and 100.2 per palm per year as against 51.1 by Andaman Ordinary, 42.4 by Gangabondam and 64.3 by West Coast Tall. In copra and

Table 2.29. Biometric and yield characters of the hybrid PHC 1 (Laksha Ganga) and its parents, Lakshadweep Ordinary and Gangabondam

Character	Laksha Ganga	Parent: Lakshadweep Ordinary	Parent: Ganga-bondam
Habit	Tall	Tall	Semi Tall
No. of functional leaves per palm	31.00	27.20	26.70
Annual production of female flowers/palm	304.00	345.00	350.00
Mean number of nuts/palm	108.30	86.70	42.40
Age at first flowering (rainfed condition) in years	5	6	4.5
Polar diameter of nut (cm)	20.45	19.38	21.73
Equitorial diameter of nut (cm)	14.85	14.05	13.50
Weight of nut (g)	677.00	810.25	912.00
Thickness of husk (cm)	1.85	1.26	1.38
Weight of husked nut (g)	380.00	526.75	578.00
Diameter of eye (cm)	0.75	1.04	1.09
Thickness of meat (cm)	1.03	1.25	1.15
Weight of opened nut (g)	351.50	453.25	487.25
Weight of copra/nut (g)	194.50	193.70	159.50
Reaction to pests and diseases			
Stem Bleeding	Susceptible	Susceptible	Susceptible
Adaptability	Adaptable to all soil types	Adaptable to all soil types	Adaptable to all soil types

oil out turn also PHC 2 andPHC 3 showed their superiority over the parents (Table 2.30). These hybrids, christened as 'Anantha Ganga' and 'Kera Ganga', respectively, are expected to be officially released shortly. The agronomic traits of PHC 2 and PHC 3 are summarised in Table 2.31.

Table 2.30. Yield performance of the hybrids Andaman Ordinary x Gangabondam (PHC 2) and West Coast Tall x Gangabondam (PHC 3) as compared to their parents (mean of 23 years)

Hybrid/ cultivar	Nut yield per palm per year	Copra per nut (g)	Copra yield/ ha/year (kg)	Setting (%)	Oil content (%)	Oil yield per ha (kg)
PHC 2	95.20	216.00	3639	28.85	68.00	2474
PHC 3	100.20	201.00	3602	38.24	69.00	2485
Andaman Ordinary	51.08	186.50	1687	21.55	68.00	1147
Gangabondam	42.40	159.50	1203	12.11	62.79	756
West Coast Tall	64.30	180.00	2059	27.13	68.19	1404

Table 2.31. Yield characters of the hybrids PHC 2 (Andaman Ordinary x Gangabondam) and PHC 3 (West Coast Tall x Gangabondam) in comparison with their parents

Character	PHC 2	PHC 3	AO	GB	WCT
Habit	Tall	Tall	Tall	Semi Tall	Tall
No. of functional leaves/palm	32.0	36.0	25.5	26.7	31.0
Production of female flowers/ palm/annum	330.0	262.0	237.0	350.0	237.0
No. of nuts/palm (mean of 23 years)	95.2	100 2	51.1	42.4	64.3
Age at first flowering (years)	5	5	7	4.5	7
Polar diameter of nut (cm)	22.6	20.2	22.5	21.7	20.9
Equitorial diameter of nut (cm)	16.8	16.4	17.5	13.5	16.0
Weight of nut (kg)	1.1	1.2	1.1	0.9	0.9
Thickness of husk (cm)	1.9	1.7	2.8	1.4	2.4
Weight of husked nut (g)	795.0	760.0	769.0	578.0	550.0
Diameter of the eye (cm)	1.57	1.18	1.28	1.09	1.13
Thicknes of meat (cm)	1.29	1.20	1.29	1.15	1.22
Weight of opened nut (g)	591.0	578.0	507.0	487.0	422.0
Weight of copra per nut (g)	216 0	201.0	186.0	159.0	180.0
Reaction to stem bleeding	Susceptible	Susceptible	Susceptible	Susceptible	Susceptible
Adaptability	Adaptable to all soil types	Adaptable to all soil types	Adaptable to all soil types	Adaptable to all soil types	Adaptable to all soil types

Being a perennial crop which is committed to the land for over 60 years, the importance of evolution of high yielding varieties and hybrids for increasing coconut production in the country cannot be over emphasised. Research efforts are also to be directed in the agronomic and nutritional aspects to develop technologies for realising the maximum yield potential of these palms.

CHAPTER 3

Cultural Practices in Coconut

I. P. S. Nambiar and N. K. Sasidharan

Coconut cultivation requires considerable planning owing to the perennial nature of the crop. The lapses and mistakes made in the beginning will manifest their effects only when the crop attains the stage of steady bearing. It takes about fifteen years for a West Coast Tall palm to reach the stage of steady bearing and at this stage it would be impossible to rectify the omissions. Therefore, the adoption of appropriate management technologies is as important as the choice of varieties in coconut culture. The research conducted in the coconu research stations in Kerala state during the last six decades have helped to evolve management practices, which are summarised in this chapter.

Density of planting

In the major coconut growing countries, different standards of spacing are adopted. The spacing adopted in Kerala varies from 5 m to 9 m. Generally, the cultivators adjust the spacing in such a way that the fronds of the adjacent palms, when fully grown, do not overlap.

The yield response of coconut cv. West Coast Tall to density of planting was studied at the Coconut Researah Station, Pilicode during the period 1925-1966 with three spacings-6.7 m, 7.6 m and 9.1 m—to accommodate 247, 198 and 148 palms per hectare, respectively in a triangular planting method. The results revealed that the density of planting had no significant effect on individual palm yield although the nut yield per unit area was the highest in the plant stand of 247 per ha (6.7 m spacing) obviously due to higher plant population. The study also indicated that the expenditure on maintenance was more when the seedlings were planted close. Nevertheless, the maximum return per rupee invested on maintenance was realised from the plant stand of 247 per ha (Table 3.1).

Table 3.1. Response of coconut cv. West Coast Tall to planting density

Spacing (m) (triangular system)	Plant population per ha	Nuts per palm per year	Nut yield per ha per year	Ratio of net income/ investment on maintenance
6.7	247	36.7	9076	1.35
7.6	198	35.2	6469	1.16
9.1	148	37.2	5511	1.15

In a more recent study (1964–1985) on the effect of spacing and manuring on the yield of coconut (West Coast Tall) under rainfed conditions conducted at the Coconut Research Station, Balaramapuram, (soil type: red, loam), it was found that wider spacing led to a marked increase in per palm yield. The treatments comprised of factorial combinations of three spacings (5 m x 5 m, 7.5 m x 7.5 m and 10 m x 10 m) and three fertility levels (absolute control, 0.345–0.225–0.450 kg NPK per palm per year and 0.680-0.450–0.900 kg NPK per palm per year). The square method of planting was adopted. In the 5 m x 5 m planting, the palms tended to grow tall and lanky and failed to give satisfactory yield. They also exhibited symptoms of moisture stress during the hot summer months (Table 3.2). The depressive effect of high plant density on nut yield was due to severe competition for light and moisture. The cumulative increase in nut yield registered by 7.5 m x 7.5 m spacing over 5 m x 5 m spacing was 311 per palm during the period 1976 to to 1985. The wider spacing of 10 m x 10 m consistently recorded the highest yield per palm, but the magnitude of increase over the 7.5m x 7.5 m spacing was only marginal.

Table 3.2. Cumulative nut yield per palm for 10 years (1976-1985) as influenced by spacing and manuring.

Spacing (m)	Fertility level (NPK kg per ha)			Mean
	0-0-0	0.340-0.225-0.450	0.680-0.450-0.900	
5.0 x 5.0	13.9	149·1	156.6	106 5
7.5 x 7.5	121.9	501.9	629.3	417.7
10.0 x 10.0	187.6	596.5	764.3	516.1
Mean	107.5	415.8	516.7	
C. D. (0.05)	73.6			

At all the three levels of manuring, an increase in spacing tended to improve the productivity of palms with the 10 m x 10 m spacing recording the maximum nut yield although the difference between it and 7.5 m x 7.5 m spacing did touch the level of statistical significance at the higher fertility level of 0.680-0.450-0.900 kg NPK per ha. The results conclusively proved that under average fertility conditions (0.340-0.225-0.450 kg NPK per ha), a spacing of 7.5 m x 7.5 m was the optimum for the variety West Coast Tall.

Depth of planting

The depth of planting of coconut seedlings depends on the texture and depth of soil and the local climatic conditions. Where water table is deep and dry season prevails for a larger part of the year and soil is hard, surface planting is not advisable because it restricts the bole area and favours the formation of a shallow root system. In order to arrive at an optimum planting depth for coconut, a field trial was initiated at the Coconut Research Station, Pilicode (soil type, laterite) as early as in 1923. There were four planting depths in this trial : 0, (surface planting) 30, 60 and 90 cm. Each treatment had 3 rows of 12 palms. In all the treatments, 90 cm^3 pits were dug and filled to the required depth before planting the seedlings. The test variety was West Coast Tall.

The growth performance of the surface-planted seedlings was poor and the mortality rate was high. Such seedlings developed very shallow root system and dried up during the summer months. The deeper the planting, the better was the growth performance. However, in nut yield, female flower production and setting percentage, the depths of planting did not exert significant differences.

Intercultivation

Intercultivation *per se* has been observed to increase the yield substantially. In order to find out the effect of leaving a cultivated plot uncultivated for a number of years and again bringing it to cultivation, an experiment was conducted at the Coconut Research Station, Kasaragod during 1932-36. It was found that though the female flower production was not affected, there was significant reduction in the setting percentage and yield of nuts for want of intercultivation. From 1937 onwards, when the garden was brought under regular cultivation and manuring, it was seen that the yield of nuts and setting percentage increased significantly. A definite improvement in female flower production, setting percentage and nut yield was noticed from 1940 onwards. The increase in yield due to intercultivation alone was 32.9 nuts per palm per year (Table 3.3). Manuring further improved the yield by 9.4 nuts per palm per year.

Table 3.3. Effect of intercultivation on the yield and yield attributes of coconut cv. West Coast Tall (1934-1958)

Practice	Nut yield per palm per year	Number of bunches per palm	Number of nuts per bunch	Setting percent-age
No cultivation, no manuring	15.3	4.4	2.9	28.9
Regular intercultivation	48.2	9.8	4.8	29.7
Regular intercultivation and manuring	57.6	10.7	5.5	29.7

In another trial to study the comparative performance of coconut cv. West Coast Tall in a regularly cultivated but unmanured plot and an uncultivated and un-manured plot, the difference in mean yield was significant with the former recording 54.3 nuts per palm as against 11.9 nuts per palm by the latter. The beneficial effect of regular cultivation was well brought out by this study.

An experiment to compare the effect of ploughing and digging on coconut yield was started in 1942 at Pilicode with the following 4 treatments:

1) Ploughing once with a monsoon plough in August

2) Ploughing twice with a monsoon plough in June and September

3. Ploughing thrice with a monsoon plough in June, September and October
4. Digging once with a mammatty (23 cm deep) in August/September

The results did not show any significant difference among the treatments. However, ploughing thrice in June, September and October (treatment 3) resulted in the highest net return per palm (Table 3.4) and it was closely followed by treatment 4 receiving one digging in August/September. It was also observed that digging resulted in the maximum control of weeds.

Table 3.4. Economics of different methods of intercultivation

Particulars	Treatment			
	Ploughing once with a monsoon plough	Ploughing twice with a monsoon plough	Ploughing thrice with a monsoon plough	Digging once with a mammatty
Cost of cultivation excluding experimental observation	74.85	74.85	74.85	74.85
Cost of cultivation for experimental operations	4.25	8.50	12.75	28.75
Cost of weeding	6.54	4.36	2.18	—
Total cost of cultivation	85.75	87.75	89.82	103.66
Cost of cultivation per palm per year	1.75	1.75	1.80	2.07
Yield of nuts per palm per year	17.50	19.30	23.90	24.50
Value of nuts at Re. 0.22 per nut	3.80	4.19	5.19	5.31
Net gain per palm per year	2.05	2.44	3.39	3.25

Depth of cultivation

In order to find out the optimum depth of inter-cultivation in a coconut garden, an experiment was conducted at Pilicode with the following treatments

1) Ploughing thrice at a depth of 10 cm with a monsoon plough during July, September and November
2) Ploughing thrice at 15 cm depth with a victory plough
3) Digging to a depth of 12.5 cm with a mammatty and forming mounds in September and breaking up the mounds and levelling in December/January

The test variety was West Coast Tall. The results revealed no significant difference among the treatments.

The effect of cultural practices on the yield and bearing habit of cv. West Coast Tall was studied in the reclaimed alluvial soil of Kumarakom during 1962 to 1969. There were four treatments in the trial:

1) Two diggings per annum during August/September and December/January

2) Clean surface removal of grass once in thirty days during the rainy months and once in fortyfive days during rest of the year
3) Perennial cover of a leguminous crop (*Peuraria javanica*)
4) Perennial cover of grass (control)

Each treatment had a plant population of 12 West Coast Tall palms of the age group 30-45 years. The treatments were imposed in 1962 and the yield data were gathered for a period of five years from 1965. The yield of coconut during the transition period of 1963 and 1964 was not considered on the assumption that the treatment effect would be manifested only two years after its application. The data on nut yield (Table 3 5) indicated that clean surface removal of weeds was the best treatment producing the highest yield of 43.3 nuts per palm although it was on a par with treatments 1 (2 diggings) and 3 (perennial grass cover). However, all these culrural practices were significantly superior to the control in their effect on yield.

Table 3.5. Effect of cultural practices on the yield of coconut (nuts per palm) cv. West Coast Tall in the reclaimed alluvial soil of Kumarakom

Treatment	Pre-treatment period (1959-1962)	Year					Mean
		1965	1966	1967	1968	1969	
Two diggings during August/September and December/January	37.2	37.0	52.8	40.8	37.2	36.8	40.9
Clean surface removal of grass	35.2	48.7	55.6	43.0	35.3	33 6	43.3
Leguminous cover crop	28 9	38.9	49.4	42.0	32.4	30.3	38.6
Grass cover (control)	32.7	32.7	35.3	27.7	24.0	25.0	28 9
C D (0.05)				4.7			

The relative merits of manual and chemical methods of weed control in coconut gardens were studied at the Regional Agricultural Research Station, Kumarakom (Soil typa, reclaimed alluvium) during the period 1984-'86. There were eleven treatments each replicated three times in a randomised block design. The treatments were:

1) Two diggings in August/September and December/January
2) Regular digging to keep the garden weed-free
3) Sickle weeding once in three months in March, June, September and October
4) Forming mounds in September/October and levelling them in December/January
5) Application of paraquat (Gramoxone) at 2 5 l per ha in March, June and October
6) Application of Dalapon at 3.75 kg per ha in March and paraquat at 2.5 l per ha in April, June and October
7) Combined application of paraquat at 2.5 l per ha and 2, 4-D at 1.25 kg per ha in March, June and October

8) Application of paraquat at 2.5 l per ha in March, June and October plus one digging in December/January
9) Application of Dalapon at 3.75 kg per ha in March plus paraquat at 2.5 l per ha in April, June and October plus one digging in December/January
10) Sickle weeding in March and August and application of paraquat at 2.5 l per per ha in April and September
11) No weeding (control)

The predominant weed species in the experimental area were, *Ischaemum muticum*, *Panicum repens*, *Digitaria ciliaris*, *Brachiaria reptans*, *Commelina diffusa* (grasses), *Cyperus iria*, *Cyperus rotundas* (sedges), *Leucas aspera* and *Ageratum conyzoides* (broad leaved weeds).

The methods of weed control were observed to influence the composition of the weed flora in the experimental plots. The cultural methods of weed control tended to increase the number of species. Paraquat either alone or in combination with '2, 4-D observed to encourage the regeneration of Graminae weeds like *Brachiaria mutica* and *Ischaemum muticum*, Dalapon effectively controlled these two species but encouraged the establishment of broad leaved weeds.

The data on the dry matter of weeds showed that a combination of cultural and chemical methods was more effective in weed control than either of them alone. The treatments 7 (16.2 per cent), 4 (16.0 per cent), 1 (15.7 per cent), 5 (12.8 per cent) and 2 (12.1 per cent) registered marked increases in nut yield over the pre-treatment yield while the unweeded control recorded a decrease of 15.9 per cent (Table 3.6).

Moisture conservation

Coconut husk is generally utilized for the extraction of fibre (coir). However, in some areas, a good percentage of the husk produced is utilized for fuel and other purposes. The husk could also be utilized for moisture conservation in coconut gardens. Coconut husk when buried in the soil absorbs moisture and acts as a water reservoir. The moisture so stored can be extracted by plant roots. In an experiment conducted at Pilicode to study the effect of burying coconut husk (58292 per ha) and leaf (3335 per ha) in linear trenches of 1.8 m x 0.45 m dug in between rows of coconut palms, it was found that the yield of nut increased significantly from the third year onwards. The first visible effect was a general improvement in the condition of the palms followed by an increase in the number of functional leaves, female flowers, setting percentage and nut yield. Further, the results also showed that the beneficial effect of burying husk lasted for 6 years (Table 3.7).

In order to study the effect of opening trenches in the coconut gardens and filling them with trash and compost on moisture conservation and growth and yield of coconut, an experiment was conducted at Pilicode during 1932. Trenches were cut open in the experimental plots to a depth of 30 cm and a width of 60 cm at the close of the South-West monsoon. They were then filled with dry coconut leaves, green leaves and compost and covered at the end of the North-East monsoon. The

Table 3.6. Effect of cultural and chemical methods of weed control on dry matter of weeds and yield of coconut cv. West Coast Tall

Sl. No.	Treatment	Dry matter weight of weeds (mean of 1985, '86 '87) (g/m²)	Nut yield per palm per year: Pre-treat ment	1984	1985	1986	Mean
1.	Two diggings	880	28.6	29.9	41.2	28.3	33.2
2.	Weed free	3	33.0	34.9	47.3	29.5	37.5
3.	Sickle weeding 3 times	773	34.7	31.9	43.3	35.4	36.6
4.	Mound formation and levelling	702	34.2	32.8	53.0	32.9	39.6
5.	Paraquat 3 times	915	39.2	32.8	66.2	33.6	44.2
6.	Dalapon once+ Paraquat 3 times	709	38.1	35.1	43.4	26.9	39.4
7.	Paraquat + 2, 4-D 3 times	1061	33.9	35.3	51.4	31.3	35.1
8.	Paraquat 3 times + 1 digging	621	42.5	41.2	48.9	38.4	42.8
9.	Dalapon once + paraquat 3 times + one digging	537	39.9	36.4	52.6	34.4	41.5
10.	Sickle weeding twice + paraquat 2 times	1034	36.1	33.9	48.6	31.8	38.1
11.	No weed control	1923	34.5	33.4	40.6	24.0	32.7

Table 3.7. Effect of burying coconut husk in the soil on the growth and yield of coconut cv. West Coast Tall

Year	Nut yield per palm	C. D. (0.05)	Increase over pre-treatment yield (per cent)	Number of leaves per palm	C. D. (0.05)
1937 (Pre-treatment)	38.0	—	—	29.3	—
1939 (Post-treatment)	40.8	—	7.4	31.3	0.9
1940	63.0	7.5	65.8	32.5	0.8
1941	69.6	7.5	83.2	31.1	1.2
1942	54.0	6.7	42.1	30.1	—
1943	64.5	7.1	69.7	30.7	1.3
1944	46.1	3.9	21.3	28.2	0.7

growth and yield performance of coconut palms cv. West Coast Tall in both the trenched and non-trenched plots were studied over a period of 3 years. From the results, the following conclusions were drawn.

1) Trenching resulted in a marginal increase in leaf production.
2) There occurred a general increase in the production of spadices in both the treatments in the first two years. In the third year, there was a significant increase in spadix production due to trenching.
3) The production of female flowers increased by 38 per cent due to trenching in the third year.
4) Trenching led to a 5.1 per cent reduction in the shedding of buttons.
5) Trenching resulted in a marginal increase in nut yield

Defoliation and yield

During the summer months, older leaves of coconut palm get dried up faster and are shed. If moisture stress is servere, the petioles break and the leaves hang on to the tree. In the southern parts of Kerala, there exists a practice of cutting down older coconut leaves in summer months in order to check transpiration.

Table 3.8. Effect of defoliation on female flower production, setting percentage and yield of coconut cv. West Coast Tall (mean of 1977-'81)

Treatment	Female flower per palm	Setting percentage	Nut yield per palm per year		Net profit (Rs)
			Pre-treat. (1973-1976)	Post treat. (1977-1981)	
Control	134.5	36.3	54.2	49.6	—
Removal of one leaf every month	145 7	35.4	50.6	51.6	559
Removal of one leaf in alternate months	137.9	36.5	52.3	53.6	335
Removal of two leaves every month	141.3	36.0	58.4	52.4	1109
Removal of two leaves in alternate months	151.8	36.0	54.1	53.9	665
Removal of three leaves in alternate months	136.4	36.1	52.3	50.3	989
F (0.05)	NS	NS	NS	NS	--

NS—Not Significant

Some researchers hold the view that drastic pruning of leaves is definitely harmful to the palm. With the objective of elucidating more information on this aspect, a study was undertaken on a 55 year-old plantation of West Coast Tall in the F block of the Regional Agricultural Research Station, Pilicode during 1977-81. The treatments are listed in Table 3.8. One or two older functioning leaves were cut every month from January to May involving five cuttings of leaf in each treatment every year. In another set of treatments, one, two or three older functioning leaves were cut every alternative month from January to May. In these treatments there were three cuttings of leaf every year. The leaves were cut at the base of the petiole. Besides these five treatments, there was an absolute control wherein no defoliation was imposed. Each treatment was allotted randomly on single tree plot basis to twenty palms.

The data on female flower production, setting percentage and nut yield, on statistical analysis revealed that none of the yield attributes was significantly influenced by defoliation, indicating that removal of older leaves had no adverse effect on the coconut palm. However, there was a general decline in nut yield in all the treatments which was attributed to the senility of the test palms.

The economics of defoliation was worked out and it indicated that cutting two leaves every month from January to May fetched the maximum net profit of Rs. 1109/-per hectare per year.

CHAPTER 4

Soils and Nutrition

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Coconut being a yielder throughout the year and a heavy consumer of soil nutrients, especially, N, K and Cl, it is essential that adequate supply of nutrients is ensured for sustaining and/or maximising the productivity of the palm. Coconut palm can tolerate several adverse soil conditions to a high degree and can come up well in almost all soil types. Research on the nutritional aspects and fertilizer requirement of this important crop was started as early as in 1923 at the Coconu Research Station, Pilicode. Some of the early experiments gave important information on the nutritional requirements of the palm. At present, accent is given not only on the fertilizer requirements but also on several fundamental aspects of nutrition to bring out clearly the major nutritional constraints in coconut production. Several experiments are in progress at the Regional Agricultural Research Station, Pilicode, the Coconut Research Station, Balaramapuram, the College of Horticulture, Vellanikkara and the College of Agriculture, Vellayani, on these aspects.

Fertilizer requirement

Three field trials one each at Nileswar I (Pilicode), Nileswar II and Nileswar III representing laterite, red sandy loam and litforal sand respectively, were started in the year 1923-24 and concluded in the year 1931. The physico-chemical characteristics of these soils were highly variable (Table 4.1). The manures and fertilizers used in this study were ammonium sulphate, superphosphate, muriate of potash, fish guano, ash, common salt and cattle manure in various combinations. These were applied evenly on the soil and then ploughed in. The treatments per palm per year were:

i) Ammonium sulphate (1.8 kg)
ii) Fish guano (4.5 kg)
iii) Ammonium sulphate (1.8 kg) + superphosphate (2.7 kg)
iv) Ammonium sulphate (1.8 kg) + potassium sulphate (0.9kg)
v) Common salt (1.8 kg) +ash (9.1 kg)
vi) Ammonium sulphate (1.8 kg) + ash (9.1 kg)
vii) Fish guano (4.5 kg) + ash (9.1 kg)
viii) Ammonium sulphate (1.8 kg) + Superphosphate (2.7 kg) + Potassium sulphate (0.9 kg)

ix) Ash (9.1 kg)
x) Cattle manure (45.4 kg)
xi) Fish guano (4.5 kg) + ash (13.6 kg)
xii) Fish guano (2.3 kg) + ash (6.8 kg)
xiii) No manure

At Pilicode (laterite soil) the average number of leaves per palm per year was the highest in plots receiving cattle manure and least in plots receiving fish guano at the rate of 4.5 kg per palm. The production of nuts, however, was more in palms receiving ammonium sulphate, superphosphate and muriate of potash. The yield was the highest in palms growing on red sandy loam and littoral sand which received 4 5 kg fish guano and 13.6 kg ash per palm. These palms yielded 25 nuts per annum whereas those received half the dose yielded only 18 nuts.

Table 4.1. Physico-chemical characteristics of laterite, red sandy loam and littoral sands

Characteristics	Laterite		Red sandy loam		Littoral sand	
	0-30 cm	30-60 cm	0-30 cm	30-60 cm	0-30 cm	30-60 cm
Mositure (per cent)	1.48	1.67	1.78	1.90	0.28	0.28
Loss on ignition (per cent)	5.28	5.48	3.41	4.15	0 77	0.87
CaO (per cent)	0.06	0.06	0.03	0.06	0.16	0.13
MgO (per cent)	0.09	0.08	0.07	0.06	0.09	0.08
P_2O_5 (per cent)	0.09	0.09	0.07	0.05	0.02	0.01
K_2O (per cent)	0.23	0.23	0.13	0.11	0.15	0.05
Nitrogen (per cent)	0.09	0.08	0 05	0.05	0.02	0.02
Available N (per cent)	0.01	0.01	0.01	0.01	0.01	0.01
Available P_2O_5 (ppm)	40.00	30.00	40.00	50.00	40.00	40.00
Available K_2O (ppm)	40.00	30.00	30.00	20.00	20.00	30.00
pH	5.00	4.90	4.90	5.50	6.10	5.90
Mechanical composition (per cent)						
Coarse sand	48.71	42.03	59.60	57.90	76.80	72.70
Fine sand	20.84	17.83	16.50	16.10	10.60	12.90
Silt	6.60	6.90	3.90	2.80	2.90	2.70
Clay	23.85	33.24	20.00	23.20	9.70	11.70

At the Coconut Research station, Balaramapuram a fertilizer trial involving three levels of N, P and K in factorial combinations (3^3 confounded design confounding NPK^2 and NP^2K^2) with two replications is in progress since 1964. This particular experiment was designed to test only inorganic fertilizers namely, ammonium sulphate as N source, single superphosphate as P source and muriate of potash as K source right from the seedling stage. The palms during the past 24 years have not received any organic matter application. In this respect, this experiment is unique and is perhaps the only experiment in the world being continued even after two decades. The levels of N were 0, 340 and 680 g, that of P_2O_5 were 0, 225 and 450 g and that of K_2O were 0,450 and 900 g per palm per year.

Among the three nutrients, consistent effects on nut production were observed for N and K although superphosphate application also showed significant effects in certain years (Table 4.2). During the initial stages of the experiment, the differences in yield increases were more conspicuous for all the three nutrients. However, the differences decreased with time excepting for potash receiving palms. The results of the study clearly brought out the role of potassium in coconut production. Further, the data also showed the importance of balanced application of NPK fertilizer as evidenced from the significant NK, PK and NP interactions (Table 4.3). It may be noted that nitrogen application in the absence of K is rather harmful to the palm. The highest yield of 79.1 nut per palm per year was recorded for the $N_2P_2K_2$ combination.

Some of the early experiments conducted at Pilicode has indicated that husk and leaf burial at the rate of 58292 husks and 3335 leaves per ha, in linear trenches of 1.8m x 0.45 m dug in between rows of coconut palms was as effective as the application of 1.36 kg ammonium sulphate, 0.68 kg of potassium sulphate and 0.91 kg of bone meal per palm per year. Similarly, when applied on equal nitrogen basis, groundnut cake and ammonium sulphate had more or less the same effect on coconut yield. A comparison of different sources of potash, namely sulphate of potash, muriate of potash (KCl) and wood ash at the rate of 0.45 kg K_2O per palm per year indicated that the latter two sources were superior to sulphate of potash. Muriate of potash application at the rate of 0.9 kg K_2O per palm was not found to be better than the 0.45 kg level.

Table 4.2. Effect of N, P and K on the nut yield of coconut cv. West Coast Tall in the red loam soil, Balaramapuram (nut yield per palm)

Year	Nitrogen			Phosphorus			Potash			C. D
	N_0	N_1	N_2	P_0	P_1	P_2	K_0	K_1	K_2	(0.05)
1976	3.1	11.6	16.4	4.7	14.6	11.9	0.3	12.2	18.7	4.63
1977	5.9	18.3	27.9	9.3	21.2	20.9	1.0	21.3	29.1	6.06
1978	6.8	18.1	24.9	9.2	21.2	19.4	0.9	21.4	27.5	5.60
1979	5.6	22.5	38.0	14.5	30.4	22.2	0.8	28.1	38.2	6.44
1980	6.2	22.4	34.1	15.6	25.4	21.7	1.5	27.9	33.3	5.99
1981	15.3	26.7	40.4	23.3	32.6	26.7	4.6	36.1	41.8	7.47
1982	21.8	24.7	48.8	31.2	38.4	35.7	6.3	46.3	52.6	8.81
1983	14.9	25.5	36.5	22.9	28.6	25.4	3.4	33.5	40.0	7.64
1984	12.8	21.7	25.1	16.1	19.2	24.3	2.1	23.9	33.6	6.10
1985	43.0	48.3	60.2	49.1	50.1	52.2	6.7	67.7	77.0	11.11
Cumulative yield 1976-1985	136.6	248.2	324.8	192.8	256.8	260.0	27.6	318.2	263.7	72.71

Table 4.3. Effect of nutrient interaction on the cumulative nut yield (per palm) of coconut, 1976-'85

N x K	Nut yield (1976-1985)	P x K	Nut yield (1976-1985)	N x P	Nut yield (1976-1985)
N_0K_0	36.87	P_0K_0	46.71	N_0P_0	139.33
N_0K_1	179 33	P_0K_1	267 00	N_0P_1	133.96
N_0K_2	194.21	P_0K_2	264 67	N_0P_2	138.42
N_1K_0	22.00	P_1K_0	23.63	N_1P_0	160.50
N_1K_1	323.96	P_1K_1	383.75	N_1P_1	357.21
N_1K_2	398 67	P_1K_2	362.92	N_1P_2	226.92
N_2K_0	24.75	P_2K_0	12.58	N_2P_0	278.54
N_2K_1	451.40	P_2K_1	303.94	N_2P_1	281.13
N_2K_2	498.27	P_2K_2	463.56	N_2P_2	414.76
C D (0.05)	125.95		125.95		125.95

In another study, it was observed that application of phosphatic fertilizers singly or in combination with N had no effect on nut yield. The fertilizer trials conducted to study the response of coconut palm to NPK fertilizers with and without Mg. revealed that in laterite soils the fertilizer requirement of the palm was 0.5 kg N, 0.25 kg P_2O_5 and 1.25 kg K_2O per palm per year. The response to applied micronutrients with NPK fertilizers was also studied in field trials. The micronutrients tested were B, Cu, Mn, Mo and Zn individually with NPK or the combination of all the micronutrients in the presence of NPK. The highest yield was obtained from N, P, K and Zn treated palms.

Several field trials have been conducted to study the response to NPK fertilizers in farmers' field conditions. In all these cases, application of fertilizers had proved beneficial and effective in increasing coconut yield. An experiment conducted at the Regional Agricultural Research Station, Kumarakom to study the optimum NPK requirement of coconut palms growing in the backwater areas of Kerala showed that fertilizer application to these acidic reclaimed alluvium was in general effective in increasing nut yields. The highest increase in yield was observed when the palms were supplied with 0.25 kg N, 0.34 kg P_2O_5 and 0.68 kg K_2O per palm per year.

Long-term inorganic fertilization

The changes in soil chemical properties and nutrient availability as a result of 22 years of regular annual application of ammonium sulphate, superphosphate and muriate of potash at varying levels were evaluated in the NPK factorial experiment at the Coconut Research Station, Balaramapuram. The soil samples were drawn from 0-50 cm depth at a lateral distance of 50 cm from the palm. In addition, the soil cores from 0-25, 25-50, 50-75 and 75-100 cm were also collected from eight selected treatments, namely, the three-factor combinations of N_0, N_2; P_0 P_2

and K_0, K_2 for chemical analysis. The nutritional status of the palms receiving different fertilizer treatments was also studied through foliar analysis. The chemical analysis of 0-50 cm soil indicated that regular annual application of ammonium sulphate, superphosphate and muriate of potash influenced the soil characteristics to varying degrees (Table 4 4). With increasing rate of applied ammonium sulphate, soil pH decreased markedly from 4.88 in N_0 plots to 4.38 in N_2 plots. A similar trend was also seen in the case of available Mn. (Table 4.5). On the other hand, available S increased with increasing rate of fertilization. These effects were noticed not only in the 0 to 50 cm layer but also at various other depths from 0 to 100cm (Fig. 4.1). The lowering of soil pH following the application of ammoniacal fertilizers is a well known phenomenon. The application of ammoniacal fertilizers increases the availability of soil Mn as a consequence of lowering of the pH, but prolonged use of the fertilizer may lead to erosion of Mn even from very low soil depths through excessive dissolution and leaching.

Table 4.4. Effect of NPK fertilizer application on the chemical characteristics of 0-50 cm soil under coconut

Treatment	pH	Organic carbon (%)	Bray-1P (ppm)	Exch. K (ppm)	Exch Ca (me/100 g)	Exch. Mg (me/100 g)
N^0	4.88	0 46	76.9	94.1	1.55	0.79
N_1	4.52	0.50	72.4	66.5	1.65	0 71
N_2	4.38	0.50	67.9	65.4	1.29	0.52
P_0	4.55	0.49	5.7	85 8	1.35	0.81
P_1	4.52	0 46	65.1	77.8	1.45	0.63
P_2	4.70	0.48	146.5	62 4	1.67	0.57
K_0	4.50	0.43	87.3	45 0	1.63	0.69
K_1	4.57	0.50	57.6	90.1	1.55	0.59
K_2	4.71	0.52	72.4	90.9	1.30	0.74
C D (0.05)	0.20	0.06	31.8	15.5	N S	N S
SE	0.10	0.03	15.4	7.5	0.33	0.03

NS: Not significant

The S status of the soil was considerably improved following ammonium sulphate application. Regular application of ammonium sulphate at the rate of 0.35 kg N per year increased the available S status of the soil two fold. The enrichment had occurred even at very low depths down to 75 cm. Large amounts of sesquioxides inherently present in this acid soil could also have helped in the retention of sulphate.

Application of superphosphate increased the available P content of the soil 25 fold at the highest level of application. Depthwise analysis of the soil revealed P accumulation even at a depth of 75-100 cm (Fig. 4.2). In acid soils containing large amounts of sesquioxides, the mobility of P is limited due to fixation. The results, however, revealed that long continued application of superphosphate can enhance

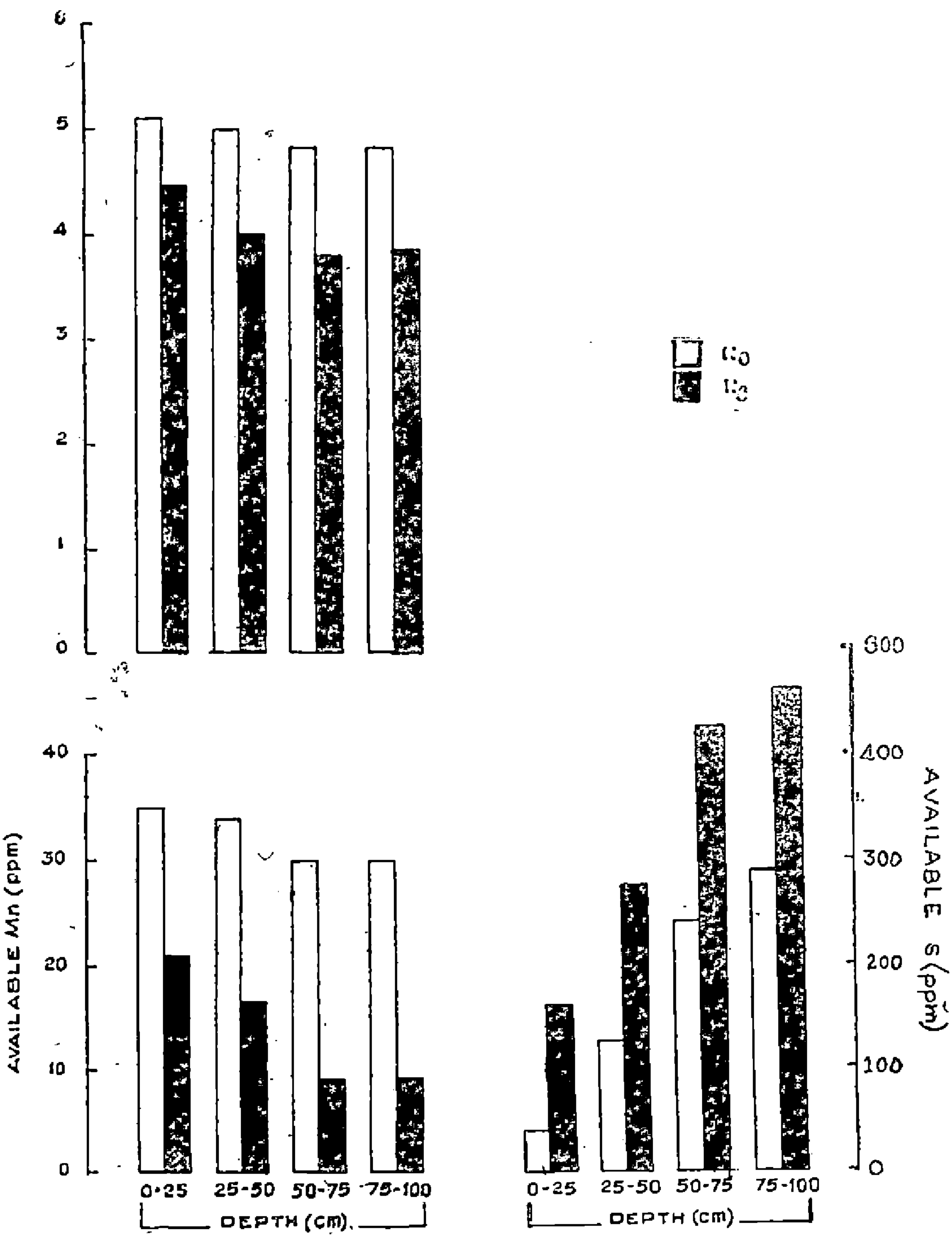


Fig. 4.1. Effect of ammonium sulphate application on soil pH, available Mn and S,

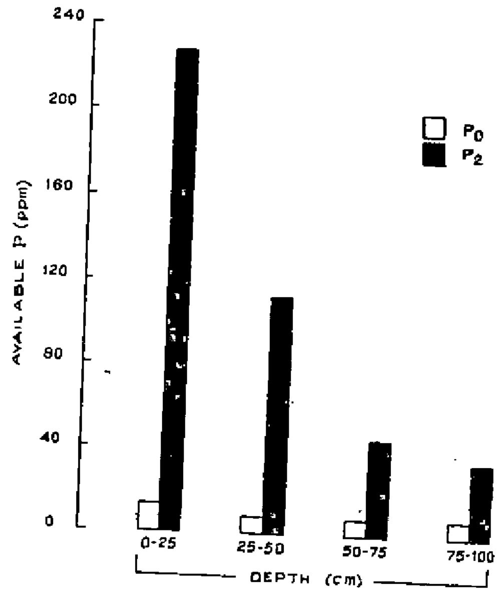


Fig. 4.2. Effect of superphosphate application on soil available P

the movement of P into deeper layers even in acid soils. In this respect, the behaviour of P in the soil is more or less the same as that of S. Heavy rainfall received during the time of fertilizer application might also be responsible for the leaching of these anions in dissolved forms from the relatively more saturated upper soil layers. The application of superphosphate over the years also reduced the exchangeable K content of the soil significantly (Table 4.4). This effect could be perhaps due to the influence of Ca present in the fertilizer material on replacing K from the exchange sites in the soil. Such a possibility cannot be ruled out as there was a tendency for the exchangeable Ca to increase with increasing rates of added superphosphate.

Table 4.5. Effect of NPK fertilizer application on S and micronutrient availability in soil (0-50 cm) under coconut (ppm)

Treatment	S	Fe	Mn	Zn	Cu
N_0	75.0	23.8	40.4	3.01	0.80
N_1	155.6	31.3	31.3	2.75	0.79
N_2	186.1	22.6	25.9	2.47	0.87
P_0	133.9	27.7	25.4	2.78	0.87
P_1	143.9	22.3	33.7	2 59	0.79
P_2	138.9	24.4	34.3	2.86	0.80
K_0	162.2	24.1	31.0	2.81	0.82
K_1	143.9	26.8	32.6	2.78	0.80
K_2	110.6	23.6	33.9	2.66	0.83
CD (0 05)	60.1	NS	9.9	NS	NS
SE	28.9	3.4	4.8	0.22	0.06

The application of muriate of potash increased the available K and organic carbon content of the soil(Fig. 4.3). The effect on soil exchangeable K was, however, N—dependant as revealed from the significant N x K interaction(Table 4.6) Higher rates of ammonium sulphate application led to lowering of soil exchangeable K. The effect could be due to the removal of K from the exchange site by NH_4^+ as well as the H+ions generation in the nitrification process. Nevertheless, in general, there was a build-up of exchangeable K in plots receiving muriate of potash even upto 75-100 cm soil depth.

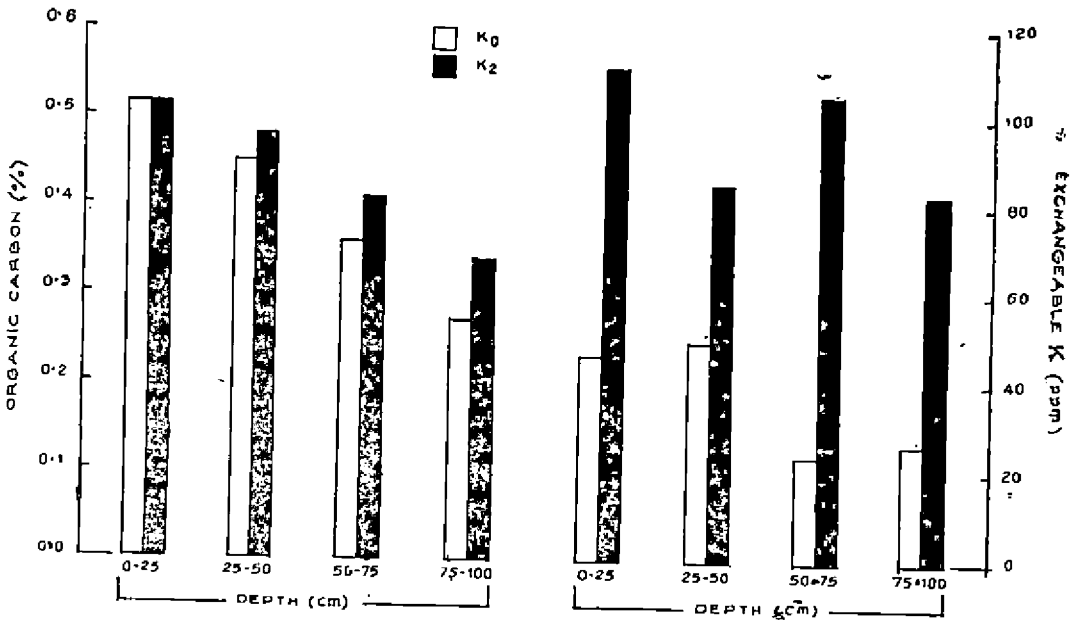


Fig. 4.3. Effect of application of muriate of potash on soil available K and organic matter

Table 4.6. Effect of N x K fertilizer interaction on soil exchangeable K,in the 0-50 cm soil

Nitrogen	Potash			Mean
	K_0	K_1	K_2	
N_0	41.3	125.8	115.1	94.1
N_1	54.9	75.3	69.2	66.5
N_2	38.7	69.2	88.3	65.4
Mean	45.0	90.1	90.9	—
CD (0.05)	N x K=10.9			

The effect of long term NPK fertilizer application on the availability of Fe, Zn, Cu and Mg was not found to be significant (Table 4.5). The data on Cl content of the soil was insignificantly small irrespective of the treatment.

Nutrient uptake

Foliar level of N increased as a consequence of N fertilization (Table 4.7a). The absorption of K increased with increasing rate of KCl application while K dressings depressed the foliar Mg levels. Besides these, there was a steady increase in Ca content of the leaf with increasing levels of applied superphosphate. The increased absorption of Ca could be due to the increase in Ca content of the soil as a result of regular application of this Ca carrying fertilizer material. It is surprising

Table 4.7a. Effect of fertilizer application on nutrient composition of 14th leaf

Treatment	N(%)	P(%)	K(%)	Ca(%)	Mg(%)	S(%)
N_0	0 91	0.114	1.48	0.276	0.328	0.100
N_1	1.07	0.116	1.39	0.260	0.352	0.106
N_2	1.03	0.116	1.19	0.344	0.340	0.104
P_0	1.04	0.112	1.31	0.264	0.330	0.105
P_1	1.01	0 118	1.33	0 281	0.339	0.101
P_2	0.96	0.115	1.42	0.334	0.348	0.107
K_0	0 99	0.112	0.54	0.306	0.399	0.103
K_1	0.99	0.119	1.37	0.304	0.322	0.104
K_2	1.03	0.114	2.15	0.269	0.299	0.106
CD (0.05)	0.09	NS	0.31	0.070	0.060	NS
SEM ±	0.04	0.01	0.15	0.030	0.030	0.013

NS. Not significant

to note that superphosphate application over the years did not improve the P uptake. Perhaps the yield response of palms receiving superphosphate might be due to the increased uptake of Ca rather than P. A similar observation as that of P can also be made of foliar S level of the palms receiving ammonium sulphate. Irrespective of the treatments the Cl levels in the foliage were well above the critical level of 0.5 per cent (Table 4.7 b). The nearness of the location (about 2 km) to the sea coast would explain the supply of adequate Cl to the palms through wind transport.

Table 4.7b. Effect of NPK application on the nutrient composition of the 14th leaf of coconut

Treatment	Cl (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
N_0	0.61	143	468	21.8	3.9
N_1	0.70	142	439	21.2	4.3
N_2	0.73	146	538	19 3	5.8
P_0	0.66	148	505	19.1	4.5
P_1	0.72	135	459	23.8	3.9
P_2	0.67	148	481	19.4	5.7
K_0	0.66	136	492	21.5	5.0
K_1	0.69	152	466	21.8	4.4
K_2	0.70	144	488	19.0	4.6
CD (0.05)	NS	NS	NS	NS	NS
SE	0.05	14.79	39.49	4.9	0.78

NS—Not Significant

Root activity pattern

Efficient management of fertilizers in crop cultivation requires a knowledge of the distribution of active roots of the plant. An experiment was conducted to study the pattern of root activity with nine-year-old coconut palms (var. West Coast Tall) growing on acidic laterite soil. Phosphorus-32 soil-injection technique was employed in the study. The experiment was phased over two years during the monsoon season between August and November. In the first year, the study was confined to 2 m radial distance from the palm and in the second year the study was continued from 2 m to 4 m. There were altogether fifteen P-32 placement treatments in the first year experiment being the combinations of five radial distances (30, 60, 100, 150 and 200 cm) and three depths,(30, 60 and 90 cm). In the second year experiment, twelve P-32 treatments covering the combinations of four lateral distances (200, 250, 300 and 400 cm) and three depths (30, 60 and 90 cm) were included.

The data generated in the first year experiment on the recovery of radioactivity in the palm indicated that the absorption of the radio-label was more or less uniform from various radial distances namely 30, 60, 100, 150 and 200 cms from the palm (Table 4.8). A significant reduction was, however, noticed in the absorption of P-32 from 90 cm depth at 13, 33 and 71 days after application. The overall absorption of applied P-32 increased from 32 ppm on the 13th day to 792 cpm/g leaf at the end of the experiment, 71st day after application. The absorption of P-32 from different soil zones between 2 and 4 m redius around the palm indicated that it was not influnced by lateral distance and depth of placement during the first 33 days (Table 4.9). However, significant differences in the absorption of the applied P-32 were evident at later intervals of sampling, 47 and 63 days after P-32 application. Thus there was a marked decrease in the absorption of P-32 from 200 and 400 cm distances from the palm. Among the three depths of

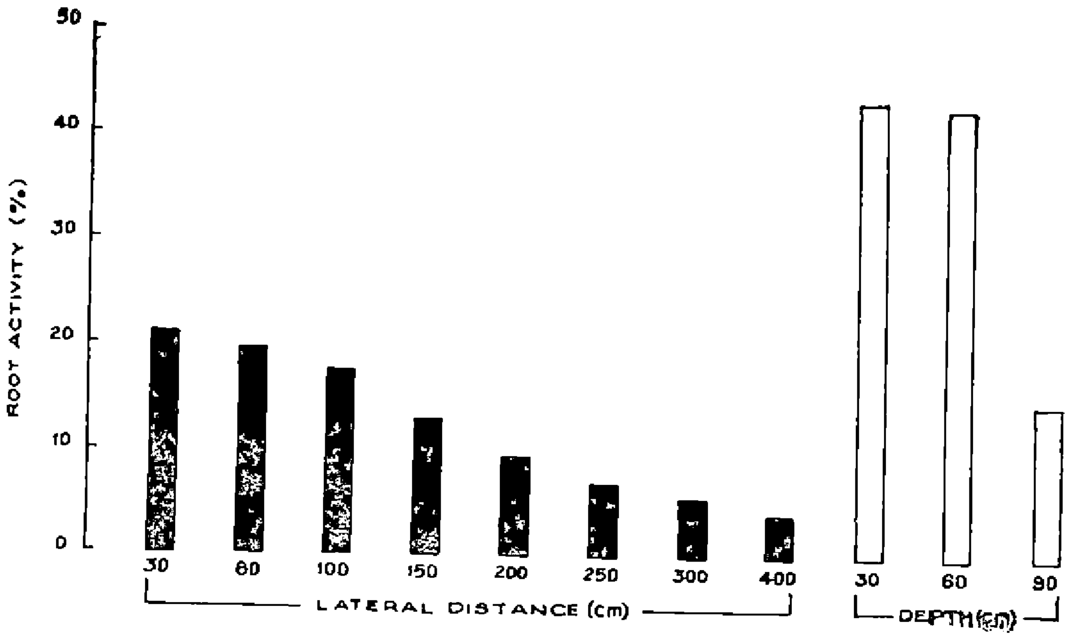


Fig. 4.4. Distribution of active roots of coconut palm in relation to lateral distance from the palm and soil depth

placements, the absorption from 90 cm was the least here again. Based on these results, the relative densities of active roots at different soil zones in a soil column of 4 m radius around the palm were worked out (Table 4.10). A major portion of the root activity (82.5 per cent) was found within an area of 2 m radius around the palm (Fig. 4.4). The vertical distribution of active roots (84.8 per cent) was mainly confined to a depth of 60 cm beyond which the root activity decreased sharply.

Table 4.8. Absorption of applied P-32 by coconut palm (cpm/g leaf) from different soil zones within an area upto 2 m radius around the palm (log transformed values)

Treatment	Days after P-32 placement			
	13	33	50	71
Lateral distance (cm)				
30	1.442	2.579	2.996	2.940
	(27.6)	(379.4)	(990.7)	(870.0)
60	1.398	2.514	2.892	2 918
	(25.0)	(326.6)	(779.4)	(827.6)
100	1.445	2.427	2.653	2.927
	(27.9)	(267.4)	(449.7)	(844.3)
150	1.202.	2.310	2.623	2.775
	(15.9)	(204.1)	(419.3)	(595.0)
200	1.272	2.219	2.623	2.718
	(18.7)	(165.4)	(419.3)	(522.5)
C D (0.05)	NS	NS	NS	NS
Depth (cm)				
30	1.719	2.670	2.896	2.996
	(54.4)	(468.0)	(787.2)	(990.7)
60	1.580	2.557	2.857	3.009
	(38.0)	(360.9)	(719.5)	(1020.9)
90	0.755	1.997	2.518	2.562
	(5.6)	(99.3)	(329.8)	(364.5)
C D (0.05)	0.521	0.420	N S	0.261
SE	0.403	0.324	0.256	0.201

Values in parentheses denote retransformed values
N. S. Not significant

Method of fertilizer application and spacing

Studies conducted at Pilicode showed that application of 1.0 kg N, 0.64 kg P_2O_5 and 2.4 kg K_2O per tree/year in two splits was better than single application. The yield increased over a five-year period from 43.5 to 58.9 nuts per palm per year. The results obtained in another field trial at Kumarakom indicated that annual application of 375 g N, 478 g P_2O_6 and 875 g K_2O in basins was superior to application of the fertilizers in alternate years and in linear trenches or by broadcast. In another experiment at Pilicode with palms growing on laterite soil, it was

Table 4.9. Absorption of applied P-32 by coconut palm (cpm/g leaf) from different soil zones within an area of 2 to 4m radius around the palm (log transformed values)

Treatment	Days after P-32 application			
	15	33	47	63
Lateral distance (cm)				
200	1.776	2.323	2.323	2.366
	(59.6)	(210.3)	(210.3)	(232.4)
250	1.850	2.049	2.106	2.180
	(70.7)	(112.0)	(127.6)	(151.2)
300	1.589	2.032	2.041	2.036
	(38.8)	(107.6)	(109.8)	(108.7)
400	1.395	2.032	1.772	1.989
	(24.7)	(107.6)	(59.0)	(97.4)
C D (0.05)	NS	NS	0.346	0.281
Depth (cm)				
30	1.615	2.197	2.262	2.319
	(41.2)	(157.4)	(182.8)	(208.2)
60	1.763	2.193	2.062	2.180
	(57.9)	(155.8)	(115.4)	(151.2)
90	1.580	1.941	1.854	1.924
	(38.0)	(87.2)	(71.4)	(83.8)
C D (0.05)	NS	NS	0.300	0.243
SEM	0.247	0.166	0.205	0.166

Values in parentheses denote retransformed values
N. S. Not significant

observed that broadcasting fertilizers over the entire area and ploughing in or applying the fertilizers in circular basins of 1.8 m radius and 30 cm depth around the palm was superior to the method of applying fertilizers in linear trenches in between the rows of palms. These results agree well with the root activity pattern of the palm.

At Balaramapuram, an experiment has been in progress since 1964 to study the effect of spacing and manuring on the growth and productivity of coconut. The treatments consisted of three spacings (5 x 5 m, 7.5 x 7.5 m and 10 x 10 m) and three fertilizer treatments (no NPK; 0.35 kg N, 0.25 kg P_2O_5 and 0.45 kg K_2O; 0.68 kg N, 0.45 kg P_2O_5 and 0.9 kg K_2O per palm per year). The results indicated that wider spacings than 5 m x 5 m increased the yield significantly (Table 4.11). An increase in nut yield was also observed at higher levels of fertilizer application than in the control. It was however, observed that the interation between spacing and fertilizer treatment was also significant. Thus, wider spaced palms than those spaced at 5 m x 5 m responded better to fertilizer application (Table 4.12).

Table 4.10. Percentage root activity of coconut palm at different lateral distances and depths

Lateral distance (cm)	Depth (cm) 30	60	90
30	9.4 (1405.9)	9.4 (1405.9)	2.2 (329.9)
60	10 7 (1617.1)	6.5 (990.8)	2 3 (353.8)
100	6 9 (1052.0)	7.7 (1174.3)	3.2 (492.1)
150	5.2 (795.2)	7.1 (1084·1)	1.6 (244.4)
200	3.3 (497.0)	4.0 (619.3)	3.0 (458.8)
250	3.0 (461.7)	3.4 (519.2)	1.1 (161.7)
300	2.6 (401.3)	2.3 (344.5)	0.7 (104.2)
400	1.7 (253.4)	1.6 (205.3)	1.1 (163.3)

Values in parentheses denote leaf P-32 content (mean cpm/g leaf)

Table 4.11. Effect of spacing and manuring on the yield of coconut cv. West Coast Tall (nuts per palm per year)

Year	Fertilizer level			Spacing			C D
	M_0	M_1	M_2	S_1	S_2	S_3	(0.05)
1976	2.24	22.40	42.07	9.89	26.25	28.78	7 41
1977	1.06	36.54	55.37	10 96	34.78	47.25	15.78
1978	0.68	33 64	46.78	11.30	30.73	39 06	11.84
1979	2.13	42.12	69.00	17.03	47.63	48.70	10.60
1980	2.78	41.49	52.63	15.73	37.57	43.60	6.91
1981	9.41	16.07	52 83	16.18	39.06	43.08	8.49
1982	10.66	52.14	73.94	24.61	55.54	56.58	9.39
1983	6.44	52.54	70.20	24.14	49.38	55.67	8.78
1984	3.42	40.26	42.74	13.96	34.76	37.69	8.56
1985	11.72	70.45	81.19	32.44	61.78	69.14	13.73
Cumulative yield per palm	107.81	415.85	516.71	106.56	417.70	516.11	73.56

Table 4.12. Effect of fertilizer x spacing interaction on the nut yield of coconut cv. West Coast Tall, Balaramapuram (cumulative yield per palm,1976–'85)

Spacing	Fertilizer level M_0	M_1	M_2
S_1(5 m x 5 m)	13.94	149.12	156.62
S_2(7.5 m x 7.5 m)	121.92	501.92	629.96
S_3(10 m x 10 m)	187.58	596.51	764.25
	CD (0.05)	127.40	

Nitrogen deficiency

The coconut seedlings planted in the laterite soils of Vellanikkara occasionally develop foliar yellowing in one or two years after planting. In order to investigate the cause of the disorder, studies were conducted with field-grown and pot-grown seedlings during 1979-'80 at Vellanikkara.

One-year-old coconut seedlings (var. West Coast Tall) were planted in pits of one cubic meter spaced at 7 m from each other. The soil was laterite with a pH of 5.0 and contained 1.0 per cent organic carbon, 7.0 ppm Bray—1 p and 65 ppm available K. The plants received one-third of the full dose of NPK fertilizers in the first year, two-thirds in the second year and full dose from third year onwards. (The full dose of N, P and K recommended for an adult coconut palm per year was 0.5 kg N, 0.32 kg P_2O_5 and 1.2 kg K_2O).

Most of the experimental seedlings developed foliar yellowing one year after planting. Based on the severity of foliar yellowing, they were grouped into severely affected, mildly affected and normal (healthy). Yellowing generally started on the older leaves which slowly spread to younger leaves. In severely affected plants, the colour of the older leaves turned bright yellow followed by necrosis of the leaflets from tip inwards. Eventually the lower leaves dried up. Mildy affected plants were characterised by yellowing of older leaves with younger leaves turning pale green. Leaf samples were collected separately from three plants belonging to each category.

A pot culture experiment with one-year-old coconut seedlings (var. West Coast Tall) was conducted to study the effect of NPK fertilizer treatments on the foliar symptoms and growth of the seedlings. Fifty five kilograms of air dried and 2 mm sieved laterite soil from the same field were transferred into concrete pots and one seedling, was planted to each pot. After two months, each of the following treatments was randomly allotted to four pots.

1. N : 100 g urea (46 per cent N)
2. P : 75 g superphosphate (16 per cent P_2O_5)
3. K : 100 g muriate of potash (60 per cent K_2O)
4. NPK : 100 g urea+75 g superphosphate+100 g muriate of potash
5. Control : No fertilizer

The fertilizers were applied in four equal splits at six month intervals. At the end of the experimental period, the roots from each plant and samples from every leaf of each plant were collected for analysis.

A comparison of the foliar nutrient composition of the three categories of the field-grown plants namely, severely affected, mildly affected and normal indicated that the concentrations of N, P and S in the leaves of severely and mildly affected plants were much lower than in healthy plants (Table 4.13). The levels of other nutrients viz., K, Ca and Mg did not vary with respect to condition of the plants. The levels of N and P were higher in the upper leaves than in the older ones. The differences in foliar levels of N and P were however more marked than that of S among the three groups of plants. The plants of the pot culture experiment which did not receive N also developed foliar yellowing in 18 months. The yellowing was more pronounced in plants receiving either P or K fertilizer. This indicated that the foliar yellowing was due to nitrogen deficiency.

Table 4.13. Leaf nutrient composition (per cent) of coconut seedlings showing foliar yellowing*

Condition of the seedling	Leaf position	N	P	K	Ca	Mg	S
Severely affected	Upper	1.44	0.102	1.50	0.28	0.33	0.071
	Lower	0.78	0.069	1.45	0.32	0.35	0.089
Mildly affected	Upper	1.59	0.107	1.43	0.28	0.29	0.106
	Lower	0.95	0.075	1.07	0.46	0.33	0.102
Normal (Healthy)	Upper	1.70	0.124	1.31	0.29	0.36	0.142
	Lower	1.12	0.109	1.31	0.26	0.35	0.102

* Mean of three replications

The leaf analysis of these plants revealed that the N content of the foliage of urea-received plants was more than in other plants confirming nitrogen deficiency in the others (Table 4.14). The results further indicated that a foliar level of 1.0 per cent may be considered as the threshold level of N below which visible deficiency symptoms may appear. The leaf N levels of plants receiving no nitrogen also agree well with that found for the field-grown seedlings showing foliar yellowing.

Table 4.14. Root production and leaf nutrient composition (per cent) of coconut seedlings as influenced by NPK fertilizer application

Treatment	Dry weight of roots (g per plant)	N	P	K	Ca	Mg	S
Urea	87.1	1.93	0.085	1.65	0.459	0.195	0.090
Superphosphate	115.0	0.70	0.079	2.32	0.558	0.282	0.092
Muriate of potash	84.4	0.66	0.060	2.85	0.235	0.115	0.063
Urea+super phosphate+ muriate of potash	199.9	1.23	0.082	2.00	0.585	0.208	0.095
No fertilizer (Control)	83 9	1.07	0.075	1.84	0.464	0.270	0.112
C D (0.05)	29.3	0.51	NS	0.54	0.145	NS	NS
SE	9.7	0.17	0.012	0.18	0.048	0.059	0.018

It was also observed that the root production was significantly higher in plants receiving superphosphate (Table 4.14). A perusal of the foliar nutrient composition revealed that the absorption of Ca rather than P was comparatively more in these plants, though significant differences in foliar Ca levels were found only between superphosphate and muriate of potash receiving plants. In order to confirm the role of Ca in root production, the data were subjected to correlation analysis. Interestingly, none of the leaf nutrients except Ca yielded significant correlation ($r = 0.536^*$) with root production. This finding is of significance in the interpretation of the results of fertilizer trials. Perhaps, the often-reported effects of superphosphate application on coconut growth during pre-bearing stage may be the effect of Ca or S rather than P contained in the material.

Effect of Sodium chloride

Application of common salt (NaCl) is a common practice by the farmers of Kerala state though the exact role of NaCl in coconut is not well understood. It is also believed that application of common salt hastens the disintegration of the hard substrata (plinthite) of laterite soil, the major soil type of the state. To find out the effect of long term application of NaCl to coconut palms, an experiment was conducted with 24-year-old hybrid coconut palms at Pilicode in 1976. These palms had been receiving NPK and lime as per the package of practices recommendations of the Kerala Agricultural University till the commencement of experiment. The trial was laid out in a randomised block design with six treatments and four replications maintaining six palm in each plot. The soil of the experimental site was laterite with pH 4.9. The treatments per palm per year consisted of:

1 Control
2 1000 g K_2O
3 750 g K_2O + 250 g Na_2O
4 500 g K_2O + 500 g Na_2O
5 250 g K_2O + 750 g Na_2O
6 1000 g Na_2O

Potassium was applied as KCl and Na as NaCl in two splits. All the palms received 500 g N, 320 g P_2O_5, 300 g CaO and 170 g MgO in two doses. The crop was rain fed and all cultural and management operations were followed as per the recommendations of the Kerala Agricultural University. The soil and leaf samples were collected in 1986 in order to evaluate the effect of continuous application of NaCl on the soil as well as on the plant.

When the mean yield was subjected to analysis of co-variance, the treatments showed significant differences in their influence (Table 4.15). The highest yield was recorded by T_2 (86.84 nuts per palm per year). This was closely followed by T_4 and the difference between T_2 and T_4 was not significant. The yield of palms receiving only NaCl was on par with that of control palms.

As expected, the level of K and Na in leaves differed significantly by the imposition of the treatments (Table 4.16), The foliar concentration of K in palms

Table 4.15. Effect of NaCl on the yield of coconut cv. West Coast Tall

Treatment	K_2O (g per palm per year)	Na_2O (g per palm per year)	Yield (nuts per palm per year): Pre-treatment 1973–'76	Post treatment 1980–'85	Adjusted mean
T_1	0	0	68.84	75.37	69.72
T_2	1000	0	68.31	92.07	86.84
T_3	750	250	58.67	71.32	73.82
T_4	500	500	59.91	83.30	84.81
T_5	250	750	46.07	70.41	83.02
T_6	0	1000	68.96	81.13	75.38
C D (0.05)				15.49	

receiving full dose of K_2O without Na_2O was 1.12 per cent whereas in palms receiving full dose of Na_2O (without K_2O), it was 0.604 per cent. Antagonism between K and Na was evident from the negative correlation between K and Na content of leaf (–0.5914*). In general, the palms receiving high level of Na retained slightly higher amount of Na in their leaves.

Table 4.16. Effect of NaCl on the leaf nutrient level of coconut cv. West Coast Tall

Treatment	K_2O (g per palm per year)	Na_2O (g per palm per year)	Nutrient content of leaf (per cent): N	P	K	Na	Ca	Mg	Cl
T_1	0	0	1.67	0.11	0.62	0.32	0.78	0.20	0.75
T_2	1000	0	1.88	0.12	1.12	0.25	0.76	0.17	0.80
T_3	750	250	1.86	0.12	0.94	0.30	0.74	0.14	0.77
T_4	500	500	1.69	0.12	0.86	0.34	0.72	0.27	0.82
T_5	250	750	2.02	0.12	0.84	0.35	0.78	0.14	0.77
T_6	0	1000	2 11	0.12	0.60	0.35	0.82	0.23	0.79
C D (0.05)			—	—	0.67	0.02	—	—	—

Among the soil chemical properties, only available K status was found to differ significantly (Table 4.17). The observation that pH, EC and aggregate stability of soil are not adversely affected by the application of NaCl indicates that application of NaCl to a laterite soil of pH 4.9 receiving an annual rainfall of 3200 mm will not cause any detrimental effect on the physico-chemical properties of the soil.

In order to assess the influence of common salt on the quality parameters, coconut water and the oil were subjected to various chemical analyses (Table 4.18). The Na content of coconut water increased with increasing rates of application of NaCl. The content of coconut water was significantly correlated with Na content of copra ($r = 0.685^{**}$). The copra weight per nut and oil recovery were not affected by the application of NaCl. It was observed that the level of N, P, K, Ca,

Table 4.17. Influence of NaCl applied to coconut palm on soil chemical properties

Treatment (g per palm per year)	K_2O :	Na_2O	Available K (kg per palm)	Available Na (kg per palm)	Available Cl (kg per palm)	pH	EC (mmho per cm)
T_1	0	0	168	117	95	5.14	0.12
T_2	1000	0	623	108	99	5.29	0.12
T_3	750	250	497	106	85	5.25	0.11
T_4	500	500	469	118	85	5.39	0.10
T_5	250	750	294	121	74	5.39	0.13
T_6	0	1000	189	131	100	5.40	0.11
C D (0.05)			128	19.89	57.2	0.41	0.04

Mg and Cl in copra was not significantly influenced by the treatments. However, Na content of copra increased with increasing level of NaCl applied. The Na content of copra in T_2 was 0.018 per cent whereas in T_6 it was 0.047 per cent. The treatments did not influence the quality of oil.

Table 4.18. Effect of NaCl on quality parameters

Treatment (g per palm per year) K_2O :	Na_2O	Coconut water K (%)	Coconut water Na (%)	Copra weight per nut (g)	Oil recovery (%)	Nutrient content of copra (per cent) N	P	K	Na
0	0	0.203	0.048	123.31	56.47	1.573	0.226	0.776	0.027
1000	0	0.231	0.031	109.19	57.37	1.616	0.211	0.606	0.018
750	250	0.264	0.034	134.75	52.99	1.401	0.190	0.662	0.019
500	500	0.242	0.047	131.88	60.47	1.443	0.205	0.768	0.024
250	750	0.247	0.048	106.44	54.20	1.494	0.221	0.740	0.027
0	1000	0.182	0.062	125.81	58.48	1.452	0.219	0.673	0.047
CD (0.05)		NS	0.013	NS	NS	NS	NS	NS	0.013

NS. Not Significant

Another experiment was laid out in 1976 at Pilicode using newly planted D x T coconut palms. The treatments were the same as those in the above mentioned experiment, with the difference that the treatments were given from the date of planting. These experimental palms have not yet reached the steady bearing stage and therefore their yield data are not discussed in relation to the treatments. In general, observations on the morphological characteristics of the palm show that partial substitution of K_2O by Na_2O as NaCl is possible without affecting the growth parameters of the palm (Table 4.19). Whether the morphological expression will reflect in the yield is to be confirmed from the data to be collected subsequently. The early flowering index of the palm was relatively high in treatments receiving NaCl as compared to those receiving KCl alone. There was a gradual build-up of K and Na in the leaves in accordance with the increasing level of K or Na applied. This was true for the available K or Na in soil also. However the range of variation in the content of available Na in the soil was 104-193 kg/ha while that of available K was from 84-756 kg/ha. The pH, EC, physical constants, moisture retention characteristics and aggregate stability of the soil were] not adversely affected by the application of NaCl.

Table 4.19. Effect of NaCl on growth and leaf nutrient content of Dwarf x Tall palms

Treatment (g per palm per year) K_2O	: Na_2O	No. of leaves on the palm	Leaves produced (1976-1985)	Early flowering index	Nutrient content of leaf (per cent)				
					N	P	K	Na	Cl
0	0	15.30	73.86	1.00	2.05	0.19	0.95	0.21	0.60
1000	0	17.21	73.33	1.94	2.07	0.18	1.86	0.15	0.72
750	250	18.23	78.25	2.58	2.16	0.17	1.52	0.18	0.77
500	500	18.48	79.29	2.38	1.92	0.17	1.31	0.21	0.73
250	750	18.16	72.73	2.63	2.01	0.15	1.20	0.28	0 67
0	1000	17.48	77.46	2.38	1.80	0.16	0.80	0.41	0.67
C D (0.05)		2.84	10.60	1.78	0.407	0.027	0.298	0.066	0.076

Factors affecting nutrition

Cultivation of high yielding varieties and hybrids is being popularised in recent years in a bid to boost up coconut production. Not much attention has been, however, given to the probable differences in their fertilizer requirement. Studies conducted in this line at Pilicode have clearly indicated differential uptake of nutrients by different varieties and hybrids (Table 4.20). Ten popular varieties/ hybrids namely Lakshadweep Ordinary, Philippines, Cochin China, Java, West Coast Tall, Gangabondam, Chowghat Dwarf Green, Lakshadweep Ordinary x Gangabondam, West Coast Tall x Gangabondam and Natural Cross Dwarf (DxT) were compared to examine the relative absorption of nutrients as shown by foliar and soil analysis. These palms were in the age group of 35 to 50 years and were receiving uniform fertilizer doses annually. It was observed that barring the levels of Na, Ca and Cu concentrations of all the other nutrients in the leaves varied significantly among the varieties/hybrids. West Coast Tall, Gangabondam, Natural Cross Dwarf, Lakshadweep Ordinary and Philippines were found to be more efficient than others in the absorption of soil N. West Coast Tall was also found to accumulate more P in the leaf compared to others. The varieties such as Cochin China, Philippines, Lakshadweep Ordinary, West Coast Tall, Gangabondam and Natural Cross Dwarf contained relatively more K in their leaves than others. In general, variety Java seemed to have the lowest concentrations of N, P and K in the leaf. Gangabondam accumulated large quantities of Mg in the leaf. West Coast Tall, Chowghat Dwarf Green, Natural Cross Dwarf and Tall x Gangabondam hybrid absorbed more S. Leaf Fe content of Tall x Gangabondam was found to be the least while that of Cochin China was the highest. The highest concentration of Mn (521 ppm) was observed in Lakshadweep Ordinary x Gangabondam palms as against a level of 181 ppm in Philippines.

Table 4.20. Nutrient concentrations in the leaves of coconut genotypes

Genotype	N (%)	P (%)	K (%)	Mg (%)	S (%)	Fe (ppm)	Mn (ppm)
Laccadive Ordinary	1.34	0.111	1.36	0.272	0.102	378	259
Philippines	1.28	0.118	1.37	0.246	0.094	326	181
Cochin China	1.14	0.111	1.46	0.234	0.078	455	235
Java	1.03	0.107	0.85	0.216	0.084	414	287
Laccadive Ordinary x Gangabondam	1.08	0.114	1.00	0.280	0.100	366	521
Tall x Gangabondam	1.19	0.117	1.09	0.302	0.132	293	323
Gangabondam	1.48	0.119	1.39	0.326	0.086	301	248
Natural Cross Dwarf	1.36	0.114	1.19	0.310	0.142	272	265
Chowghat Dwarf Green	1.08	0.120	1.07	0.272	0.154	386	256
West Coast Tall	1.41	0.133	1.25	0.198	0.172	349	348
C D (0.05)	0.282	0.013	0.369	0.071	0.024	124.1	93.8

The pattern of seasonal variations in the concentrations of macro and micro nutrients in the palms did not differ markedly. Nitrogen content of the leaf declined with the onset of monsoon and increased following the application of fertilizers in September (Fig. 4.5.) Heavy leaching of soil N during the rainy months of June to October must be responsible for the reduced uptake of soil N by the palms. It is also important to note that the N content of the leaf is very low irrespective of the genotype and that at no other time during the year, did it approach the critical level of 1.8 per cent. Perhaps foliar yellowing commonly encountered in palms grown along the West Coast of Kerala may be due to N deficiency. Unlike N, there was a steady absorption of K by the palm with the onset of monsoon which declined, however, in December. With the fall in K level, the absorption of calcium and Mg increased, a trend which can be attributed to the antagonism among these mono and divalent cations. A slight improvement in P content and a drop in S level of the foliage were observed during rainy season. The foliar levels of Cu and Mn did not vary much with season; however, a slight decrease in Fe concentration was noticed.

As in the case of foliar nutrients, the chemical characteristics of soil basins, except for available P and Na ,were also influenced by the variety/hybrids (Table 4.21). The soil pH ranged from 4.38 for Chowghat Dwarf Green to 5.24 for Natural Cross Dwarf. The lowest organic matter content, 0.5 per cent was found in the soil basin of Java as against 1.29 per cent in the case of Gangabondam. These variations cannot be considered as inherent to the soil. Instead, prolonged growth of the palm might have altered the soil environment to varying degrees. Probably, genetic variation in the number and distribution

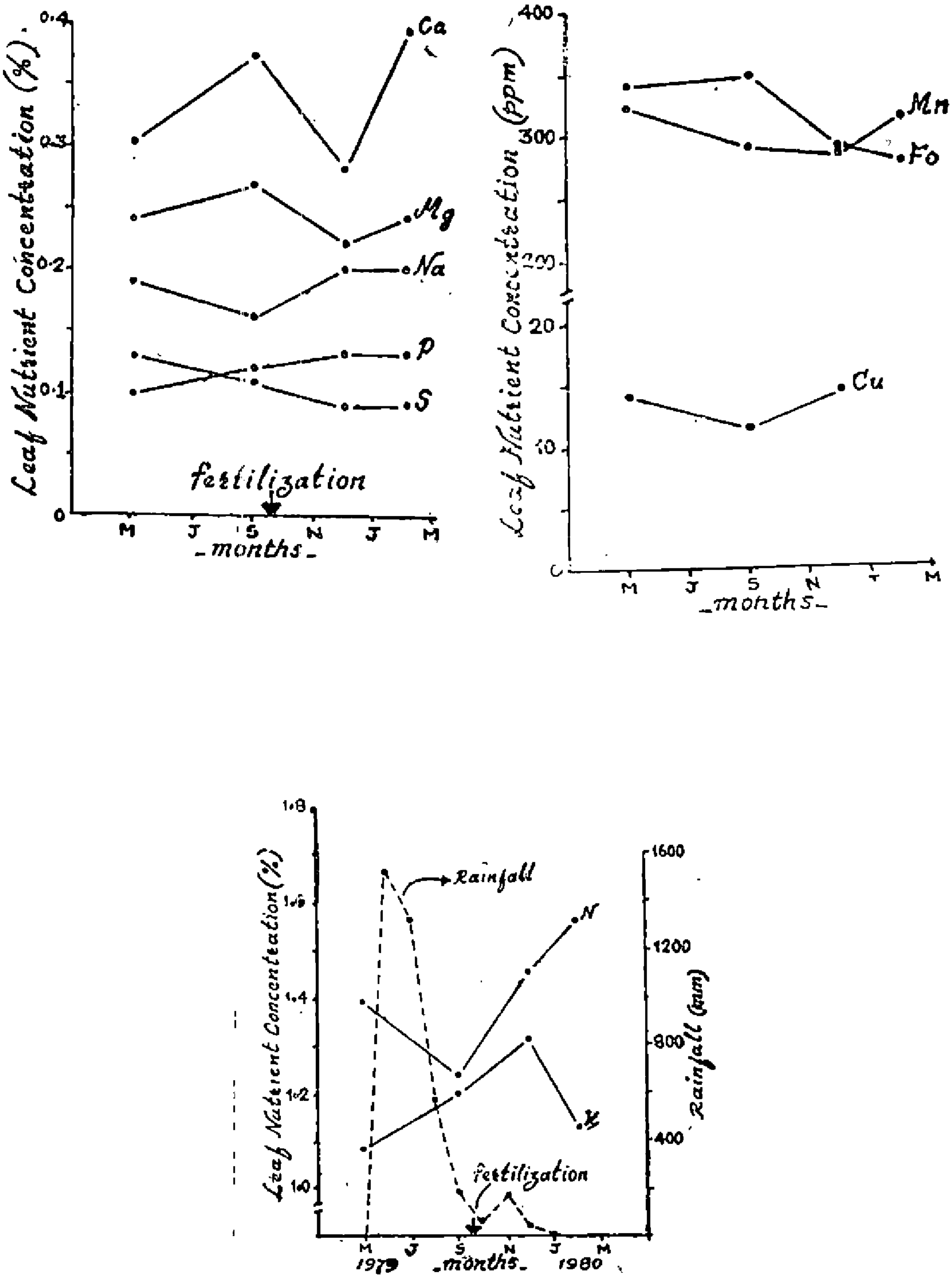


Fig. 4.5. Seasonal variations in nutrient concentration in the leaf

patterns of roots and natural root exudates as well as the rate of degeneration and regeneration of roots might have been responsible for these observed changes in the root zone soil characteristics. Heavy build-up of available P and K were noticed in the soil basins following regular application of superphosphate and muriate of potash to these palms. These results do indicate the possibility of skipping of P and K fertilizers in laterite soil for certain period. The lowest content of exchangeable Ca was observed in the soil basins of the variety Java.

Table 4.21. Yield and chemical characteristics of soil basins of coconut genotypes

Genotype	Yield* (nuts per palm per year)	pH	Organic carbon (per cent)	Available P (ppm)	Available K (ppm)	Available Na (ppm)	Exchangeable Ca (ppm)
Laccadive Ordinary	101.0	5.07	0.71	99.5	465	18.8	512
Philippines	76.2	5.20	1,04	58.5	335	13.6	542
Cochin China	79.0	4.80	0.74	93.7	518	19.0	508
Java	65.6	4,88	0.50	61.5	272	12.4	314
Laccadive Ordinary x Gangabondam	109.8	4.73	0.82	76.6	376	15.0	348
Tall x Gangabondam	92.4	4.93	0.80	38.7	262	16.4	363
Gangabondam	64.6	4.59	1.29	112.2	476	16.2	524
Natural Cross Dwarf	120.0	5.24	1.09	106.5	269	17.6	540
Choughat Dwarf Green	71.5	4.38	1.09	87.2	284	16.8	474
West Coast Tall	63.7	4.89	0.84	101.7	333	15.4	441
C D (0.05)	33.31	0.29	0.20	N S	169	N S	150

* Mean of 6 years N S: Not significant

Soil submergence and nutrient availability

Coconut palm does not thrive well under conditions of poor soil drainage. Despite this, in many parts of Kerala it is grown on bunds in low-lying rice fields and also on mounds in backwater areas where husk-retting for coir industry is a common practice. The fields are generally completely flooded during heavy rains in the monsoon season which normally lasts for four to five months starting from May/June. In backwater areas, where saline water inundation also takes place, flooding persists still longer. It is observed that in certain areas, water may be present at about 30 cm below the surface of the raised beds or mounds even in summer months. In such cases, soil above the water level is more or less saturated with water due to capillary rise.

Soil and leaf samples were collected from two locations viz., Chemancheri and Edakkadu of Kerala state. At each location, it was possible to obtain adjacent areas with and without husk retting. For convenience, the abbreviations HR and NHR will be used hereafter to designate husk-retting and non-husk-retting areas.

respectively. Coconuts were grown on raised beds of approximately 45–60 cm height with two to three rows of palms on each bed. The soil samples were drawn from 15-45 cm layer separately from three beds each of the HR and NHR areas at each location. The soil samples along with the stagnant water were transported to the laboratory in screw-capped polyethylene bottles for pH and redox potential measurements. *In situ* measurement of redox potential of the root zone of coconut was also carried out at each sampling site using a stick electrode (Pt–reference combination electrode). Leaf samples were taken for analysis from the same coconut trees selected for the soil sampling.

In order to examine the changes brought about in pH, EC, Eh, available P, available SO_4^{2-}, Fe^{2+} and Mn^{2+} upon flooding, one soil sample each from HR and NHR areas of the two locations was incubated in glass tubes with distilled water in the laboratory and studied for three months. Electrical conductivity, pH, Eh, available P and available S were determined at different intervals.

Soils at both locations were highly saline and acidic with high content of SO_4^{2-}. The soils were also rich in available P, K and organic matter. Exchangeable Mg was higher than exchangeable Ca in these soils. Exchangeable Fe was also very high probably due to very low pH. Compared to Fe, exchangeable Mn status was very less. Excessive salinity coupled with appreciable quantities of sulphate and relatively higher content of Mg than Ca may be due to sea water inundation in these areas (Table 4.22).

Table 4.22 Physico-chemical characteristics of the air-dry soils

Soil property	Location			
	Cheman-cheri (a)	Cheman-cheri (b)	Edakkadu (a)	Edakkadu (b)
Sand (%)	79.30	82.70	60.10	55.40
Silt (%)	13.30	8.00	22.70	19.30
Clay (%)	5.30	8.00	14.70	23.30
pH (1:2.5)	3.50	3.60	4.80	4.20
EC (mmho/cm)	6.50	6.00	9.60	8.10
Eh (mV)	340.00	330.00	278.00	288.00
Organic Carbon (%)	1.15	0.77	1.39	1.47
Bray–1 P (ppm)	9.60	27.50	19.30	19.30
Ex.K (ppm)	218 00	275.00	364.00	346.00
Ex.Ca (me/100 g)	4.19	3.57	4.78	4.01
Ex.Mg (me/100 g)	6.68	4.84	10.77	9.83
Ex.Fe (ppm)	28.10	43.60	55.30	7.40
Ex.Mn (ppm)	1.80	1.30	4.60	2.20
Av.S (ppm)	1080.00	444.00	828.00	1212.00

a. Non-husk retting area (NHR) Ex. Exchangeable

b. Husk-retting area (HR) Av. Available

In situ measurement of Eh at the root zone of coconut palms revealed that the redox potential was higher in places where retting of husk was practised. It ranged from 139 to 499 mV in HR areas as compared to-111 mV to 174 mV in NHR areas. The H_2S evolved during the anaerobic husk retting process may be responsible for raising the Eh by precipitating Fe^{2+} formed in the soil as FeS.

Studies on the changes in soil characteristics are relevant because alternate dry and flooded conditions exist in many areas. The data relating to the dynamics of nutrient elements and other soil characteristics upon flooding of soils from HR and NHR areas are given in Table 4.23. The soils from husk-retting areas were initially having a lower pH than the soils from adjoining NHR areas. Presumably, increased acidity upon air-drying of the soil could be due to the oxidation of iron sulphides leading to the formation of H_2SO_4. This observation also corroborates with the higher *in situ* redox potential of soils in the HR fields. The lower the initial pH of the soil, less was the increase in pH upon flooding. Thus the pH increased from 3.26 to 3.66 in the HR soil from Chemancheri as against a pH rise to 6.0 in the case of NHR soil from Edakkadu. The pH of the soils, in general, increased during 5 to 10 days of flooding, thereafter it decreased. A slight increase was noticed at 90 days of flooding. Redox potentials of the soils decreased following submergence and attained minimum levels in 5 to 20 days. Flooding for longer periods tended to increase the Eh. The rate of decrease in Eh was faster in NHR soils as compared to HR soils.

Increase in electrical conductivity occurred soon after flooding the soils and reached peak values in about five days. Thereafter, there was a decrease at ten days of flooding. Beyond ten days, the EC increased and maintained the original level. The pattern of change in EC was similar irrespective of the type of location. However, the electrical conductivity was found to be comparatively less in soils from HR areas.

Flooding the soils increased the concentrations of extractable Fe^{2+} (Table 4.23). The release of Fe^{2+} in soils of HR areas was comparatively lower than that in NHR soils. Extractable Fe^{2+} increased exponentially with decrease in Eh. It was noted that a ten-fold increase in Fe^{2+} occurred with an Eh drop of every 233 mV. The 'r' value for this relationship was —0.944** accounting for a variation of 89 per cent. Very high concentration of Fe^{2+} (of the order of 500 to 3025 ppm) attainable in these soils upon flooding may lead to iron toxicity in coconut palms. Compared to Fe^{2+}, the release of Mn^{2+} from the soils following submergence was very less. The data did not reveal any apparent differences in the transformation in Mn between HR and NHR soils.

Submergence of soils resulted in the increase of available P. Reduction of ferric phosphate and phosphate compounds co-precipitated with iron oxide to the more soluble ferrous form was attributed to the release of P in submerged soils. Extractable SO_4^{2-} increased in flooded soils during the initial stages. This increase was almost twice the original sulphate status of the soils. The duration of

Table 4.23. Effect of submergence on the chemical characteristics of soils from husk-retting (HR) and non-husk retting (NHR) areas*

Soil characteristics	Peak values obtained		Duration of flooding for attaining peak values (d)	
	NR	NHR	HR	NHR
pH	5.8	5.90	8	8
Eh minimum(mV)	100.0	50·00	5	17
EC (mmho cm)	12.0	15.00	5	5
Fe^{2+} (ppm)	1500.0	2500.00	10	10
Mn (ppm)	6.0	5.50	5	5
P (ppm)	25.0	30.00	15	15
SO_4^{2-} (ppm)	1100.0	1200.00	Irregular	Irregular

* Mean values of two soils

flooding required for the maximum release of SO_4^{2-} varied considerably among soils. Beyond these peak intervals, the concentration of sulphate decreased, perhaps due to its reduction.

The foliar nutrient levels of the palms along with the critical levels are presented in Table 4.24. The palms were found to be well supplied with all the nutrient except nitrogen whose levels were much below the critical level. This indicates that palms growing on these soils are under nitrogen stress. The nitrogen deficiency may be expected in these areas as a result of denitrification occuring under anaerobic conditions. Absorption of large quantities of Fe was observed in these palms. This is expected because of the very high concentrations of Fe^{2+} attained in these soils upon flooding. In contrast to foliar concentration of Fe, Mn levels were not too high and hence, Mn toxicity may not be a problem in these soils. Moreover, it was observed that the absorption of Mn was influenced by Fe. The Mn levels in leaf increased with Fe upto 320 ppm. Further increase in Fe concentration decreased the Mn levels in the leaf.

Table 4.24. Foliar nutrient levels in the coconut palms grown in submerged soils

Nutrient	Chemancheri		Edakkadu		Mean	Critical level(%)
	NHR	HR	NHR	HR		
N (%)	1.44	1.22	1.45	1.56	1.42	1.80-2.00
P (%)	0.10	0.11	0.13	0.13	0.12	0.12
K (%)	0.96	0.73	1.05	0.96	0.93	0.80-1.00
Ca (%)	0.24	0.46	0.38	0.38	0.37	0.50
Mg (%)	0.39	0.44	0.40	0.45	3.42	0·30
S (%)	0.20	0.16	0.16	0.15	0.17	—
Fe (ppm)	543	323	415	435	429	50 ppm
Mn (ppm)	90	180	106	148	131	60 ppm

Nutrient deficiency diagnosis

Standardisation of leaf tissue for foliar diagnosis of N, P and K in relation to yield was carried out in coconut palms(West Coast Tall)of the NPK fertilizer trial at the Coconut Research Station, Balaramapuram. For this purpose, samples of leaf lamina were drawn separately from all the leaves of the experimental palms and analysed chemically.

The N content of leaf increased with increasing age of the leaf till leaf number 6 and thereafter steadily declined whereas the content of P and K continuously decreased with increasing age of the leaf (Table 4.25).

Table 4.25 Distribution of N, P and K (per cent) in different leaf ranks in relation to level of nutrient applied

Leaf position*	Nitrogen			Phosphorus			Potassium		
	N_0	N_1	N_2	P_0	P_1	P_2	K_0	K_1	K_2
1	1.20	1.99	1.98	0.16	0.15	0.18	1.14	2.24	2.54
2	1.56	1.94	2.01	0.15	0.15	0.17	0.75	2.10	2.38
3	1.54	1.99	2.05	0.15	0.15	0.17	0.57	1.87	2.24
4	1.68	2.19	2.28	0.16	0.15	0.18	0.44	1.68	2.04
5	1.86	2.21	2.11	0.17	0.15	0.16	0.35	1.53	1.92
6	1.93	2.37	2.22	0.15	0.15	0.18	0.36	1.19	1.79
7	1.79	2.22	2.42	0.15	0.15	0.18	0.32	1.30	1.68
8	1.84	2.19	2.67	0.14	0.15	0.18	0.30	1.23	1.65
9	1.79	2.08	2.24	0.15	0.14	0.17	0.28	1.19	1.61
10	1.91	2.15	2.12	0.15	0.14	0.17	0.28	1.15	1.57
11	1.88	2.19	2.05	0.16	0.14	0.16	0.28	1.09	1.55
12	1.77	2.13	1.86	0.18	0.14	0.17	0.23	0.98	1.45
13	1.96	2.19	2.12	0.15	0.13	0.16	0.23	0.98	1.44
14	1.48	2.04	1.98	0.16	0.14	0.16	0.25	0.86	1.37
15	1.51	2.03	1.94	0.14	0.13	0.17	0.26	0.86	1.23
16	1.51	2.19	2.08	0.14	0.14	0.16	—	0.81	1.19
17	1.68	2.10	1.96	0.14	0.12	0.15	—	0.75	1.15
18	1.68	1.96	2.10	0.14	0.13	0.15	—	0.70	1.10
19	1.76	1.96	1.94	0.13	0.14	0.15	—	0.65	1.06
20	1.58	1.94	1.89	0.14	0.13	0.14	—	0.64	1.05
21	1.56	1.82	1.89	0.13	0.12	0.13	—	0.64	0.98
22	1.32	1.84	1.77	0.12	0.13	0.13	—	0.58	0.92
23	1.40	1.82	1.80	0.13	0.13	0.14	—	0.57	0.93
24	1.44	1.73	1.77	0.14	0.12	0.14	—	0.52	0.91
25	1.20	1.59	1.89	0.14	0.13	0.13	—	0.52	0.88
26	1.22	1.61	1.80	0.12	0.12	0.12	—	0.41	0.81
27	1.18	1.70	1.66	0.14	0.13	0.12	—	0.44	0.77
28	1.23	1.51	1.71	0.14	0.10	0.12	—	0.35	0.75
29	1.40	1.49	1.60	0.11	0.10	0.13	—	0.32	0.71
30	1.26	1.33	1.96	0.12	0.09	0.12	—	0.40	0.72

* Starting from the first fully opened one

The coefficiants of partial correlation between yield and content of both N and K in leaf lamina were high for leaf number 2 and therefore, the leaf lamina of the 2nd frond is suggested as the best reflect for the foliar diagnosis of N and K. The P content of leaf was not found to be correlated with yield irrespective of the positions (Table 4.26).

Table 4.26. Coefficients of correlation between yield and N, P and K per cent of leaf (lamina) of coconut palms in relation to leaf position

Leaf position	No. of pairs (n)	Coefficient of correlation N	P	K	Multiple correlation coefficient
1	27	0.395	–0.098	0.449*	0.629**
2	27	0.572**	0.053	0.663**	0.771**
3	27	0.338	0.020	0.576**	0.620**
4	27	0.379	–0.036	0.492*	0.663**
5	27	0.116	–0.120	0.462*	0.517
6	27	0.169	0.144	0.526**	0.541*
7	27	0.352	0.096	0.485*	0.587*
8	27	0.511**	0.021	0.366	0.662**
9	27	0.354	0.069	0.474*	0.586*
10	27	0.480*	–0.257	0.406*	0.626**
11	26	0.336	–0.041	0.424*	0.537
12	26	0.343	–0.213	0.303	0.462
13	24	0.062	–0.025	0.272	0.282
14	22	0.687**	–0.160	–0.056	0.713**
15	20	0.661**	0.012	–0.119	0.666*
16	20	0.484*	–0.076	–0.044	0.514
17	19	0.237	–0.252	–0.257	0.480
18	19	0.445	–0.054	–0.202	0.537
19	19	0.579*	–0.139	–0.008	0.570
20	19	0.216	–0.304	–0.322	0.502
21	19	0.229	–0.229	–0.367	0.468
22	19	0.250	–0.359	–0.427	0.629
23	19	0.361	–0.193	–0.412	0.652*
24	19	0.424	–0.274	–0.417	0.652*
25	19	0.489*	–0.143	–0.261	0.615
26	19	0.617**	–0.021	–0.193	0.666*
27	17	0.540*	–0.090	–0.268	0.667*

** Significant at 1 per cent level

* Significant at 5 per cent level

Another study was undertaken to standardise the foliar diagnostic technique in coconut palm and to work out regression models for predicting the yield based on foliar nutrient contents. The palms were selected from three different zones of Kerala state, namely, the Coconut Research Station, Balaramapuram, the Agricultural Research Station, Mannuthy and the Regional Agricultural Research Station, Pilicode. The leaf samples drawn from leaf positions 2, 10 and 14 from each palm were analysed for N, P, K, Ca, Mg and Na. Attempts were made to standardise the leaf position and nutrient status which will best reflect the yield as well as the critical levels of the nutrients in the index leaf.

The observations revealed that application of N, P and K resulted in an increase in the content of these nutrients in the 2nd, 10th and 14th leaves. The number of leaves retained by the palm was mainly a function of potassium applied. The highest correlation of 0.710** was registered for the leaf position 10. The number of leaves retained was also significantly correlated with yield (r=0.735**).

The yield of the palms was significantly correlated with nitrogen content of 2nd, 10th and 14th leaves, the highest coefficient of partial correlation being registered by the 10th leaf (r=0.499**). The partial correlation coefficients between yield and phosphorus content of leaf lamina of the three leaf positions were not significant. The coefficient of partial correlation between yield and potassium contents of 2nd and 10th leaves were significant, the highest values of 0.432** being recorded by the 10th leaf. On the other hand, the contents of calcium, magnesium and sodium in the leaf lamina showed significant correlation with yield only in the case of the leaf position 14 (Table 4.27a and 4.27b).

Table 4.27a. Coefficients of correlation between yield and NPK content of the leaf lamina in relation to leaf position

Leaf position	Location	No. of pairs (n)	Coefficient of correlation (r) N	P	K
2nd	Balaramapuram	214	0.315**	–0.031	0.319**
	Mannuthy	60	0.334**	0.083	0.223
	Pilicode	60	0.402**	–0.213	0.842**
	Pooled	334	0.475**	–0.164**	0.355**
10th	Balaramapuram	192	0.611**	0.027	0.191**
	Mannuthy	60	0.488**	0.145	0.215
	Pilicode	60	0.369**	–0.103	0.563**
	Pooled	312	0.518**	0.199**	0.448**
14th	Balaramapuram	163	0.365**	–0.009	–0.172*
	Mannuthy	60	– 0.071	0.036	0.270
	Pilicode	60	0.366	0.014	0.185
	Pooled	283	0.338**	0.205**	0.223**

* Significant at 5 per cent level
** Significant at 1 per cent level

Table 4.27b. Coefficients of correlation between yield and Ca, Mg, and Na content of the leaf lamina in relation to leaf position

Leaf position	Location	No. of pairs (n)	Coefficients of correlation (r)		
			Ca	Mg	Na
2nd	Balaramapuram	214	—0.166*	—0.103	—0.225**
	Mannuthy	60	—0.250	0.249	—0.236
	Pilicode	60	—0.595**	—0.096	—0.058
	Pooled	334	—0.058**	0.049	—0.012
10th	Balaramapuram	192	—0.060	—0.086	0.807
	Mannuthy	60	—0.063	—0.021	—0.022
	Pilicode	60	—0.248	—0.294*	—0.167
	Pooled	312	0.067	—0.130*	—0.035
14te	Balaramapuram	163	0.271**	0.263**	—0.057
	Mannuthy	60	—0.176	0.191	0.092
	Pilicode	60	—0.202	—0.143	0.056
	Pooled	283	0.386**	—0.060	0.215**

* Significant at 5 per cent level
** Significant at 1 per cent level

Nutrient distribution pattern in the crown

A comparison of nutrient distribution in the crown of healthy and root (wilt) diseased palms was made in another study. The concentration of N increased from the first (from the top) to the fourth leaf and then maintained a steady level upto 15th leaf beyond which there was a gradual decrease in the root (wilt)-diseased palm (Fig.4.6). Almost similar pattern was seen in healthy palms also. Nevertheless the N content of healthy leaves was comparatively much lower than that of diseased palms especially in the upper 16 fronds. In the case of phosphorus, the concentration increased initially upto 4th frond in the diseased palms and decreased gradually thereafter. The healthy palms showed a gradual decrease in P content from first to the last frond. In younger leaves upto 10th frond, the concentration of P was higher in the diseased palms than in healthy ones. Beyond 14th leaf, the concentration of P in the diseased palms was less than that of the healthy palms. In both healthy and diseased palms, there was a gradual decrease in foliar K level with increasing age of the leaves. As in the case of N, the K level of the healthy fronds was relatively less than that of the diseased ones.

A gradual increase in the concentration of foliar Ca was observed with increasing age of the frond in both healthy and diseased palms (Fig.4.7). Calcium levels were higher in diseasad palms upto the first twelve ranks compared to the healthy ones. However, it was less than in the healthy palms beyond 14th leaf. Magnesium levels in the foliage decreased steadily with increasing rank of the leaf. The diseased palms registered a higher Mg content in all the leaves than healthy palms. In the case of S, the concentration increased upto the 8th frond beyond which there was not much difference in healthy palms. Eventhough a similar trend was seen in

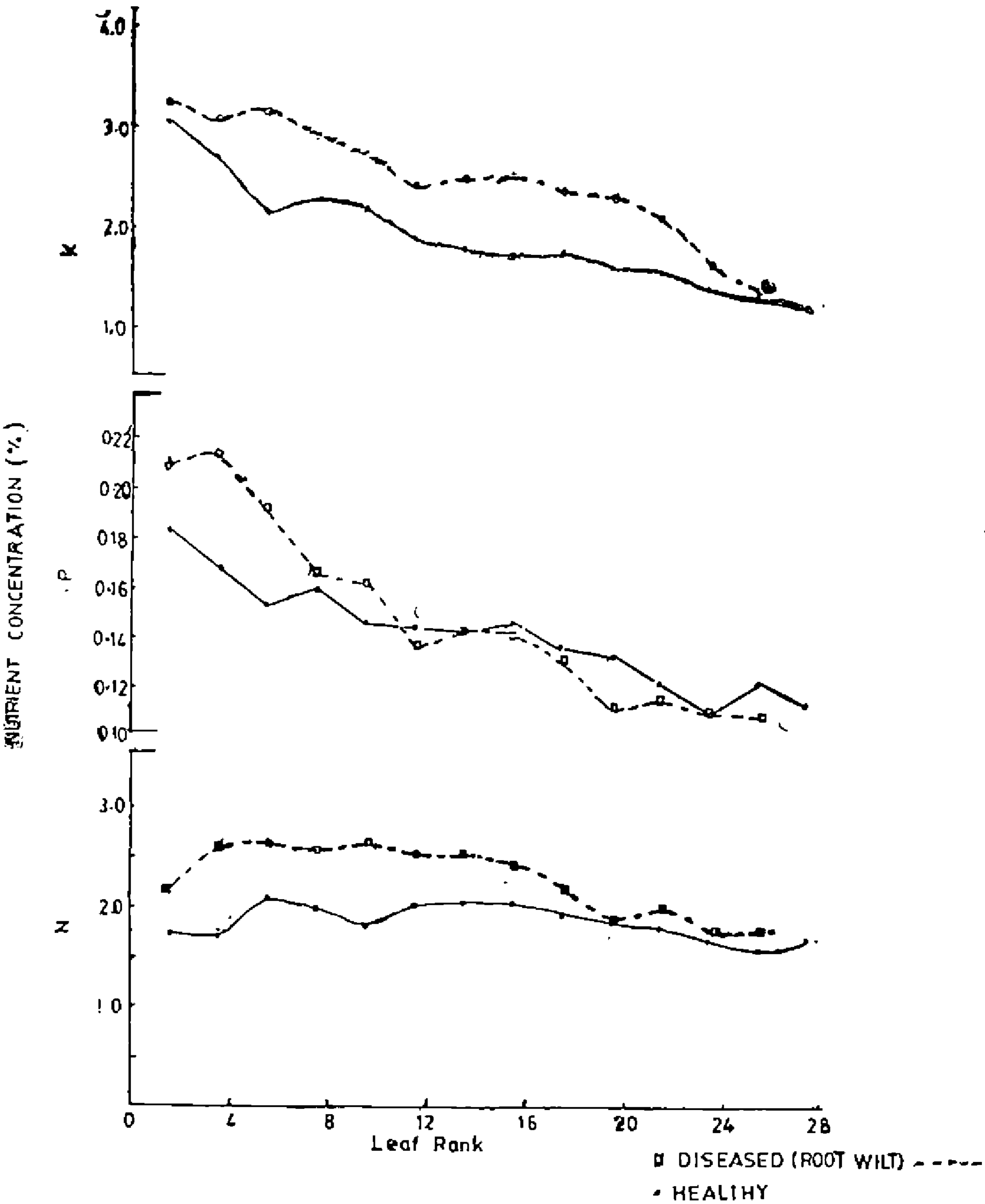


Fig. 4.6. Distribution of N, P and K in the leaves of healthy and diseased palms.

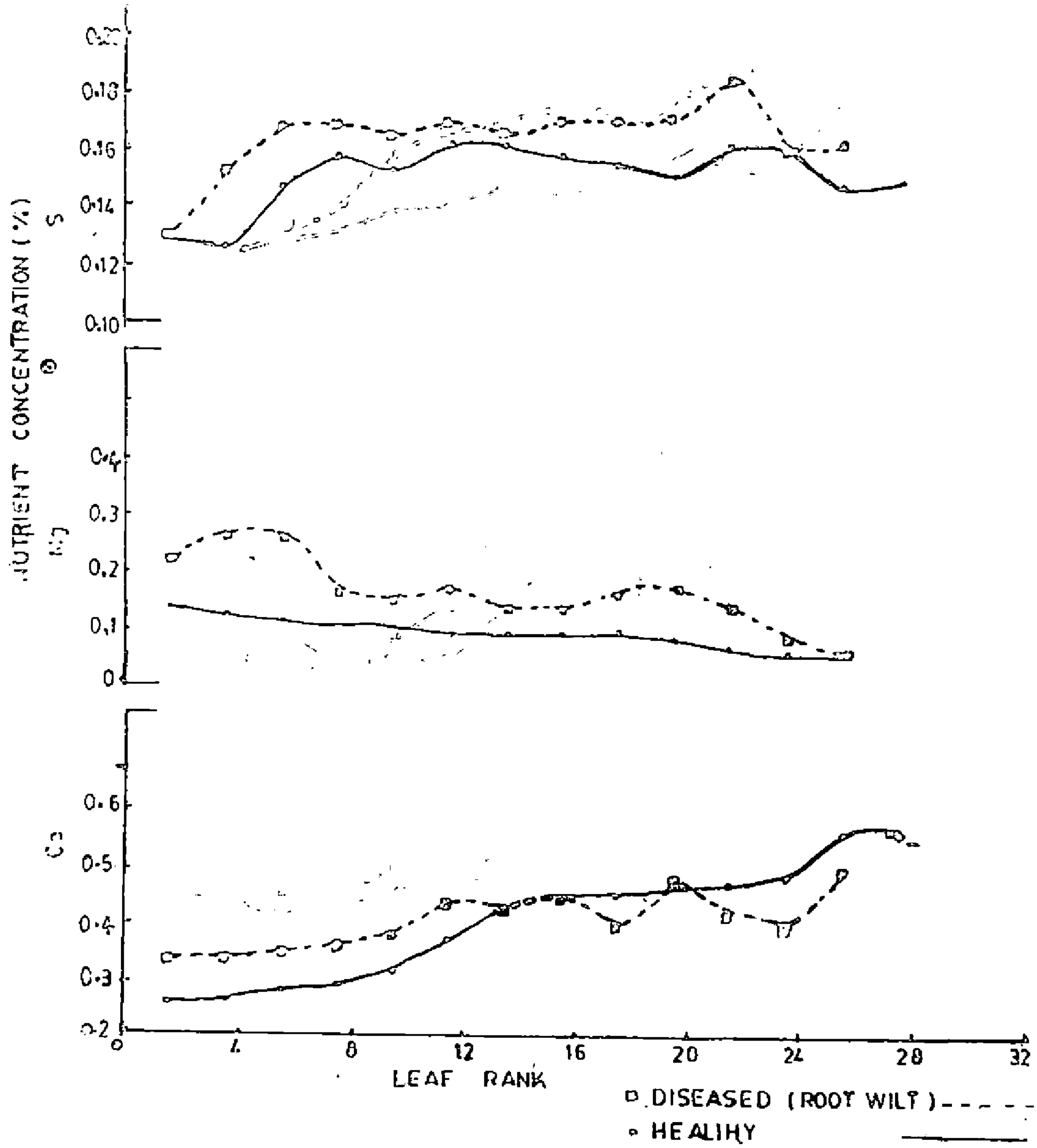


Fig. 4.7 Distribution of Ca, Mg and S in the leaves of healthy and diseased palms.

the diseased palm also, a decrease in levels occurred in leaves beyond the 20th rank. Upto this rank, the concentration of S was higher in the diseased palms than in the healthy palms.

Iron levels did not change much with the age of the leaves (Fig.4.8). The concentration of Fe was more in the leaves of the diseased palms. The manganese concentration remained the same upto 10th leaf and increased thereafter upto 16th leaf in the healthy palms. Beyond 16th leaf, Mn levels remained almost constant. In the diseased palms, Mn levels were higher than in healthy palms. However, the pattern of distribution of Mn was almost the same upto 20th frond; thereafter, there was an increase in the older leaves.

Generally, the diseased palms registered a higher level of nutrients in their foliage than the healthy ones except for P and Ca. In these two cases, the foliar levels were less than that of the healthy palms in the older leaves beyond the 12th frond. Another observation was that for most of the nutrients, the differences in levels were much more conspicuous in the younger leaves than in the older leaves. In fact, the differences in nutrient levels between healthy and the diseased palms were absent for P, S and Ca if the nutrient composition of the 14th leaf was considered for comparison. The differences in nutrient levels were much more pronounced if leaf ranks 4 to 6 were considered for comparison. 'This indicates that the generally

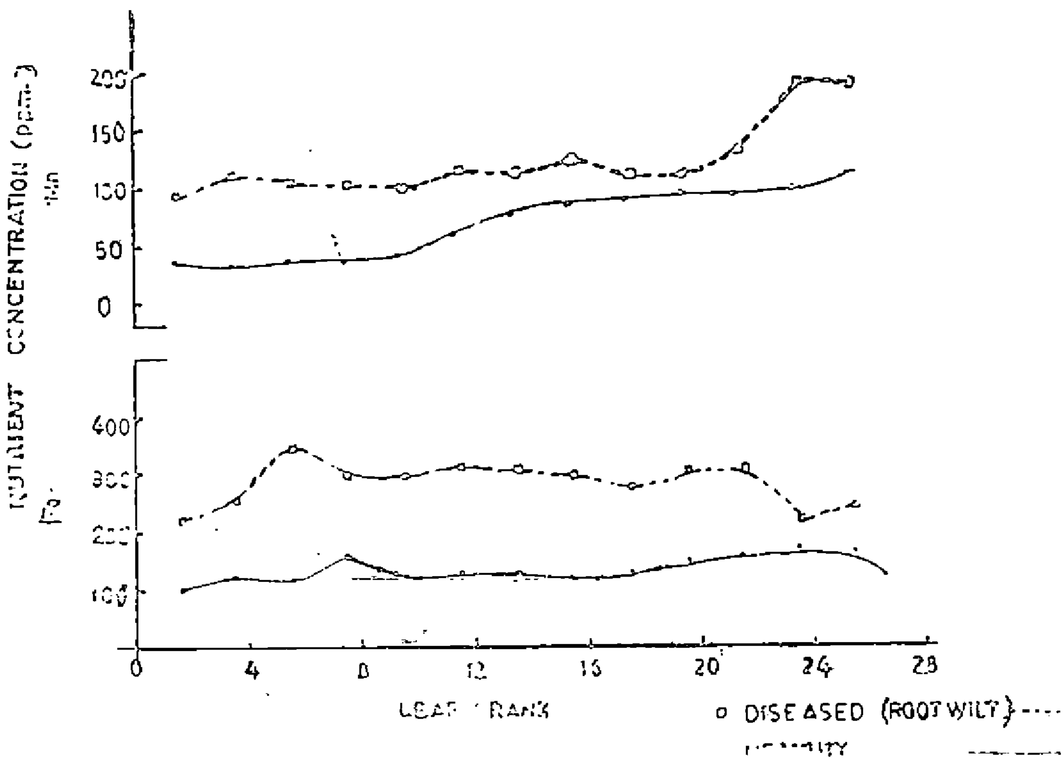


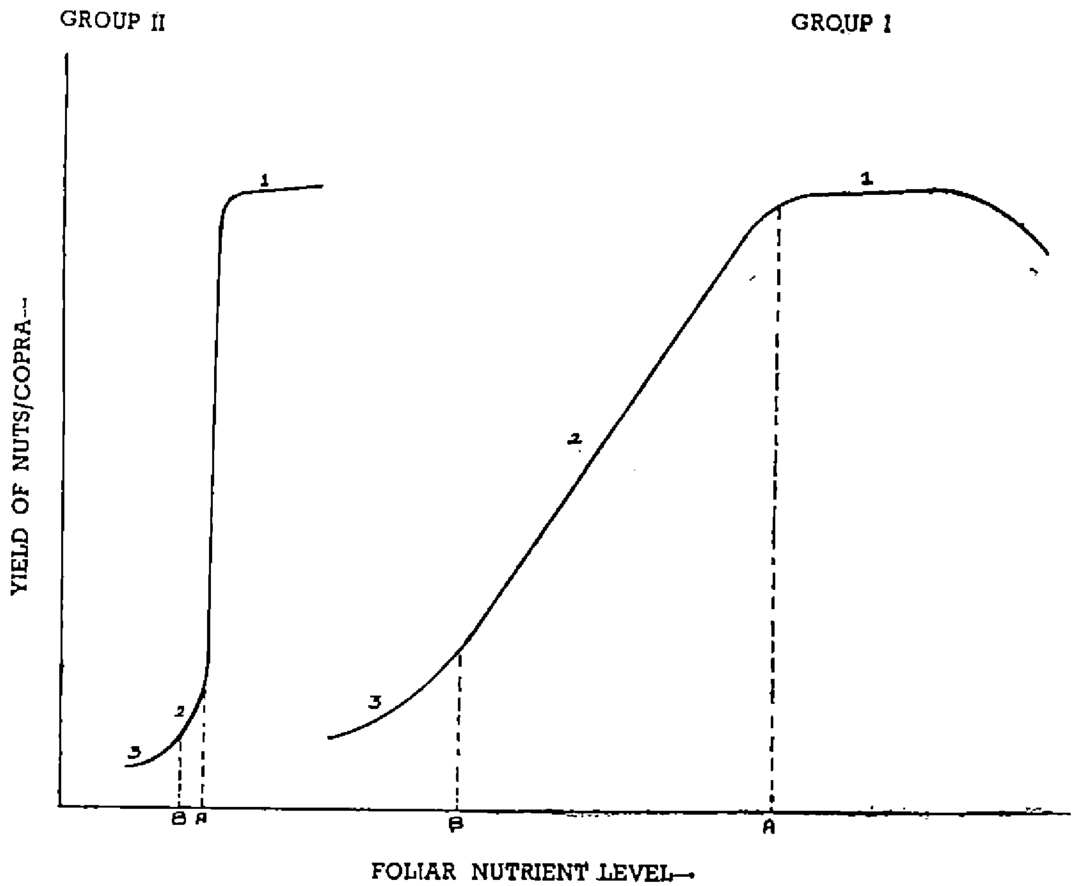
Fig. 4.8. Distribution of Fe and Mn in the leaves of healthy and diseased palms.

accepted procedure of sampling the 14th leaf for nutrient analysis in coconut may not hold good, if comparison is to be made between the healthy and root (wilt) affected palms. For this purpose, younger leaves will be more suitable.

The distribution patterns of several nutrients studied in the coconut crop indicate that N, P, K and Mg are relatively more mobile in the palm than Ca, S, and Mn. Perhaps, this may be the reason for the decrease of levels of the former nutrients with the age of the leaves.

Proposed technique for nutrient deficiency diagnosis

The essential mineral nutrient elements in coconut have been distinguished into two groups based on the yield response to the applied fertilizers and the nature of the relationships between foliar nutrient level and yield of nuts and/or of copra. (Fig. 4.9)



A – critical level, B – level below which visual deficiency symptoms appear. Regions 1, 2 and 3 represent foliar levels associated with sufficiency, latent deficiency and visual deficiency symptoms respectively.

Fig. 4.9. The relationships of foliar nutrient concentrations with yield

Group-I nutrient elements which are directly involved in coconut production include N, K and Cl while Group-II nutrients which adversely affect the palm yield only when their levels in the leaf are too low for the satisfactory growth, comprise P, Ca, Mg, S and probably the micronutrients as well. It is proposed that chemical diagnosis and correction of deficiencies based on foliar critical levels are effective only in the case of Group-I nutrients while visual diagnosis is the most practical approach in the detection of deficiencies of Group-II nutrients. Routine leaf analysis for the diagnosis of latent deficiencies of N, K and Cl and correction of their deficiencies based on foliar critical levels has been recommended for sustained yield in coconut gardens. Regular monitoring of the foliar levels, of Group-II nutrients is not recommended. The leaf analysis, in this case, will be helpful only to confirm the visual deficiency symptoms of the suspected nutrient.

Soil testing

Eventhough 'chemical analysis of soil' has been recognised as a means of detecting deficiencies or toxicities of nutrient elements, not much attention has been given in this area to develop soil test methods suitable for coconut gardens. Slow progress in the development of soil tests may be mainly due to the laborious nature of soil test—yield calibration studies with a perennial tree crop like coconut.

In view of its importance, studies were conducted at the College of Horticulture, Vellanikkara, to relate nutrient concentrations in various soil zones of coconut rhizosphere with that of the foliar nutrient concentrations. Among the available nutrients studied namely, P, K, Ca, Mg, S, Fe, Mn, Zn and Cu, significant correlations were obtained only for K. Available K content (ammonium acetate extract) of 0-25 cm soil depth was positively correlated with K content of 6th leaf (r=0.657**) and 14th leaf (r=0.694**). The correlation coefficients were 0.804** and 0.715**, respectively, for the 6th and 14th fronds when 50-70 cm soil core was considered. Available K content of 75-100 cm depth also yielded positive correlations of 0.611** and 0.731** with the K levels of the 6th and 14th leaves, respectively. The correlations between available K content of 25-50 cm and 0-50 cm soil depths and foliar K levels were, however, not significant.

The soil nutrient concentrations were also correlated with yield of nuts (Table 4.28). Here again, the soil test values for 0-50 cm soil depth were not correlated with yield. In the case of 0-25 cm depth, exchangeable K was positively correlated with yield while in the case of 25-50 cm depth, available Fe and available Cu gave positive correlation with yield. Exchangeable K and available Zn content of the 50-75 cm soil depth were positively correlated with yield, whereas, in the case of 75-100 cm soil depth, only exchangeable K showed significant relationship with yield. The results indicate that ammonium acetate extractant is suitable for evaluating the available K status of the coconut soil basins. The data also suggest that taking 0-50 cm soil for available K tests in coconut gardens may not give reliable information on the soil K availability to the palm. Instead, soil samples from 0-25 cm depth or from deeper layers below 50 cm would be more appropriate and suitable for the purpose. Eventhough 0-25 cm soil layer does not support active roots, good correlation was obtained between the K content of this layer and foliar K level and yield. Perhaps it may be because the K concentration in this surface layer might be influencing the K concentration of the deeper layers also.

Table 4.28. Correlation (r) between soil test values and coconut yield

Soil characteristics	Soil sampling depth (cm)				
	0-50	0-25	25-50	50-75	75-100
Organic carbon	0.316*	0.085	0.555*	0.286	0.845**
Bray 1P	—0.100	—0.113	—0.051	—0.230	—0.168
Exch. K	0.093	0.506*	0.218	0.520*	0.717**
Exch. Ca	—0.068	—0.385	0.166	—0.184	0.067
Exch. Mg	0.033	—0.376	—0.128	0.006	0.106
Available S	—0.057	0.122	0.122	0.135	0.269
Available Fe	—0.112	0.173	0.502*	0.129	0.004
Available Mn	0.087	—0.096	—0.122	—0.222	—0.166
Available Zn	—0.207	0.306	—0.024	—0.501*	0.151
Available Cu	—0.031	0.246	0.547	0.128	0.241

* Significant at 5 per cent level

** Significant at 1 per cent level

df: 14

The available Fe and Cu contents in the 50-75 cm depth were also correlated with yield. However, the trends in the relationships of those nutrients in other soil depths were not as consistent as that obtained for K.

A striking influence of the organic carbon content of 0-50, 25-50 and 75-100 cm soil depths on yield was observed. As the palms were not receiving organic matter applications, the changes which had occurred could be mainly due to the rate of addition of organic matter through degeneration of roots as well as root exudates over a long period.

CHAPTER 5

Agrometeorology of Coconut

G. S. L. H. V. Prasada Rao

Coconut is grown in the low and mid land regions of Kerala under rainfed conditions. Though the state is endowed with plentiful rainfall (1479 mm at Parassala in the south to 3562 mm at Hosdurg in the north), the crop is affected by a prolonged drought from January to May. This is particularly true of the northern districts of Cannanore and Kasaragod where a dry spell prevails from November through May. This adversely affects crop growth and production. It is due to this reason that nut production per unit area is less in the northern parts of Kerala when compared with that of the southern districts, where the rainfall is evenly distributed Being a coastal state, the surface air temperature is more uniform throughout the year, the mean annual temperature being 27°C. Surface temperature, therefore, does not inhibit plant growth and production. The weather factors like low solar radiation, high relative humidity, high rainfall and cloudiness and low evapotranspiration during the south-west monsoon together with the soil moisture deficit during the summer hamper nut production to a great extent.

Weather parameters and nut yield

The nut yield of 168 West Coast Tall palms planted in 1922 under rainfed conditions in block D of the Regional Agricultural Research Station, Pilicode was gathered from 1942 to 1982 and the correlation between the seasonal rainfall and the yield of three successive years was worked out (Table 5.1).

The study revealed that the second year's yield was positively correlated with October to April rainfall while it was negatively correlated with June to August rainfall. This indicated that the absence of rains and consequently moisture stress during the post and pre-monsoon seasons and high rainfall during the South-West monsoon period adversely affected the second year's yield of coconut. The data on nut yield further showed that the maximum nut yield (70 nuts per palm) was recorded in 1948 and the minimum (15 nuts per palm) in 1951. The high yield in 1948 could be attributed to low water deficit (184 mm) from November 1946 to April 1947 and the low yield in 1951 was due to high water deficit (598 mm) from November 1949 to April 1950. Interestingly, the water surplus during July 1950 (1281 mm) was also high when compared to that of July 1947 (934 mm). It appears that the dry spell for six months from November to April and the high rainfall during July decreased the coconut yield in the following year considerably.

Table 5.1 Correlation between the seasonal rainfall and annual coconut yield, Pilicode, 1942-'82

Parameter	Correlation coefficient (r)	Significance
Rainfall during October to April and yield of first year	−0.0346	NS
Rainfall during October to April and yield of second year	+0.2891	Sig.
Rainfall during October to April and yield of third year	−0.1598	NS
Rainfall during June to August and yield of first year	−0.0340	NS
Rainfall during June to August and yield of second year	−0.3141	Sig.
Rainfall during June to August and yield of third year	−0.0112	NS

N S. Not Significant

Sig. Significant

The influence of weather parameters on the yield of coconut grown in the back water areas of Kuttanad under rainfed conditions was also studied from the data available at the Regional Agricultural Research Station, Kumarakom. The yield data gathered over a period of six years from 1981 to 1986 were utilized. Weather parameters such as the maximum and minimum temperatures, relative humidity, rainfall, number of rainy days and the average rain per day were considered for the study. Correlations were worked out between each of the above weather elements and the average annual nut yield for that year and for the two successive years. A significant positive correlation was found between the monsoon rainfall and the first and the third year-nut yields (Table 5.2). The average rainfall per day during the year and the monsoon season (June—September) had a significant negative correlation with the second year's nut yield. A positive correlation between the average rainfall per rainy day during the monsoon season and the third year's nut yield was also observed.

The correlations between the different weather elements and nut yield are presented in Table 5.3. It could be seen that there was a significant negative correlation ($r = -0.9212$) between the yield of nut during the third year and the annual mean maximum temperature of the first year. However, the values of correlation were not significant during the monsoon (June—September) but significant during the pre-monsoon (February—May) and post-monsoon (October—January) periods. The reasons for a significant decline in yield during the third year waa attributed to the high temperature prevalent at the initial stages of inflorescence development.

Table 5.2. Correlation between rainfall and annual coconut yield, Kumarakom, 1981–'86

Variable	First year	Second year	Third year
Total rainfall and yield	+0.4362	—0.4686	+0.6590
Monsoon rainfall and yield	+0.8069*	—0.7034	+0.8352*
No. of rainy days and yield	+0.1585	+0.2360	+0.1708
Monsoon rainy days and yield	+0.8174*	—0.6250	+0.7225
Average rainfall per rainy day during the year and yield	+0.4817	—0.8365**	+0.7356
Average rainfall per rainy day during the monsoon and yield	+0.0941	—0.7344*	+0.9135**

* Significant at 5 per cent level, ** Significant at 1 per cent level

The increased nut yield in the third year due to an increase in the annual rainfall could be due to enhanced production of female flowers. The number of female flowers in coconut is determined two years prior to the maturity of nuts. The correlation between the monsoon rains and yield also followed the above pattern of response and the 'r' values were still higher, indicating the importance of monsoon rains in determining the yield of coconut in the backwater regions of Kuttanad.

Table 5.3. Correlation between weather parameters and nut yield

Sl. No.	Characters correlated	'r' value
1.	Pre-monsoon mean maximum temperature x 3rd year yield	—0.7794*
2.	Post-monsoon mean maximum temperature x 3rd year yield	—0.8947**
3.	Annual mean maximum temperature x 3rd year yield	—0.9212**
4.	Monsoon rainfall x current year yield	+0.8069*
5.	Monsoon rainfall x 3rd year yield	+0.8352*
6.	Number of rainy days in monsoon x current year yield	+0.8174*
7.	Annual average rainfall per rainy day x second year yield	—0.8365*
8.	Average rainfall/rainy day during monsoon x second year yield	—0.7344*
9.	Average monsoon rainfall/rainy day x third year yield	+0.9135**
10.	Pre-monsoon mean relative humidity x current year yield	—0.8462**

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

Rainfall and button shedding

The studies conducted at the Regional Agricultural Research Station, Pilicode during 1983–'84 to qualify the effect of rainfall on button shedding on ten West Coast Tall palms of uniform age and growth indicated that the number of female flowers and percentage button shedding were low during December to February (Table 5.4). A significant positive correlation (+0.7848) was also observed between the number of female flowers and the percentage button shedding.

The maximum number of female flowers (38.43 per palm) was produced during the summer months (March—May) and the minimum (13.38 per palm) during the winter (December - January).

Table 5.4. Seasonal variations in female flower production and percentage button shedding in coconut cv. West Coast Tall

Season	Female flowers per palm (No.)	Button shedding (per cent)
Summer (March—May)	38.43	78.38
South-West Monsoon (June—September)	29.40	83.02
North-East Monsoon (October—November)	24.73	69.70
Winter (December—February)	13.58	39.12

The button shedding attained the highest value of 83.02 per cent during the South-West monsoon. The study also indicated significant positive correlations between the percentage button shedding and the amount of rainfall, the intensity of rainfall and the minimum temperature (Table 5.5).

Table 5.5. Correlation between different weather elements and button shedding (per cent), 1983-'84

Weather parameter	Correlation coefficient (r)	Level of significance
Maximum temperature (°C)	—0.3243	N S
Minimum temperature (°C)	+0.5892	0 05
No. of rainy days	+0.1406	N S
Rainfall (mm)	+0.5598	0.01
Intensity of rainfall (mm/h)	+0.5279	0.01
Bright sunshine (h/day)	—0.4513	N S
Relative humidity (per cent) in the morning	—0.1330	N S
Relative humidity (per cent) in the evening	+0.1525	N S
Pan evaporation (mm/day)	—0.2407	N S

N S = Not significant

Drought and nut yield

The coconut palms in the northern districts of Kerala are generally affected by soil moisture stress from December to March under normal conditions. The prolonged dry spell extending upto May often aggravates the soil moisture stress further. The unprecedented drought during 1982-'83 (no measurable rainfall was received from 8th November 1982 to 13th June 1983 at Pilicode) severely affected the coconut gardens in the tract. Utilizing the data on weekly soil moisture deficit and the expression of drooping symptoms of coconut leaves (drooping of lower leaves of coconut palms is an early symptom of the soil moisture stress) during this period, weekly aridity indices were worked out at the Regional Agricultural Research

Station, Pilicode and an arbitrary classification was derived for assessing the effect of drought on coconut palm (Table 5.6).

Table 5.6. Criteria for assessing the effect of drought on coconut—an arbitrary clasification

Aridity index (%)	Visual stress symptoms on coconut palm	Drought intensity rating	Standard week in which symptoms are noticed
65	No visual symptoms	Slight	46-51 (12th November to 23rd December)
65-85	Drooping of lower leaves	Moderate	52-4 (24th December to 28th January)
85-100	Beginning of drying of drooped leaves; button shedding	Large	5-13 (29th January to 1st March)
Prolonged with 100 for 5 weeks	Drying of drooped leaves; falling of tender and immature nuts; burning on nuts due to the high intensity of radiation	Severe	14-17 (2nd March to 29th April)
Prolonged with 100 for 5-10 weeks	Drying symptoms due to drying up of the spindle leaf	Disas-trous	30th April to the onset of monsoon (June 13th in 1983)

According to this classification, the first visual symptom of moisture stress (drooping of leaves) was manifested when the weekly aridity index reached 65. An aridity index above this led to severe loss in yield. This classification, based on visual symptoms of drought on coconut, needs further refinement to relate drought expression with the physiological aspects of growth *vis-a-vis* moisture stress.

The monthly aridity indices during December to April for the selected stations of Kerala have been computed using the climate normals and the data are presented in Table 5.7.

Table 5.7. Mean monthly aridity indices (%) from December to April at selected stations of Kerala

Station	December	January	February	March	April
Kasaragode	37.69	75.36	90.44	93.29	74.52
Pilicode	37.69	65.94	85.29	92.07	64.33
Cochin	10.22	38.85	44.27	49.04	8.86
Trivandrum	4.38	28 05	46.56	49.35	17.08

It could be seen that in the southern districts of Kerala, the aridity index seldom goes above 65 per cent during summer. The coconut gardens in the southern tracts suffer from soil moisture stress under normal conditions.

Severe drought occurred in the northern districts during January-May, 1983. However, the effect of 1983 drought on nut production was pronounced only in the succeeding year (Table 5.8).

Table 5.8. Monthly and annual nut yields of coconut in the Regional Agricultural Research Station, Pilicode during 1979-'85 (Area of the farm : 25 ha)

Month of the year	1979-'82 (mean)	1983*	1984		1985
January	9735	12649	12346	(2.40)**	9421
February	12499	17632	11915	(32.42)	15258
March	15142	21139	12090	(42.80)	23872
April	18822	24951	11732	(52.97)	27585
May	17321	27341	11293	(58.69)	23016
June	11767	21752	8452	(61.14)	18232
July	12390	18269	6554	(64.12)	18701
August	16435	20354	8509	(58.10)	18301
September	16467	19346	9595	(50 40)	17314
October	11927	16131	9625	(40.33)	16131
November	9795	13248	7917	(40.24)	14443
December	9082	11487	7062	(38.52)	12532
Annual nut yield	161382	224299	117090	(47.79)	214806

* Drought year

** Percentage decline during 1984 to the corresponding month of the previous year (drought year)

The total production in the 25 ha farm of the Regional Agricultural Research Station, Pilicode during 1984 amounted to 1.17 lakh nuts which worked out to 47.8 per cent of the production in the drought year, 1983 (2.24 lakhs). The decline in monthly nut yield was seen from February 1984 to January 1985. It indicated that the effect of drought on monthly nut yield was seen in the eighth month with the maximum reduction (64.1 per cent), during the thirteenth month after the drought period and the fall in the nut yield continued for twelve months.

Assuming that the alternate bearing tendency was manifestable even in the years of drought, the actual yield decline at Pilicode was estimated at thirty per cent due to unprecedented drought in 1983. The possible yield decline due to the alternate bearing tendency was worked out at 16.6 per cent. The overall decline in yield was 28.48 per cent in another study involving fifteen hybrids and West Coast Tall which had exhibited no tendency for alternative bearing.

Drought tolerance of coconut hybrids

The growth and yield response of coconut to drought was studied using the data collected in fifteen hybrids and West Coast Tall planted in 1973 in block N VI of the Regional Agricultural Research Station, Pilicode.

All the test varieties except the hybrids Andaman Ordinary x Chowghat Dwarf Orange, Fijix Chowghat Dwarf Orange, Chowghat Dwarf Orange x West Coast Tall, West Coast Tall x Lakshadweep Dwarf exhibited increasing trend in nut production from 1979 to 1983 (Table 5.9).

The percentage decline in annual nut yield was the highest (70.2) in Chowghat Dwarf Orange x West Coast Tall, followed by Fiji x Chowghat Dwarf Orange (56.6) and West Coast Tall x Chowghat Dwarf Orange (55.5). The yield of the test varieties was recovered in 1985 which indicated that the impact of prolonged drought in a year was more manifested in the succeeding year.

Table 5.9 Annual nut yield of coconut hybrids and percentage decline in nut yield due to drought in 1983

Test variety	Year						Percentage reduction in yield in 1984 due to drought in 1982-83
	1980	1981	1982	1983	1984	1985	
WCT x CDO	13.6	33.0	46.2	66.4	48.2	106.4	27.4
CC x CDO	5.0	15.0	19.0	27.4	33.8	67.2	0.0
AO x CDO	5.2	26.0	21.8	58.4	32.2	77.8	44.7
LO x CDO	10.0	21.6	21.6	50.6	24.4	67.0	51.8
Fiji x CDO	10.8	37.2	31.2	74.6	32.4	89.2	56.6
Fiji x GB	3.4	12.0	30.4	34.2	37.8	41.0	0.0
WCT x MDY	18.8	59.8	64.4	79.4	60.2	112.0	24.2
WCT x TBL	5.6	25.2	33.4	37.8	38.2	88.8	0.0
WCT x SS	8.2	25.0	35.2	54.6	50.4	81.2	7.7
WCT x CDG	29.0	44.0	50.0	102.8	45.8	111.8	55.5
WCT	0	2.6	12.3	26.6	24.6	35.4	7.5
CDO x WCT	3.2	18.0	15.4	48.4	14.4	82.4	70.2
CDO x LD	3.8	23.6	15.0	23.4	14.2	71.5	39.3
GB x LO	2.6	24.6	30.6	61.4	30.2	69.8	50.8
WCT x LD	19.0	39.4	37.8	57.2	46.4	80.8	18.9
WCT x GB	2.4	20.2	35.0	46.4	46.0	68.4	0.9
Mean							28.5

The data on the total number of leaves produced and the number of drooped leaves in April 1986 (Table 5 10) showed a significant positive correlation (r=0.6603**). It indicated that the palms with a larger number of leaves could not withstand drought as those with a lower number of leaves.

Table 5.10. Expression of drought by palms: April 1986

Hybrids/Variety	Total number of leaves per palm	Total number of drooped leaves	Percentage of drooped leaves
WCT x CDO	25.6	9.4	36.72
CC x CDO	26.6	11.0	41.35
AO x CDO	25.6	9.4	36.72
LO x CDO	23.8	7.6	31.93
Fiji x CDO	24.8	6.6	33.33
Fiji x GB	27.0	8.4	31.11
WCT x MDY	28.6	12.6	44.05
WCT x TBL	26.4	7.4	28.03
WCT x SS	30.0	12.6	41.72
WCT x CDG	39.4	10.8	40.10
WCT	31.2	8.0	32.00
CDO x WCT	31.5	11.0	43.65
CDO x LO	26.5	6.2	29.25
GB x LD	32.8	10.4	39.69
WCT x GB	38.5	9.0	29.22
WCT x LD	32.8	11 6	44.27

The following inferences could be drawn from the investigations:

1) The effect of prolonged drought on nut production is considerable which is evident in the succeeding year.
2) The adverse effect of drought on annual nut yield is less pronounced on low yielders.
3) Drooping of leaves is an immediate expression of drought in coconut and palms with higher number of leaves are more susceptible to soil moisture stress.
4) The period coinciding with initiation of female flowers to opening of spathe is more sensitive to soil moisture stress.
5) Even under good management, drought affects yield up to 30 per cent in the succeeding year.

Thermal regime of coconut root zone

The soil temperature in the coconut root zone in two soil types, lateritic loam and sandy loam, were compared based on the data collected from the farms of the Regional Agricultural Research Station at Pilicode and Nileshwar during 1983-'84. The difference in soil temperature was conspicuous (3.0—3.4°C) in the surface soil while it was not so in the deeper layers (30-70 cm). The range in soil temperature was high (32.8—36.1°C) in the open and low (30.1—32.7°C) in the coconut root zone (Table 5.11).

Table 5.11. Mean annual soil temperature (°C) in the coconut root zone and in the open 1983–'84

Depth (cm)	Open (°C)	Coconut (°C)	Difference (°C)
2.5	36.1	32.7	3.4
10.0	34.0	31.0	3.0
30.0	32.3	30.1	2.2
40.0	32.8	30.6	2.2
60.0	33.0	30.9	2.1
70.0	32.8	30 6	2.2

The mean annual soil temperature in the root zone was in the range of 30.1—32.7°C in the sandy loam while it varied between 27.9—30.6°C in the lateritic loam. The soil temperature inversion was noticed (increase of temperature with depth) beyond 10 cm depth in the lateritic loam but only beyond 30 cm depth in the sandy loam. The root zone temperature and its range were higher in both the lateritic loam and the (30.1—34.1°C) sandy loam (32.4 –37.3°C) during 1983 than in 1984. The difference between the two typical years varied from 0.3 to 3.2°C in the lateritic loam and from 0.5 to 4.1°C in the sandy loam (Table 5.12)

Though the mean soil temperature during the summer was around 34°C and 37°C in the lateritic loam and sandy loam, respectively, the diurnal fluctuations were very high, shooting sometimss upto 60°C in the afternoon hours. Probably, one of the reasons for more number of surface dead roots in coconut gardens in sandy and sandy loam soils is high soil temperature. Studies of this nature need to be carried out in different soil groups in order to understand the effect of soil temperature on the development of coconut roots.

Table 5.12. Thermal regime (°C) of coconut root zone during summer under two different soils in typical years (1983 and 1984).

Depth (cm)	Sandy loam			Lateritic loam		
	1983	1984	Difference	1983	1984	Difference
2.5	37.3	33.2	4.1	34.1	30.9	3.2
10.0	32.6	32.1	0.5	30.1	29.2	0.9
30.0	32.4	30.9	1.5	30.3	29.4	0.9
40.0	32.9	31.5	1.4	31.4	30.7	0.7
60.0	32.6	31.9	0.7	31.1	30.5	0.6
70.0	32.8	31.4	1.4	30.9	30.6	0.3

Seasonal influence on nut development

The monthly variation in nut development of hybrid coconuts was studied at the Regional Agricultural Research Station, Pilicode during the year 1985. Five palms each of the three coconut hybrids, Chowghat Dwarf Orange x West Coast Tall, West Coast Tall x Chowghat Dwarf Orange and Chowghat Dwarf Orange x Lakshadweep Ordinary formed the material for this experiment. The hybrid Chowghat Dwarf Orange x West Coast Tall registered higher (538 g per nut) nut weight than West Coast Tall x Chowghat Dwarf Orange (498 g/nut) and Chowghat Dwarf Orange x Lakshadweep Ordinary (504 g/nut) (Table 5.13).

Table 5.13. Monthly husked nut weight (g/nut), and copra content (g/nut) of coconut hybrids during January, 1985 to January 1986.

	CDO x WCT		WCT x CDO		CDO x LO	
Month	Husked nut weight (g/nut)	Copra content (g/nut)	Husked nut weight (g/nut)	Copra content (g/nut)	Husked nut weight (g/nut)	Copra content (g/nut)
January	1042	—	611	—	820	—
February	696	155	663	190	720	163
March	733	200	700	206	708	183
April	650	200	673	183	675	166
May	700	111	708	201	530	134
June	—	—	—	—	—	—
July	437	121	433	130	280	76
August	366	66	366	100	300	62
September	244	93	303	122	325	100
October	304	91	320	108	350	87
November	330	110	333	113	385	100
December	410	126	373	133	466	133
January	581	172	420	146	500	154
Mean	538	131	498	149	504	123

In contrast, West Coast Tall x Chowghat Dwarf Orange recorded relatively more copra content (149 g/nut) than Chowghat Dwarf Orange x West Coast Tall (131 g/nut) and Chowghat Dwarf Orange x Lakshadweep Ordinary (123 g/nut). All the three hybrids recorded higher nut weight and copra content in the summer months of March, April and May. The fall in nut weight and copra yield was conspicuous in the rainy and post rainy periods (Table 5.14).

Table 5.14. Husked nut weight (g/nut) and copra content (g/nut) during different seasons, 1985

Hybrid	Summer (March-May)		Southern monsoon (June-September)		Post monsoon (October-November		Winter (December-February)	
	Husked nut weight	Copra content	Husked nut weight	Copra content	Husked nut weight	Copra content	Husked nut weight	Copra content
CDO x T	694	170	339	94	317	100	526	155
T x CDO	693	197	394	120	327	110	469	152
CDO x LO	635	161	301	79	367	93	555	155

In the light of the observations made by early researchers that any abnormal weather factor coinciding with the critical phases of nut development would adversely affect the rate of growth and final size of the nut and copra content, an attempt was made at the Regional Agricultural Research Station, Pilicode to work out the relationship between the total heat units during the course of nut development and nut weight. The results indicated a negative relationship between the heat units during the second phase of nut development (4-7 months after fertilization) and the husked nut weight (Table 5.15).

Table 5.15. Total heat units during the second phase of nut development and husked nut weight of coconut hybrids

Month	Heat units (°C) during the second phase of nut development	Variety		
		CDO x T (g/nut)	T x CDO (g/nut)	CDO x LO (g/nut)
January	2018	1942	611	820
February	2040	696	663	720
March	2040	733	700	700
April	2018	650	673	675
May	2040	700	708	530
June		—Not available—		
July	2077	407	433	280
August	2184	366	366	300
September	2259	244	383	325
October	2285	304	320	350
November	2219	330	333	385
December	2219	410	373	466
January	2033	581	420	500
Correlation coefficient between heat units and husked nut weight (r)		—0.83*	—0.82*	—0.72**

* Significant at 0.05 level
** Significant at 0.01 level

There was a marked decline in nut size from July to December in response to an inarease in total heat units, indicating that the total heat units above 2100 day °C were not congenial for nut development. The following quadratic equations were devloped for estimating the nut weight of the test varieties:

$$Y\ (WCT \times CDO) = 26493.2094 - 23.1107\ X + 0.0051\ X^2$$

$$Y\ (CDO \times WCT) = 47766.2579 - 42.2450\ X + 0.0094\ X^2$$

$$Y\ (CDO \times LO) = 55053.4040 - 49.7958\ X + 0.0113\ X^2$$ where Y (WCT x CDO), Y (CDO x WCT) and Y (CDO x LO) are the estimated husked nut weight of the corresponding variety and X is the total heat unit during the second phase of nut development. These equations had multiple correlation coefficients of 0.8689, 0.8443 and 0.7977 for the hybrids Chowghat Dwarf Orange x West Coast Tall, West Coast Tall x Chowghat Dwarf Orange and Chowghat Dwarf Orange x Lakshadweep Ordinary, respectively.

The process of nut development commencing from fertilization of female flower to ripening takes place in three distinct phases covering a total of ten to twelve months. During the first phase (0-4 months), the growth is slow. There is a decline in growth rate after the second phase. The nut development from fertilization to harvest takes more than 12 months (around sixteen months) at higher altitudes. High ambient temperature during the active growth phase adversely affects the rate of growth of the nut with a consequent decline in nut weight under rainfed conditions. Out of all the weather parameters studied, the heat unit, which is a function of temperature, only has a distinct influence on the final nut size.

Crop-weather models

Crop-weather relationships were worked out using the simple agroclimatic index viz., the index of moisture adequacy which is the ratio of actual evapotranspiration to potential evapotranspiration and the nut yield data of West Coast Tall palms. The data from 1946-1971 available at the Regional Agricultural Research Station, Pilicode were made use of. The data indicated that the nut yield of coconut was high (more than 45 nuts) when the index of moisture adequacy was more than 30 per cent in the previous year. A moisture adequacy index of less than 15 per cent indicated a severe moisture stress leading to very poor yield (30 nuts and below) in the subsequent year. An agricultural drought classification has been proposed for the crop depending upon the magnitude of the index of moisture adequacy and its impact on nut yield (Table 5.16).

The correlation coefficients between the monthly index of moisture adequacy in a particular year and nut yield in the succeeding year showed that the index during December to April had a highly significant value (positive) when compared to those of the other periods viz., January—April, February—April and March—April. The availability of soil moisture for the cumulative period from December to April seemed to be more important than for a period of two to three months. Based on this relationship, a multiple linear regression was fitted for estimating nut yield of the following year.

Table 5.16 Classification of agricultural droughts based on the index of moisture adequacy during the summer (December–April) and nut yield of the following year

Index of moisture adequ-acy (%)	Study years	No. of years under the category	Percentage occurrence of years in different yield groups (nuts per palm)					Intensity of drought
			45	40-45	35-40	30-35	30	
30	26	8	87.5	—	—	12.5	—	No drought
25—30	26	9	33.4	22.2	11.1	22.2	11.1	Moderate
20—25	26	5	40.0	40.0	20.0	—	—	Large
15—20	26	2	—	50.0	—	50.0	—	Severe
0—15	26	2	—	—	—	—	100 0	Disastrous

$Y = 18.7212 + 0.284 X_1 - 0.1367 X_2 + 0.5906 X_3 - 0.3245 X_4 + 0.2733 X_5$ where Y is the nut yield of the following year (nuts/palm), X_1, X_2, X_3, X_4 and X_5 are the indices of moisture adequacy for December, January, February, March and April, respectively. The equation had a multiple correlation coefficient of + 0.7087 and was significant at one per cent level.

Forecasting pest and disease incidence

Stem bleeding of coconut is a serious disease in coconut, prevalent in most parts of the northern districts of Kerala state. Drastic moisture changes are known to aggravate the intensity of the disease. It was found that the disease incidence was more in the years of drought when the mean aridity indices were higher than 90 per cent. The following equation was developed for estimating the disease incidence:

$N = 243.0155 + 2.4895 X_1 - 8.8681 X_2 + 3.7445 X_3 + 1.6488 X_4 + 0.2550 X_5$. where N is the estimated number of palms affected due to stem bleeding and X_1, X_2, X_3, X_4 and X_5 are the monthly aridity indices for January, February March, April and May, respectively. The equation had a multiple correlation coefficient of 0.8995 accounting for 80 per cent of the disease incidence.

CHAPTER 6

Water Management in Coconut

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Coconut is mainly grown as a rainfed crop in Kerala. Much of the seasonal variations in coconut yield observed in the state are attributable to the vagaries in rainfall.

How rainfall affects coconut yield? It takes about forty four months for the spadix primordia to develop into a bunch of ripe coconuts. Smaller size of nuts, low copra content and poor yield during September–November are due to the dry spell the palm faces at the time of spadix primordia initiation and early stages of kernal formation. These stages synchronise with the dry spell during January to April. Similarly, bigger sized nuts, high copra content and good nut yield are obtained during January to May. This is because the development stages of the spadix primordia of these nuts fall in the months of June to September, when the crop receives plentiful rainfall. In areas having well distributed rainfall as in Kuttiadi, Kozhikode district, the production of nuts is generally high. This shows that the coconut palm will respond to irrigation and moisture conservation practices.

Effect of moisture stress on yield

The period of development of an inflorescence from initiation to flowering has been estimated to be 32 months for Tall cultivars of coconut. With such a great time lapse between the initiation of leaves and inflorescences in various stages of development present at the same time, it is difficult to relate growth, flowering or yield responses to any particular climatic condition.

The abortion of young developing inflorescences can seriously reduce the yield of coconut. Based on the studies couducted at Nileshwar and Kasaragod in the 1930s, the reason for the abortion of developing inflorescences of coconut palms was traced to a drought effect from fifteen to sixteen months before the spathe opened. The adverse effects of drought during the time of ovary and perianth differentiation were also seen on the low production of flowers on the inflorescence. A recent study on the effect of drought on coconut yield conducted at Pilicode indicated that the decrease in nut yield started from the eighth month with the maximum reduction in the thirteenth month after the drought was over. The decline in nut yield due to drought in 1983 continued for twelve months from February 1984 to January 1985. In another study at Pilicode, it was found that the effect of drought on coconut palm (drooping of leaves) became evident when the aridity index exceeded 65 per cent. The central and southern parts of Kerala never attain aridity indices above 65 per cent while the northern parts experience aridity indices above 65 per cent for 3 or 4 months in the summer.. This is one of the reasons why the productivity of coconut is higher in the southern districts. .

Response to irrigation

Response of coconut palm to summer irrigation has been observed in almost all the experiments conducted, the magnitude of response depending on soil type, depth of water table and moisture conservation practices. At Nileshwar where the soil type was littoral sand, the yield response to irrigation was assessed on a group of 70 year-old palms from 1959 onwards (1959-1965). One group of 35 palms was irrigated in basins of 2m radius once in 5 days with 800 l of water per irrigation. In the other group of 35 palms, an arecanut nursery was raised in the interspaces and the whole area was flood-irrigated with 5 cm of water once in 5 days. The rainfed crop in the littoral sand was almost a poor specimen with tapering crown and 6 to 10 leaves. On irrigation, the functional leaves increased to 26.5 in the case of basin irrigation and 42.3 in the case of flood irrigation (Table 6.1). Basin-irrigated palms recorded a mean yield increase of 22.6 nuts as against the yield increase of 85 4 nuts in the case of flood irrigation. The response to basin irrigation was comparatively high in red sandy loam soil than in littoral sand. In the latter soil type having low moisture holding capacity better irrigation response could be achieved by giving flood irrigation.

In another experiment laid out in the red sandy loam soils of Nileshwar, 60 palms belonging to 4 yield groups were marked out based on their pre-irrigation production status. The palms yielding less than 20 nuts were grouped as 'poor', 20 to 40 nuts as 'low', 40 to 60 nuts as medium and 60 to 80 nuts as high yield groups. The palms were irrigated in basins of 2m radius at the rate of 800 l of water for irrigation once in 7 days during summer months (December-May). Manuring was done at the rate of 0.5 kg N, 0.32 kg P_2O_5 and 1.2 kg K_2O per palm per year. The study was initiated in the year 1964 as bulk observational trial with 15 palms in each yield group. The trial lasted for 11 years.

Table 6.1 Growth and yield response of coconut to summer irrigation in littoral sand, Nileshwar

Irrigation	Basin irrigation		Flood irrigation	
	Functional leaf per palm	Nuts per palm	Functional leaf per palm	Nuts per palm
Pre-irrigation	8.9	10.8	9.2	11.2
Post irrigation	26.5	33.4	43.2	96.6
Increase over	17.6	22.6	34.0	85.4
(1)	(85.4)	(209.1)	(369.5)	(762.0)

Figures in paranthesis indicate percentages

The production of female flowers and setting percentage were observed to increase considerably due to irrigation. A season-wise analysis of bunches' harvested revealed that the increase in female flower production was significantly high (64.2 per cent) during the North-East monsoon period (Table 6.2). The overall increase in female flower production was 28.8 per cent. Similarly, a significant increase in setting percentage (58.8) was seen in the bunches harvested during the south west monsoon period. The overall increase in setting percentage was 39.8 (Table 6.3). The overall influence of irrigation on these yield attributes did reflect on the final yield (Table 6.4).

Table 6.2 Effect of summer irrigation on female flower production and setting percentage in coconut cv. West Coast Tall

Season	Female flowers per palm			Setting percentage		
	Pre-irrigation	Post irrigation	Increase (%)	Pre-irrigation	Post irrigation	Increase (%)
Hot weather	68.6	81.6	19.0	30.8	44.7	45.2
South-West moonsoon	36.6	44.8	22.6	27.5	43.7	58.8
North-East monsoon	25.3	41.5	64.2	29.3	34.1	16.4
Total	130.5	167.9	28.8	29.2	40.9	39.8

Table 6.3 Influence of irrigation on female flower production setting percentage and yield of coconut

No. of female flowers produced per palm			Increase in setting percentage due to irrigation	Nut yield per palm per year		
Pre-irrigation	Post irrigation	% increase		Pre-irrigation	Post irrigation	% increase
130.4	167.9	28.8	39.8	42.2	73.5	74.2

Since spadix initiation to ripening of nuts takes 42 months, the full benefit of irrigation could be adjudged only after 3 years. Therefore, the yield response in the transit period of production and in subsequent periods were assessed separately. The maximum yield increase of 25.9 nuts per palm in the transit period was recorded by the 'low' yield group closely followed by the 'medium' yield group which registered an increase of 23.4 nuts per palm. The 'high' yield group recorded a comparatively low rate of increase in yield (12 nuts) during this period. Thus, the influence of irrigation on spadix characters was more pronounced in 'low' and 'medium' yield groups. The overall increase in yield during the transit period was 20 nuts which worked out to 48.3 per cent. Further, assessment of the yield over a period of 8 years showed an increase of 9, 13, 8 and 12 nuts, respectively, for 'poor 'low', 'medium' and 'high' yield groups with a mean increase of 11 nuts for the whole group of palms. The average increase over 11 years from the commencement of irrigation was also maximum in the 'low', yield group (38.3 nuts) followed by the 'medium' group (32 nuts). This suggests that the 'low' and 'medium' yielders are better responsive to irrigation. Probably the high yielders would respond to irrigation if the manurial doses are also increased simultaneously.

Table 6.4 Nut yield of West Coast Tall palms of varying yield groups as affected by irrigation

	Particulars	Yield group (nuts/palm/year)				
		Poor (below 20 nuts)	Low (20-40 nuts)	Medium (40-60 nuts)	High (61-80 nuts)	Mean
1	Pre-irrigation yield	13.4	30.2	54.3	70.8	42.2
2	Transit period	33.6	56.1	77.7	82.9	62.6
	Per cent increase over pre-irrigation yield	(150.4)	(85.7)	(43.3)	(16.9)	(48.3)
3	Post irrigation yield for 8 years	42.2	69.5	85.3	94.8	73.5
	Per cent increase over pre-irrigation yield	(214.9)	(130.1)	(57.4)	(33.8)	(74.2)
4	Cost: benefit ratio	1:2.9	1:3.5	1:3.1	1:2.4	1:3.1

Figures in brackets refer to percentages

A study on the effect of irrigation on the growth and yield of coconut cv. West Coast Tall was initiated in a 12-year-old private plantation at Chalakudy in the year 1982. The soil of the experimental field was sandy clay loam (0-45 cm) to clay (90-120 cm) in texture. The field capacity and wilting point ranged from 17.69 to 20.83 per cent and 8.65 to 9.20 per cent, respectively. The bulk density of the soil varied from 0.973 to 1.24 g/cc. The groundwater table of the field was always below 2m from ground surface.

Prior to the layout of the experiment, the pre-treatment yield of individual palms was recorded for one year. The aggregate nut yield of 20 groups of 4 adjoining palms was computed and ranked according to nut production. These groups were further classified into 4 blocks (replications) having 5 groups (treatments) in each in the order of nut production. The nut yield was further subjected to statistical analysis which confirmed the uniformity of the palms within a replication.

The experimental palms received a uniform dose of 0.34:0.17:0.68 kg NPK. in three split doses besides 25 kg of green manure per palm.

The treatments were (1) irrigation with 500 l of water per palm at 75 mm CPE, (2) irrigation with 500 l of water per palm at 50 mm CPE, (3) irrigation with 500 l of water per palm at 25 mm CPE, (4) irrigation with 200 l of water per palm once in three days (farmers' practice) and (5) no irrigation (control). Irrigation was given in the basin of 1.8 m radius. Each treatment was replicated 4 times in randomised block design. The rainfall received during the summer months (January–May) when irrigations were given is presented in Table 6.5.

Table 6.5. Rainfall (mm) received during the period of irrigation (January to May)

Month	Pre-experiment year, 1982	Experiment years 1983	1984	1985	1986
January	—	—	115.1	26.9	1.4
February	—	—	15.5	0.4	0.6
March	11.5	—	62.6	—	25.2
April	67.2	10.5	219.6	33.7	80.3
May	133.7	32.2	53.8	314.2	101.2
Total	212.4	42.7	466.6	375.2	208.7

There was considerable variation in the aggregate nut yield from year to year. It could be attributed to the corresponding variation In rainfall received during the preceding dry months (January to May). The drought year of 1983 with only a total of 42.7 mm of rainfall during dry months led to minimum nut production in the subsequent year (1984). On the other hand, high rainfall (466.6 mm) during the dry months of 1984 helped in the production of the maximum number of nuts in 1985. The results further indicated that the treatments did not influence the nut yield in the first two years (1983 and 1984) of the experimentation. However, in subsequent years, the palms responded well to irrigation.

The effect due to treatments on nut yield in the third and fourth year was significant and almost similar. The only difference was that in 1985, T_3 (25 mm CPE) recorded the highest nut yield as against T_4 (once in 3 days) in 1986 (Table 6 6). However, the treatments T_2 (50 mm CPE), T_3 (25 mm CPE) and T_4 (once in 3 days) were on par with each other and significantly superior to no irrigation (T_5). The increase in nut yield per palm due to irrigation at 50 mm CPE (T_2), 25 mm CPE (T_3) and once in three days (T_4) over no irrigation was 16.8, 34.0 and 28.8 in 1985 and 36.8, 41.6 and 54.8 in 1986, respectively. The treatments T_2, T_3 and T_4 received 5500, 9500 and 7200 l of water in 11, 19 and 36 irrigations in the year 1985 and 5500, 10500 and 8600 l of water in 11, 21 and 43 irrigations in the year 1986, respectively. The number of leaves and bunches produced per palm showed a trend more or less similar to that of nut yield.

Table 6.6: Nut yield per palm per year as influenced by irrigation

Treatments	Pre-experiment period 1982	Experiment period 1983	1984	1985	1986
T_1 75 mm CPE	63.1	73 9	40.8	104.1	96.1
T_2 50 mm CPE	67.1	24.5	39.8	112.8	113.9
T_3 25 mm CPE	61.1	60.8	39.9	129.9	119.3
T_4 once in 3 days	65.1	69.7	41.4	124.7	131.8
T_5 No irrigation	59.2	80.8	31.7	95.9	77.1
CD (0 05)	NS	NS	NS	15.57	24.14

Results of the study indicated clearly that coconut responded well to irrigation during dry months (January-May) from the third year onwards. Irrigating the crop with 500 litres of water in basins of 1.8 m radius at CPE value of 50 mm (approximate interval of 12 days) was the most economical.

Response of young coconut palms to irrigation

Young coconut palms require frequent irrigations. The size and vigour of the seedlings depend on the availability of soil moisture and plant nutrients. This was clearly evident from the studies initiated at Nileshwar (red sandy loam soil) in 1981. The field capacity and wilting point of the soil were, 10.0 and 5.3 per cent (w/w), respectively. The bulk density was 1.4 g/cc. The objective of the experiment was to find out the response of Tall x Gangabondam hybrids to irrigation and fertilizer application right from the initial stages of planting. The design of the experiment was split plot with combinations of 3 levels of irrigation (IW/CPE 0.50, 0.75 and 1.00 at 30mm CPE) and 4 levels of fertilizers(0.5, 0.5, 1.5 kg N, P_2O_5, K_2O respectively, per palm per year; 0.5, 0.5, 2.0 kg per palm; 0.5, 1.0, 2.0 kg per palm; 1.0, 0.5, 2.0 kg per palm) in the whole plots and the age at which the full dose of fertilizer was applied to the palm in the sub plots (full dose of fertilizer in the second year; full dose in the third year and full dose in the fourth year). The irrigation water was applied in basins the radius of which varied from year to year in responss to the expansion of effective canopy cover. In other words, the depth of water applied varied with the effective leaf canopy cover. The fertilizer doses were applied in two instalments in May and September. The irrigation period was 5 months from December to May.

Regular observations on growth characters were recorded from 1984. Soil samples were drawn from the basins one metre away from the bole of the seedlings using an auger before and 24 hours after each irrigation. The moisture content was estimated gravimetrically.

Irrigation at IW/CPE 1.00 significantly increased the girth at collar and the number of leaves during all the years of observation from 1984 onwards. The best fertilizer dose promoting the maximum expression of these plant characters was 0.50, 0.50, 1.00 kg N, P_2O_5, K_2O respectively, per palm per year. A combination of both these treatments—irrigation at IW/CPE 1.0 and a fertilizer dose of 0.5, 0.5, 1.5 kg N, P_2O_5, K_2O per palm per annum was found to be ideal for Tall x Gangabondam hybrids, as could be judged from the data so far gathered (Table 6.7)

The effect due to sub plot treatments and their interaction with the main plot treatments were not significant on any of the charaeters studied.

The consumptive use of water by coconut seedlings is given in Table 6.8. The top most soil layer (0-30 cm) recorded the maximum consumptive use irrespective of the irrigation treatments. Irrigation at IW/CPE ratio of 1.00 resulted in the maximum consumptive use of 794 mm. The higher consumptive use in the upper layer was attributable to the rapid evaporation of moisture from the soil surface. The consumptive use increased with an increase in the IW/CPE ratio owing to the frequent wetting of the soil surface.

Table 6.7. Growth characters of young Tall x Gangabondam hybrids as influenced by irrigation and fertilizer application, Nileshwar

Treatment	Cumulative plant girth (cm)			No. of leaves produced per palm			
	1984	1985	1986	1984	1985	1986	Cumulative number
Irrigation							
IW/CPE 0.50	72	100	106	7.4	8.3	9.9	52.47
IW/CPE 0.75	66	95	107	6.9	8.3	10.0	52.48
IW/CPE 1.00	74	109	117	7.5	9.1	11.4	55.68
C D (0.05)	—	9	9	—	0.5	0.4	2.05
**Fertilizer*							
0.5,0.5,1.5	71	103	116	7.7	8.9	11.3	54.76
0.5,0.5,2.0	71	101	110	7.3	8.6	10.5	54.15
0.5,1.0,2.0	77	110	117	7.5	9.0	10.7	54.93
1.0,0.5,2.0	82	88	98	6.7	7.7	9.5	50.32
C D (0.05)	0.6	10	9	0.6	0.6	0.5	2.36

* Kg N, P_2O_5, K_2O/palm/year

Table 6.8. Consumptive use of water by the young Tall x Gangabondam hybrids

Irrigation (IW/CPE ratio)	Soil depth (cm)			Total
	0-30	30-60	60-90	
0.50	367	373	100	640
0.75	317	183	216	716
1.00	278	242	274	794

The moisture extraction pattern under different irrigation regimes showed that extraction was high in the upper (0-30) layer and it was relatively uniform in the middle layer. The moisture depletion was relatively low from the 60-90 cm layer at IW/CPE 0.50.

The ratio of consumptive use to pan evaporation (crop coefficient) was computed under different irrigation treatments and the mean worked out to 0.75. The water requirement of coconut seedlings can be estimated using this crop coefficient, if pan evaporation values are known.

Another experiment was started in the year 1983 at the same station to find out the effect of water saving irrigation techniques on the growth and productivity of coconut cv. West Coast Tall right from the seedling stage. The treatments consisted of combinations of irrigation techniques, two fertilizer levels and two controls as detailed below.

Irrigation (I)

I_0 rainfed control (but life saving irrigation would be given once in a month to prevent death of seedlings)

I_1 Pitcher (4 l capacity) irrigation (one pot in the first year of planting, two pots in the second year of planting and 3 pots from the third year onwards)

I_2 Basin irrigation at IW/CPE 0.50 (depth of water 30 mm)

I_3 Basin irrigation at IW/CPE 0.75 (depth of water 30 mm)

I_4 Drip irrigation at IW/CPE 0.50 (depth 2 l water per day in the first year)

I_5 Drip irrigation at IW/CPE 0.75 (depth 3 l water per day in the first year)

Fertilizer (F)

F_1 0.50 kg N, 0.32 kg P_2O_5 and 1.20 kg K_2O per palm per year

F_2 0.75 kg N, 0.48 kg P_2O_5 and 1.80 kg K_2O per palm per year

Control (C)

C_0 Basin irrigation (IW/CPE 0.50) with no fertilizer

C_1 Drip irrigation (IW/CPE 0.50) with no fertilizer

The depth of water varied with the basin size, the radius of which was increased year after year in response to the expansion of effective canopy. During the year 1986, the basin irrigation was given at 50 l and 75 l per palm and drip irrigation at 8 and 12 l per palm.

One-year-old seedlings of cv. West Coast Tall were planted in the year 1983 at a spacing of 7.5 m x 7.5 m. The initial basin size was 1 m x 1 m. The soil was red sandy loam with a bulk density of 1.4 g/cc. The field capacity and wilting percentage were 10.0 and 5.3, respectively.

The observations on growth characters recorded during 1985 and 1986 indicated that the treatment receiving drip irrigation at IW/CPE 0.50 and a fertilizer dose of 0.50, 0.32, 1.20 kg N, P_2O_5,K_2O per palm per year was superior to the rest (Tables 6.9 and 6.10).

Table 6.9. Growth characters of West Coast Tall seedlings as influenced by irrigation and fertilizer application (1985)

Irrigation	Height (m)			Collar girth (cm)			No. of leaves per seedling		
	F_1	F_2	Mean	F_1	F_2	Mean	F_1	F_2	Mean
I_0 Rainfed	1.7	1.6	1.6	19.0	18.4	18.7	3.4	4.2	3.8
I_1 Pitcher	1.7	1.8	1.8	22.2	23.0	22.6	3.8	4.5	4.2
I_2 Basin (IW/CPE 0.50)	2.0	2.1	2.1	27.2	26.9	27.1	4.7	4.6	4.7
I_3 -do- (0.75)	1.5	1.9	1.7	18.2	25.2	21.7	4.2	4.9	4.6
I_4 Drip (0.50)	2.3	2.2	2.3	32.8	28.8	30.1	5.0	4.7	4.9
I_5 -do- (0.75)	1.9	2.1	2.0	24.6	28.8	26.7	4.8	4.9	4.9
Control									
I_3F_0 Basin (0.50, no fertilizer)	2.2			26.4			4.0		
I_5F_0 Drop (0.50 no fertilizer)	2.3			22.8			4.5		

Table 6.10 Growth characters of West Coast Tall seedlings as influenced by irrigation and fertilizer application (1986)

Irri-gation	Height (m)			Collar girth (cm)			No. of leaves per seedling		
	F_1	F_2	Mean	F_1	F_2	Mean	F_1	F_2	Mean
I_0	2.2	2.0	2.08	30.8	29.2	30.0	5.3	4.9	5.1
I_1	1.8	1.9	1.85	22.7	27.4	25.1	4.8	5.5	5.2
I_2	2.8	2.2	2.50	38.2	30.2	34.2	5.4	5.2	5.3
I_3	1.9	2.6	2.30	22.4	34.7	28.6	4.9	5.6	5.3
I_4	2.9	2.9	2.90	46.1	38.9	42.5	6.9	6.1	6.5
I_5	2.3	2.8	2.55	32.8	37.3	35.0	5.9	6.4	6.1
Control									
$I_3 F_0$	1.98			25.6			4.8		
$I_5 F_0$	2.49			31.3			5.4		

Water management in areas having high water table

Adequate drainage is necessary to alleviate the ill-effects of high water table. In a study conducted at Nileshwar, it was found that surface drains of 1.5m depth provided in between rows of coconut increased the yield by 84.8 per cent (Pre-treatment yield 35.7 nuts per palm; post-treatment yield 66.1 nuts per palm). The crop was irrigated during summer months.

With the available observations and experimental evidences, it can be concluded that summer irrigation is the most productive input in coconut cultivation.

CHAPTER 7

Pest Management in Coconut

Sumangala S. Nambiar and P. J. Joy

The coconut palm is infested by a number of insect and noninsect pests and parasites inflicting heavy crop losses. The most devastating among them are the rhinoceros beetles, the red palm weevils, the black headed caterpillars and root grubs.

Rhinoceros beetle *(Oryctes rhinoceros* L.)

It is one of the 42 described species of *Oryctes* and is a very common destructive pest in coconut. The adult beetle bores through the unopened fronds and spathes hampering the growth of the palm and predisposing the palm to infestation by red palm weevil and bud rot.

The experiment conducted at the Regional Agricultural Research Station Pilicode revealed that the beetle attack was maximum during the summer months from March to June and minimum in September-October (Table 7.1). The exotic varieties were more susceptible than West Coast Tall and other cultivars (Table 7.2.)

Table 7.1. Monthly variation in the occurrence of rhinoceros beetle (Percentage attack)

Month	Year			
	1949	1950	1951	1952
January	3.9	1.75	12.5	6.05
February	2.7	1.50	11.3	5.17
March	23.1	8.33	12.7	14.71
April	11.1	6.60	12.7	10.13
May	12.8	2.25	19.0	11.35
June	13.3	5.25	7.5	8.68
July	9.8	8.16	2.5	6.82
August	6.5	3.16	3.8	4.49
September	4.1	0.66	2.2	2.32
October	1.2	1.25	5.2	2.55
November	5.6	1.25	6.5	4.45
December	5.9	1.25	4.2	3.78

Table 7.2. Varietal reaction to the incidence of rhinoceros beetle: (Number of beetles per palm caught and killed during 1949 to '51)

	Variety	1949	1950	1951	Mean
1	West Coast Tall	0.7	0.2	1.0	0 63
2	Fiji	1.1	0.4	0.7	0.73
3	Strait settlement	1.3	0.3	0.6	0.73
4	Lakshadeep Ordnary	0.5	0.4	0.9	0.60
5	Philippines	0.7	0.6	2.1	1.13
6	Godavari	1.0	0.2	1.6	0.93
7	Bombay	0.76	0.1	0.4	0.42
8	Andaman Ordinary	0.25	0.3	2.2	0.92
9	New guinea	1.85	1.1	1.1	1.35
10	Cochin china	2.2	0.3	1.9	1.47
11	Andaman Dwarf	0.4	1.0	2.3	1.28
12	Java	2.0	0.4	1.6	1.33
13	Omallur	0.5	0.6	2.5	1.20
14	Kulithalai	0.7	0.8	0.6	0.70
15	Indupalli	0.6	0.9	1.6	1.03
16	Ceylon	2.0	0.2	2.1	1.43
17	Laskshadeep Small	0.6	—	1.5	0.70
18	Lakshadeep ordinary	0.5	1.0	0.6	0.70
19	Andaman china	0.5	0.2	0.8	0.5
20	Kapadam	0.1	0.5	1.5	0.7

A recent study at the College of Agriculture, Vellayani showed that HCH was the most toxic pesticide for the pupating grubs of rhinoceros beetle followed by aldrin, heptachlor, chlordane and carbofuran. Field experiments showed that the treatment of soils at the bottom of manure pits with aldrin 0.12 kg ai/per ha and HCH 0.3 kg ai per ha caused more than 90 per cent grub mortality.

In another experiment, juvenile hormone analogues like diflubenzuron, were evaluated against the beetle grubs. Feeding the last instar grubs on cowdung mixed with diflubenzuron at 0.2, 0.1 and 4.05 per cent concentrations caused significant mortality and other morphogenic deformities. The affected grubs showed bulging of body at certain parts followed by the oozing out of body fluids resulting in death. The formation of larval-pupal mosaics was another effect of the treatment.

A survey of the microbial parasites of *O. rhinoceros* was undertaken at Vellayani, Trivandrum during 1982-83. The entomogenous pathogens found during the weekly collection of grubs were the bacterium *Bacillus cereus* and the fungi *Metarrhizium* sp. and *Mucos circidilloids*. The cumulative mortality by the infection of the pathogens was 39.1 per cent in April, and 36 6 per cent in May.

The pathogenicity tests of the bacterium on second instar grubs by oral feeding resulted in high mortality after three days. The efficacy of the bacterium on healthy second and their instar grubs under different conditions viz., cowdung treated with inoculum in pots, cowdung mixed with the pathogen in deal-wood case, cowdung contaminated with pathogen in pits dug in the ground and cowdung containing the bacteria in concrete tubs, were studied. Under laboratory conditions the mortality of the grubs in pots and deal-wood cases was higher.

Observations were made on the relative varietal susceptibility of coconut hybrid combination to this pest during 1986-88. Among the 16 hybrid combinations, Cochin china x Chowghat Dwarf Green was found to be the most susceptible (21.1%), followed by West Coast Tall x Lakshadweep Dwarf, Andaman Ordinary x Chowghat Dwarf Orange, and Fiji x Chowghat Dwarf Orange. The lowest susceptibility was recorded by Chowghat Dwarf Orange x West Coast Tall (8%) followed by West Coast Tall x Chowghat Dwarf Green and West Coast Tall x Gangabondam (Table 7.3).

Red palm weevil (*Rhynchophorus ferrugineus* Fabr.)

Relatively young palms of age group between 5-10 years are worst affected by this weevil. Very many studies on control of this insect pest have been attempted in the past with little success. The mode of entry, nature of infestation and colonisation of this pest go unnoticed defeating the normal pest management

Table 7.3 Reaction of coconut hybrids to rhinoceros beetle: Percentage leaf damage due to the beetle attack (mean of three years)

	Hybrid	Leaf damage (per cent)
1	West Coast Tall x Chowghat Dwarf Orange	16.8
2	Cochin China x Chowghat Dwarf Orange	21.1
3	Andaman Ordinary x Chowghat Dwarf Orange	18.3
4	Lakshadweep Ordinary x Chowghat Dwarf Yellow	14.3
5	Fiji x Gangabondam	8.9
6	West Coast Tall x Malayan Dwarf Yellow	9.5
7	West Coast Tall x Tembili	12.9
8	Fiji x Chowghat Dwarf Orange	18.1
9	West Coast Tall x Strait Settlement	10.6
10	West Coast Tall x Chowghat Dwarf Green	1.3
11	Chowghat Dwarf Orange x West Coast Tall	8.0
12	Chowghat Dwarf Orange x Lakshadweep ordinary	15.5
13	Gangabondam x Lakshadweep Ordinary	14.2
14	West Coast Tall x Lakshadweep Dwarf	18.6
15	West Coast Tall x Gangabondam	8.7
16	West Coast Tall	11.5

strategies. Hence studies were undertaken at the Regional Agricultural Research Station, Kumarakom using systemic insecticides through stem injection/root feeding techniques. Application of 50 ml to 100 ml of monocrotophos 50% in equal quantity of water by root feeding/stem injection gave good control of the pest on five to ten year old palms. The chemical was found to be superior to the other commonly used systemic insecticides like phosphamidon, dimethoate, and metasystox. However, care has to be taken to avoid any root injury during root feeding.

The application may be done during summer months and four or five mature pink roots may be selected for feeding the chemical. There should be minimum delay between cutting the root and dipping the cut end into the insecticide solution. It may take three days or more for the absorption of the chemical and if the absorption is not satisfactory, fresh roots may be selected and the process repeated.

It was also found that very often red palm weevil attack occurred through the tender portions of the crown. In that case timely destruction of the pest by cutting and removing the affected portions and treating with carbaryl for checking the further entry of the pest was also found effective in controlling the pest.

Baiting red palm weevils using coconut stem splits or discs was tried at the Regional Agricultural Research Station, Kumarakom. Of the various attractants tried, fermented cocoa pulp kept in between the split coconut pieces/discs was found to be the most ideal. However, the stem splits or discs had to be shaved once in 10-15 days to retain their freshness.

A survey of the microbial pathogens of red palm weevil was conducted in Trivandrum and Kottayam districts. A common disease of red palm weevil in these areas was found to be a polyhedrosis. The diseased grubs showed loss of appetite and possessed disproportionately large head. The hindgut was extroverted due to the blocking of the alimentary canal and consequent persistent effort of the grub to void the polyhedra. On opening a diseased grub the gut was found to be milky in appearance. When the disease condition progressed, the viral inclusions oozed out in large quantity into the lumen of the gut. The diseased adults also gave white exudations, containing thousands of polyhedral bodies.

The cumulative incidence of polyhedrosis in the field samples of second and third stages of the grubs collected from Trivandrum district was found to vary from 9.3 to 15.7 per cent compared to 2.6 per cent in Kottayam district. Further, the mortality rate of pupae and adults was 31.5 per cent in the field collection of insects from Trivandrum and 2.6 per cent from Kottayam district.

Black-headed caterpillar *(Opisina arenosella* Wlk.)

This is an endemic pest of coconut palm especially in the coastal tract of Kerala. During epidemic of this pest, the palms ofter a desolute look, the entire foliage being eaten by the caterpillars. However, during epidemics, chemical control has to be resorted to. Laboratory studies using different insecticides showed that phosalone, endosulphan, malathion and quinalphos were suitable for the control of *O. arenosella*. The LD 50 levels of toxicity of phosalone, endosulphan, malathion, quinalphos, fenthion, phosphamidon, monocrotophos, fenitrothion, dichlorvos, HCH and carbaryl on 4th instar larvae of the coconut caterpillar were 0.0243, 0.0293, 0.0529, 0.0561, 0.0842, 0.0948, 0.0983, 0.1013, 0.1639, 0.2920 and 0.4990 respectively. Toxicity of residues of dichlorvos 0.05%, fenitrothion, 0.05% and malathion 0.05% on coconut leaves to first instar larvae of

Opisina became negligible on the 8th day of their application and that of residues of quinalphos 0.05%, phosalone 0.05% and BHC 0.2% on the 16th day of application. Residues of carbaryl 0.2% and monocrotophos 0.02% showed toxicity beyond 16 days.

In another study, emulsifiable concentrates ot monocrotophos, phosphamidon and dimethoate were implanted in holes drilled on trunks of four to six-year-old palms. Monocrotophos at 4 ml ai/tree and dimethoate at 8 ml ai/tree gave absolute protection to the trees upto 48 days.

Attempts were also made for the control of the pest using insect growth regulators like oxyrane, altosid, and triflumuron. Topical application of oxyrane and altosid on the last instar larvae resulted in various malformations and mortality of the larvae and pupae, thereby inhibiting the emergence of normal adults. Chitin synthesis inhibitor, triflumuron, showed significant stomach and contact toxicity of the larvae. Feeding the early larval instars treated with 0.05 to 0.00625 per cent diflubenzuron showed complete larval mortality within four days.

Studies were conducted at the College of Agriculture, Vellayani, on a nuclear polyhedrosis virus infecting larvae of *O. arenosella*. The symptoms of the disease resembled those reported already of the nuclear polyhedrosis of other lepidopteran larvae. However, the typical behaviour of the larvae coming to the open and orienting the body with the head hung downwards at the time of death was not observed here. Some of the diseased pupae exhibited typical symptom of larval-pupal mosaic. Malformed adults with short and ruffled wings also emerged.

The inclusion bodies measured on an average 1393.30 nm with a range of 533.33 nm to 1666.67 nm. The inclusion bodies were irregular in shape and the surface was smooth without any ornamentation. The pathogen was found to be a multiple embedded virus.

The histopathological studies revealed that the hypodermis, fat body and trachea were the principal sites of virus multiplication. In addition to the above tissues, muscles, malpigian tubules, connective tissues surrounding the gut, the gut epithelium, nerve ganglia and epithelial sheath of gonads were seen infected. The extensive invasion of the tissues indicated the high virulence of the pathogen.

The female moths of *O. arenosella* infected orally or contaminated externally served as effective carriers of the pathogen to the next generation mainly through surface contamination of eggs (transovum). This facilitated the natural perpetuation and spread of the disease.

The NPV of *O. arenosella* was found cross transmissible to *Spodoptera litura, S. mauritia, Anadevidia peponis, Pericalia ricini* and *Diacrisia obliqua*. The alternate hosts themselves being major crop pests, the possibility of using the virus as a broad spectrum microbial insecticide was also indicated. Bioassay studies revealed the desirability of applying the virus in the early stages of the pest incidence since the later instars required very heavy doses of the pathogen which might render the technology non-viable.

The NPV, when exposed to field conditions retained substantial infectivity upto 84 hours which gradually declined and became inactive in 168 hours. The half life of the pathogen on coconut foliage was 83.25 hours which compared well with many of the insecticides. When exposed to a constant temperature of 35°C the infectivity declined rapidly beyond 84 hours and complete inactivation occurred at 156 hours of exposure. When the NPV was exposed to infrared rays, substantial infectivity was retained upto 84 hours. Exposure to UV radiation caused rapid loss of infectivity resulting in complete inactivation in 108 hours. The virus was found to be comparatively safe to silkworm (*Bombyx mori*), parasitoids (*Bracon previcornis* and *Trichospilus pupivora*), vertebrates (white rats and white mice) and even to the embryonated chick egg.

In the field evaluation of NPV against *O. arenosella* the virus spray containing 22.14 x 10^7 PIBs/ml was found to be on par with the insecticidal treatment of thiodan 0.05 per cent.

As already mentioned, parasitoids form an important means of checking the pest menace both by natural and by artificial means. Hence studies were conducted in the Kerala Agricultural University on important parasitoides of *Opisina*. During such a study, seventeen insecticides were evaluated for its toxicity to adult *Trichospilus pupivora* (Fam. Eulophidae), an important pupal parasitoid of *O. arenosella*. The study showed that dipterex. diazinon and DDVP were less toxic than DDT being 0.4666, 0.5360 and 0.5421 times respectively less toxic than DDT. Thiodan, malathion, sevin, BHC, formothion, parathion, trithion, imidan, rogar, phosphamidon, lindane and endrin were more toxic than DDT being respectively 1.276, 2.161, 2.191, 2.932, 3.347, 3.899, 4.674, 6.105, 7.513, 8.513, 13.25 and 13.76 as toxic as DDT to the parasitoid. At the end of 28 days after spraying, residues of all insecticides excepting malathion, sevin and thiodan were lost totally. Residues of these three insecticides gave 9.4, 99.85 and 25 per cent mortality of the parasitoids respectively when exposed to the sprayed coconut leaves. The three insecticides also lost their residual toxicity by the end of 42 days after spraying.

In a study to evaluate fourteen insecticides against *Microbracon brevicornis* (Wesmal), a braconid larval parasite of *Opisina*, it was found that parathion was the most toxic and diclorvos the least. Dichlorvos did not show any mortality among the parasites even at a concentration of 0.05 per cent. This was followed by DDT, endosulphan, sevin, HCH, trichlorphon, carbophenothion, diazinon, lindane, endrin, malathion, imidan and phosphamidon in the ascending order of toxicity. In another study, toxicity of residues of the same concentrations of dichlorvos, fenitrothion, fenthion, endosulphan and phosphamidon on coconut leaves to adults of *M. brevicornis* became negligible in 8 days of application and that of residues of malathion, quinalphos, phosalone and BHC in 16 days of application, residues of monocrotophos and carbaryl remained toxic to the parasitoid beyond 16 days.

Studies on the effect of host nutrition on *M. brevicornis* showed that the shortest duration of larval development was noticed in hosts reared on a medium containing wheat flour and the medium containing basic diet to which thiamin was added. Parasitoids reared from hosts fed on basic diet to which fructose was added and parasitoids reared from hosts fed on basic diet to which black gram flour and glucose fortified with yeast were added lived for the maximum number of days (16 to 17). The largest number of eggs were laid by parasitoids reared on hosts fed on basic diet to which thiamin was added.

The number of adult parasitoids emerged also varied with different hosts. The largest number of parasitoids emerged from the hosts fed on medium containing wheat flour and the medium containing basic diet to which fructose was added.

The fecundity, progeny production and sex ratio of the progeny of *M. brevicornis* as influenced by density and weight of host larvae of *Corcyra cephalonica* and the sex-ratio of the parent parasite population were studied at three temperature—humidity combinations, namely 28°C/75% RH, 30°C/60% RH and 32°C/50% RH. The maximum fecundity of the parasitoid was observed consistently in all the three temperature/humidity conditions when the host density level of two larvae per female parasite and the parental parasite sex ratios (female:male) of 2:1 and 3:1 were maintained. The population of the progeny was the highest at a temperature—humidity condition of 28%°C/75% RH and 30°C/60% RH and under a host density level of two heavier larvae (30—35 mg) per female parasite. The influence of host-larva density on the propagation of female was pronounced only at the temperature humidity level of 32°C/50% RH. In this condition, a density of two larvae per female parasite was found to be satisfactory for the production of higher proportion of females. At the temperature—humidity levels of 30°C/60% RH the parental sex-ratios of 1:3 produced more number of females.

Cockchafer beetle *(Leucopholis coneophora* Burm.)

This is the only major soil inhabiting pest of coconut. It feeds on the roots leading to the yellowing of leaves, delayed flowering and immature nut-fall.

The biology of the pest have been studied in detail. The duration of first, second and third instar larval periods and pupal duration of males were found to be 40.3, 51.6, 168.1 and 25.3 days, respectively and those of females were 40.9, 51.6, 177.5 and 25.7 days, respectively. Morphological studies of the first, second and third instar grubs showed that the only distinguishing feature of the three stages was the width of head which were 3.19, 4.84 and 7.71 mm, respectively. Adult males and females could be distinguished by the antennal character, length of the club being twice and thrice their width in the female and male, respectively.

The adults and eggs were predominant at 30-100 cm soil depth, the first, second and third instar grubs being more numerous at 15-30, 15-45 and 15-30 cm depths respectively. Pupae were more in a deeper stratum of 60-100 cm. The adults, eggs, first-instar, second-instar, third-instar grubs and pupae were seen in May-August, May-October, July-November, October-July and April-July, respectively. It was observed that the adults preferred a soil temperature of 29 to 31°C and 8 to 10 per cent moisture, second instar grubs preferred 31 to 33°C and 8 to 10 per cent moisture, while the third instar grubs showed preference to 31 to 33° C and 7 to 9 per cent moisture.

An effort was made to correlate the larval populations with the weather, and an experiment was laid out at the Regional Agricultural Research Station, Pilicode, from 1982 to 1985. The results showed that mean monthly rainfall was the most important factor contributing to the abundance of the larvae in the soil. The mean maximum temperature had a negative correlation on the root grub abundance upto a depth of 90 cm. Positive correlation was obtained with the relative humidity also upto a depth of 60 cm, but mean minimum temperature was not having any influence on the larval abundance.

Aldrin, HCH, chlordane and heptachlor were evaluated for their efficacy against second and third instar grubs of *L. coneophora*. Chlordane was ineffective. Aldrin and heptachlor were almost equitoxic, but the former was more expensive. One application of heptachlor at 1.4 kg a. i. per ha in June or two applications of HCH at 5 kg a. i., per ha in June and September gave a complete kill of the grubs, HCH applied in April, June, August and September had half lives of 89.6, 71.7, 66.1 and 35 days, respectively, and for heptachlor, half life periods were 72.2, 76.5, 87.7 and 23 days, respectively. Downward movement of HCH and heptachlor in soil was found to be very low and insufficient to be at toxic levels to the second and third instar grubs of *L. coneophora*.

Studies conducted at the Regional Agricultural Research Station, Nileshwar on the control of root grubs revealed that soil application of chlordane 10 per cent dust at 60 kg per ha once or 30 kg per ha twice a year was effective.

A taxonomic key was developed for the identification of the three species of *Leucopholis* prevalent in Kerala viz., *L. coneophora*, *L. burmeisteri* and *L. lepidoptera* based on the external morphology of the third instar grubs.

Though coconut and cassava were more favourable hosts than cocoa and crotalaria, the latter was more sensitive to the attack of the pest.

Slug caterpillars (*Parasa lepida* Cram. and *Conthyla rotunda* H).

These two are the most common slug caterpillar pests of coconut, sporadic in occurrence and assuming epidemic properties inflicting very severe crop damage.

The biology of these pests was studied at the College of Agriculture, Vellayani. The incubation period of *Parasa lepida* was 7 days and the larval period extended up to 47 days. There were seven larval instars and the pupal period lasted for 27 to 37 days. The total life cycle took 78 days for males and 93 days for females. The female moths laid, on an average, 200 eggs. The sex ratio was found to be 1:1.5 and the longevity of the male was 4 to 6 days and that of females 6 to 8 days.

The young slugs scraped the green matter from the leaves, whereas the older larvae (fourth instar onwards) fed on the leaf in total.

It was found under laboratory conditions that 50 per cent of the total leaf consumed during the life period was during the final instar and each such larva consumed food more than ten times its body weight. Severe infestations of the pest in the field rendered a defoliated appearance to the palms.

In the field, the caterpillars were found parasitised by a braconid *Apanteles parasae* F. and by a pathogenic fungus *Aspergillus* sp. The characteristic symptom of the disease, under field conditions was that larva turned brown in colour and abstained from food embracing a gradual death.

The incubation period of *Contheyla rotunde* was 6 days. Larval period 39 days, pupal period 12 days and the adult longevity 5 days. There were six larval instars.

A pupal parasite, *Chrysis* sp. (Fam. Chrysididae) was found to attack the pest under field conditions. The percentage of parasitism was worked out to be 15 to 30 per cent among the natural population of the pest.

Coreid bug (*Paradasynus rostratus* Dist.)

Once a minor pest of coconut, this insect has gained importance in the recent past due to its large scale occurrence on coconut plantation. From 1963 onwards, there were frequent reports of coreid bug damage to coconut plantations in all the districts of Kerala. A survey on the incidence of this pest in Trivandrum district showed that the damage due to the bug was maximum in Attingal (8.7 per cent) followed by Neyyattinkara (3.9 per cent) and Nedumangad (2.1 per cent). The alternate hosts of the coreid bug are guava, cashew, cocoa and tamarind.

These bugs and their nymphs usually attack heavy bearing trees. They suck sap from tender nuts and from male and female flowers. As a result the tender nuts become crinkled and develop cracks. Often the exudation of a brown viscous ooze can be noticed at the puncture points.

The biology of the bug has been worked out in detail. An adult female lays about 40 to 50 eggs. The incubation period is 8 to 10 days. The young ones feed on tender nuts. First-instar period lasts for five days, second-instar six days, third-instar and fourth-instar five days each. Fifth instar period extends to about nine days and the adult lives for about 50 days.

A multilocational trial using carbaryl, HCH and endosulphan showed that sprays of carbaryl 0.1% and HCH 0.2% effectively controlled the pest. Spraying may be done in the afternoon so as to reduce the mortality of pollinating insects. Alternate hosts of the bug such as cashew and guava may also be sprayed for effective control of the pests.

Mealy bug (*Pseudococcus* sp.)

Like the tingid bugs (*Stephanitis typica*), mealy bugs are also widely distributed and are usually implicated in various disease conditions of coconut. Often they are believed to be responsible for crinkling, twisting and stunted growth of the leaves. Recently there are frequent reports of drying up of inflorescence and shedding of button due to mealy bug attack.

It is doubtful that any of the symptoms cited above are exclusively due to mealy bug. Because of the wide distribution of the bug and sedentary nature, there is often a strong tendency to associate the bugs with different types of symptoms. Attempts so far made at the Regional Agricultural Research Station, Kumarakom, to induce such symptoms on coconut seedlings by artificial means were not successful. The studies revealed that the usual symptoms of mealy bug attack were discolouration (yellowing) and necrosis at the site of attack. During heavy attack, there may be blackening of the central spindle or inflorescence due to sooty mould development. However, these discolourations or lesions or blackenings were not of any serious nature to induce deformation of drying the central spindle or inflorescence. On the other hand, there were cases of malformed central spindles or dried up inflorescences even in the absence of dense mealy bug populations.

Trials using quinalphos (0.05%), carbaryl (0.2%) and phosalone (0.07%) gave more than 95% reduction in the pest population.

Minor pests

The palm mite *Raoiella indica* Hirst. is a major pest of arecanut. It also attacks other palms like coconut and dates. The efficacy of some common pesticides of known acaricidal properties was tested against this pest. The chemicals included parathion, thiometon, phosphamidon, formothion, dimethoate and chinomethionate There was no significant difference in the pest population due to various treatments, 24 hours and 7 days after spraying. However, at the end of 14 days, there was significant reduction of pest population on trees treated with dimethoate and formothion.

A new species of the mealy bug, *Rhizoecus* sp. (Fam. Pseudococcidae) was found infesting roots of coconut in the sandy tracts of Trivandrum districts in 1977. The full grown mealy bug is cream coloured, sub-globular, measuring 2.4mm in length and 1.9 mm in breadth. Groups of the mealy bugs are seen on the thin fibrous roots. A female lays 67-82 eggs. The egg is white, smooth and oval in shape, measuring 0.48 mm in length and 0.24 mm in width. The crawler is white, measuring 0.48 mm in length and 0.24 mm in width.

The roots become discoloured as a result of feeding by the mealy bugs. Young palms showed yellowing and loss of vigour due to the attack. In cases of severe infestation an average of 8.5 mealy bug colonies were noted per 10 cm length of the root.

Hard scale *Lepidosaphes megregori* Banks (Fam. Diaspididae) was also found infesting the leaves and fruits of coconut in certain areas of Trivandrum district in 1981. Clusters of these elongated scales were seen on the upper surface of coconut leaflets and the surface of tender coconuts. Infestation by the scales resulted in complete drying up of the whole fronds and the trees presented a completly burnt appearance.

The adults are pinkish in colour and elongated. The mature scale showed 8-10 eggs at the anal end. The scales were controlled by spraying dimethoate 0.05 per cent or carbaryl 0.2 per cent.

Rodents

Among the non-insect pests, rodents are the most important group causing severe crop damage to coconut, and the damage is estimated as 20 per cent of the total production of nut in India.

"Kumarakom trap" developed at Kumarakom with coconut kernel bait was found to be the most effective one for the control of the pest.

Recent studies using bromadiolone cake (a single dose anticoagulant containing 0.005 per cent of the toxicant) gave encouraging results at Kumarakom and Pilicode. At Kumarakom, the bait suppressed the rodent on ten out of twelve trees by a single baiting. The attack on the remaining two trees were also brought under control by rebaiting. One packet of the cake was found necessary for baiting a single palm and it was placed in the leaf axils at three locations. The trial was repeated on another 25 palms infested with rats to get consistent results.

At Pilicode, the trial was taken up in five locations. The rat menace was controlled with one baiting. No fresh damage was noticed upto 3 months.

CHAPTER 8

Diseases and Their Management

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Of the several maladies that confront coconut production in the state the coconut root-(wilt) disease is of utmost concern. The palm also is affected by a number of other diseases, like stem bleeding, bud rot. leaf rot, immature nut fall quick yellow decline, quick wilt, nutritional disorders and disorders due to adverse conditions.

Root (wilt)

Over a century ago, the root (wilt) disease was first noticed in three isolated pockets in Kerala, one at Erattupetta of Meenachil taluk in Kottayam district and the other two at Kaviyoor and Kalloopara of Thiruvalla taluk in Pathanamthitta district. Ever since the first observation of the disease in 1882, the disease has been spreading in all directions independently from the three foci of infection noticed. The etiology of this disease still remains unknown. The disease has been noticed in all types of soils under varying ecological conditions from foot hills to coastal sands. The disease spreads faster in sandy and sandy loam soils. Although occurrence of apparently healthy palms in the midst of severely infected palms is noticed. So far no varietal resistance has been reported for this disease. The disease is debilitating in nature, but not lethal. The loss in terms of nut yield is proportional to the intensity of the disease and generally it varies from 10 to 80 per cent. The annual loss has been estimated to be approximately 300 million nuts in Kerala state.

Root studies were carried out in the root (wilt) affected areas representing different soil types as well as in the healthy areas by excavating the total root system. The objective was to correlate visual symptoms of the disease with the extent of root decay.

The roots were excavated by digging a circular pit about two metres away from the base of the palm, about one metre wide and deep. The soil inside the pit was dislodged by means of a water jet. After the water jetting was over, the roots were cut and removed at different depths viz., 0-30, 30-60 and 60-90 cm. The roots from each depth were categorised according to colour. The total number, weight and percentage decay of roots were estimated.

A total of eleven coconut palms (three at Kumarakom representing alluvial soil, three at Kayamkulam representing sandy soil and four at Mavelikkara representing laterite soil in the diseased tract and one at Pilicode representing laterite soil in the healthy tract) were studied. At the Regional Agricultural Research Station, Kumarakom three palms were excavated belonging to the same age group and were more or less uniform except in root (wilt) intensity. Among them one was apparently healthy, another was showing a medium score of root (wilt) disease and the third was showing severe symptoms of the disease. At the Rice Research Station, Kayamkulam also, three palms were selected, among which one was apparently healthy, another was with moderate symptoms of root (wilt) and the third was with severe symptoms of the disease. The four coconut palms at the District Agricultural Farm, Mavelikkara were also uniform in age, but differed in root (wilt) intensities, viz., apparently healthy, mildly diseased, medium and severely diseased. At the Regional Agricultural Research Station, Pilicode, a coconut palm similar in age to those excavated at Mavelikkara was chosen.

The results of root excavation studies at the Regional Agricultural Research Station, Kumarakom are presented in Table 8.1. In the apparently healthy palm, only 8.8 per cent of the roots were decayed, while the decay in palms with medium and severe symptoms were 22 5 and 31.5-percent respectively. Also palms varying in root (wilt) intensities did not show much difference in the decay of roots of white/cream and orange. The other two categories of roots, viz., red and dark brown or black predominated in all the palms excavated. There was remarkable difference in the percentage of decay of red and dark brown roots of apparently healthy, medium diseased and severely diseased palms.

Table 8.1. Number of roots decayed per palm, (alluvial soil, Kumarakom)

Category of root (colour)	Disease intensity					
	Apparently healthy		Moderately diseased		Severely diseased	
	Number	Decay (%)	Number	Decay (%)	Number	Decay (%)
White/cream	351	5.2	524	4.1	143	4.0
Orange	62	4.1	—	—	121	3.6
Red	3215	7.2	1936	10.8	4987	36.5
Brown	1633	7.6	3142	33.1	2027	22.7
Total	5261	8.8	5602	22.5	7278	31.5

The root excavation studies of palms at the Rice Research Station, Kayamkulam showed that the total number of roots in the apparently healthy palms was significantly more than in the diseased palms (Table 8.2). However, no difference in the number of roots between medium and severely diseased palms was noticed. The same trend was noticed with respect to root length also. With respect to weight, there was a clear cut reduction from apparently healthy to severely diseased palms. In medium diseased palms there was a reduction of about 54 per cent in the weight of roots when compared with those of the apparently healthy palms. The severely affected palms showed about 70 per cent reduction in the weight of roots.

At the District Agricultural Farm, Mavelikkara, white roots (current growth) were seen only in apparently healthy and medium diseased palms. (Table 8.3). Orange roots were also more in the apparently healthy and medium diseased palms. Eventhough the total length of roots in diseased palms was more, root weight was more in apparently healthy palms. The number of red roots was more in apparently healthy and severely diseased palms. A comparison of root decay in the three categories of palms indicated that the minimum was in the apparently healthy palms (8.5 per cent). This was followed by early diseased (10.3 percent) and medium diseased (11.74 percent) palms. The highest root decay was observed in the black roots of severely diseased palms (63.1 percent). A comparison of total roots and their decay indicated that the maximum number of roots and the least decay were observed in the apparently healthy palms (2,668 roots with 6.67 per cent decay). The root decay in the early and medium diseased palms were 9.5 per cent and 8.5 per cent, respectively. The maximum root decay of 14.8 per cent occurred in the severely diseased palms.

Table 8.2. Number and weight (g) of roots decayed per palm, (sandy loam soil, Kayamkulam)

Category of root (colour)	Disease intensity					
	Apparently healthy		Moderately diseased		Severely diseased	
	Number	Weight	Number	Weight	Number	Weight
White/cream	141	1.0	5	0.03	—	—
Orange	1350	20.33	215	4.57	653	13.25
Red	3690	55.20	1219	24.83	1737	26.78
Dark brown/black	1589	101.95	1769	52.25	869	12.82
Total	11767	178.48	3208	81.65	3259	52.85
Percentage of decayed roots	2.62		16.80		16.76	

At the Regional Agricultural Research Station, Pilicode representing the healthy tract and laterite soil type, the excavated coconut palm had 7164 roots, measuring a total length of 7685.5 metres. The roots weighed 225.4 kg. Among the different categories of roots, red roots predominated (Table 8.4). The number, length and weight of red roots were, 6067, 6519.1 m and 193.5 kg, respectively. Another important feature of the roots in the healthy area was that in none of the roots, decay was noticed.

Table 8.3 Number and weight (g) of roots decayed per palm, (laterite soil, Mavelikkara)

Category or root (colour)	Disease intensity							
	Apparently healthy		Mildly diseased		Moderately diseased		Severely diseased	
	Number	Weight	Number	Weight	Number	Weight	Number	Weight
White/cream	91	1.90	—	—	68	0.85	—	—
Orange	518	19.70	134	2.90	526	15.05	372	5.65
Red	2060	140.20	1585	40.30	1567	49.15	2057	82.50
Black	—	—	—	—	—	—	38	2.30
Total	2669	161.80	1719	43.20	2161	65.05	2467	90.45
Percentage of decayed roots	6.67		9.54		8.51		14.80	

In order to study the internal damage of roots, samples of healthy and diseased roots were brought to the laboratory and microtome sections were taken. It was seen that there was considerable damage of xylem and phloem vessels in the palms infected with the disease, while the xylem and pholem vessels were in tact in the roots of healthy palms.

The samples of decayed roots were plated by tissue isolation method of find out the organism, if any, associated with root decay. An unidentified fungus (*Stentomyceta*) was repeatedly obtained from the decayed portions of roots collected from root (wilt) affected coconut palms.

The root samples were also subjected to assay of rhizosphere microorganisms. The fungi belonging to the following genera were found to be associated with the rhizosphere of coconut palms infected with root (wilt) disease.

Table 8.4 Number and weight of roots in apparently healthy palms, (laterite soil, Pilicode)

Characteristic	Orange/cream			Red			Brown/ Black*	Total
	0-30	30-60	60-90 cm	0-30	30-60	60-90 cm	0-30 cm	
No. of roots	152	680	145	1495	2566	2006	120	7164
Total length (m)	217	575	104	2944	2154	1420	269	7685
Average length (cm)	142	8	72	197	84	71	225	—
Weight (kg)	7	15	2	101	66	26	8	225
Decay (per cent)	—	—	—	—	—	—	—	—

* No roots in 30-60 and 60-90 cm depths

Alleschieriellla
Cephalosporium
Diplodia
Fusarium
Mammaria
Pestalotia
Sepadonium
Candida
Colletotrichum
Gilmaniella
Helminthosporium
Mucor
Phoma
Sympodiella

A comparison of roots of coconut palms of the same age standing in the same soil type and under the same management showed that differences existed among number, length, weight and percentage of decay of different categories of roots of palms in root (wilt) free area (Pilicode) and root (wilt) affected area (Mavelikkara).

The roots in the healthy area were not decayed. However, in the diseased tract, the root decay had occurred and it varied with the disease intensity—6.7 per cent in the apparently healthy, 9.5 per cent in the early diseased, 8.5 per cent in medium diseased and 14.8 per cent in the severely diseased palms. In all the palms, the maximum roots belonged to the category of red roots. While none of the red roots in the palm of the healthy area was decayed, in the diseased tract, root decay increased with the increase in disease intensity—8 5 per cent in the apparently healthy, 10.3 per cent in the early diseased, 11.7 per cent in the medium diseased and 16.6 per cent in the severely diseased palms.

The overall picture that emerged out of the studies is that root (wilt) disease is negatively correlated with the number, length and weight of roots and is positively correlated with root decay. The observation that reduction in root number and considerable root decay in the apparently healthy palms in the diseased tract indicates that root damage occurs prior to foliar symptoms viz., flaccidity, yellowing and marginal necrosis. Hence, root rejuvenation as a programme has to be undertaken in all coconut plantations in the root (wilt) affected regions of Kerala State.

Rhizosphere microflora

Quantitative and qualitative studies on the different rhizosphere micro-organisms, viz., fungi, bacteria and actinomycetes in the rhizosphere of coconut palms in the healthy as well as apparently healthy palms and palms of varying root (wilt) intensities in the diseased area representing the main soil types (alluvium, sandy loam and laterite) were taken up. The study was initiated at the College of Agriculture, Vellayani during 1966 and continued till 1977. A detailed study was undertaken later at the College of Horticulture, Vellanikkara from 1980 to 1985.

Roots and soil samples were collected from the diseased and apparently healthy palms from a diseased area at Kayamkulam and from the healthy palms from a disease-free area at Vellayani during rainy and dry seasons. Samples from the tip and basal regions of both young and old roots were collected and microbial populations assessed from each sample using standard methods.

It was observed that the root (wilt) affected coconut palms harboured a higher fungal and bacterial population in the rhizosphere as compared to the healthy palms from both diseased and healthy areas. This increase was mainly noticed in the case of bacteria. However, a reverse trend was noticed with respect to the population of actinomycetes.

Higher fungal and bacterial populations were also observed in the rhizosphere of healthy palms of diseased area than those of disease free areas.

The total fungal population was higher during dry season than in the wet season. The reverse was true with bacteria and actinomycetes. The young and growing roots were found to harbour more microorganisms than the mature and basal portions of the root. This phenomenon was more clear in the disease affected areas. However, the basal regions of the young and old roots supported a higher bacterial population in the healthy palms in the disease free area at Vellayani.

Similar studies were initiated at the College of Horticulture, Vellanikkara. Soil and root samples for microbial analysis were collected from different locations at periodical intervals startting from May 1982 (pre monsoon period) onwards. The second set of samples was drawn during September 1982 (monsoon break), the third set during January, 1983 (post-monsoon) and the fourth during May, 1983 (pre-monsoon). The locations for the study were fixed in three different soil types, viz. alluvium, sandy loam and laterite in the healthy as well as the root (wilt) affected areas.

Alluvial soil: Aymanam, Kumarakom and Kidangara of Kottayam district to represent diseased tract and Mukkam of Calicut district to represent healthy tract.

Sandy loam soil: Kayamkulam (Rice Research Station and Farmers' field) and Ochira to represent diseased tract and Ramanattukara of Calicutdistrict to represent healthy tract.

Laterite soil: Erattupettah, Ettumanoor and Kozha of Kottayam district to represent diseased tract and Chathamangalam of Calicut district to represent the healthy tract.

In the diseased tract, samples were collected from all the locations from three palms each of apparently healthy, medium diseased and severely diseased palms. In healthy areas, the samples were collected from one palm each. From each palm, nine samples were collected (at a distance of 0-1 meter, 1-2 metres and 2-3 metres from the trunk end, also at depths of 0-30, 30-60 and 60-90 cm from ground level).

The results revealed that the rhizosphere microbial population fluctuated between seasons, soil types and condition of the palms. There was no uniform trend in the population with regard to the severity of the disease.

Qualitative studies

The fungal cultures obtained in plates during different periods (as described above) were subjected to a qualitative analysis also. For this, random cultures were picked up and were brought to pure culture by single spore isolation/hyphal tip method. These cultures were sent to the Commonwealth Mycological Institute, Kew, Surrey, England for identification upto the species level. The results are presented in Table 8.5.

Table 8.5. Qualitative analysis of fungi obtained from the rhizosphere of healthy and diseased coconut palms in different soil types

Fungus	Locality	Intensity	Soil type
Absidia corymbifera	Ramanattukara	Healthy	Sandy loam
	Kayamkulam	Early	Sandy loam
Aspergillus niger	Aymanam	Early	Alluvium
Aspergillus flavus	Aymanam	Early	Alluvium
	Chathamangalam	Healthy	Laterite
	Kayamkulam	Medium	Sandy loam
	Kumarakom	Early	Alluvium
Aspergillus ustus	Chathamangalam	Healthy	Laterite
Aspergillus sydowi	Kumarakom	Early	Alluvium
	Aymanam	Medium	Alluvium
	Kayamkulam	Early	Sandy loam
Aspergillus terreus	Kumarakom	Severe	Alluvium
Aspergillus terreus var. *aureus*	Kidangara	Severe	Alluvium
Aspergillus tamari	Chathamangalam	Healthy	Laterite
Aspergillus versicolor	Kumarakom	Early	Alluvium
Alternaria alternata	Kayamkulam	Early	Sandy loam
Botryodiplodia theobromae	Chathamangalam	Healthy	Laterite
Chaetomium globosum	Ramanattukara	Healthy	Sandy loam
Cheatomium aff. cochliodes Palliser	,,	,,	,,
Curvularia lunata	Kayamkulam	Medium	Sandy loam
Curvularia clavata	,,	,,	,,
Eupenicillim sp.	Kidangara	Early	Alluvium
Eurotium amstelodami	Kayamkulam	Medium	Sandy loam
Fusarium equiseti	Kumarakom	Medium	Alluvium
Fusarium solani	Chathamangalam	Healthy	Laterite
	Kayamkulam	Early	Sandy loam
	Ramanattukara	Healthy.	Sandy loam
Fusarium moniliforme	Kozha	Early	Laterite
	Ramanattukara	Healthy	Sandy loam
Fusarium oxysporum	Ramanattukara	Healthy	Sandy loam
	Erattupetta	Early	Laterite
Gongronella butleri	Kidangara	Early	Alluvium
Helicorhiodon sp.	Ramanattukara	Healthy	Sandy loam
Mucor hiemalis	Ramanattukara	Healthy	Sandy loam
Myrothecium verrucaria	Aymanam		Alluvium
Paecilomyces lilacinus	Ramanattukara	Healthy	Sandy loam
Penicillium citrinum	Aymanam	Early	Alluvium
Penicillium javanicum v. *beyma*	Erattupetta	Severe	Laterite
Penicillium janthinellum	Kumarakom	Early	Alluvium
Rhizopus microsporus	Ramanattukara	Healthy	Sandy loam
Rhizomucor pusillus	Kayamkulam	Early	Sandy loam
	Kozha	Medium	Laterite
Synoephalastrum racemosum	Aymanam	Early	Alluvium
Trichoderma harzianum	Mukkom	Healthy	Alluvium
	Kayamkulam	Medium	Sandy loam
	Kozha	Early	Laterite
Trichoderma koningii	Aymanam	Medium	Alluvium
Trichoderma longibrachiatum	Kayamkulam	Medium	Sandy loam

Toxin studies

Out of the several fungi obtained from the rhizosphere of root (wilt) diseased palms, a tota lof seven, namely, *Curvularia clavata,Botryo diplodia, theobromae, Fusarium moniliforme, Fusarium solani, Aspergillus flavus var. Columnaris, Aspergillus niger* and *Trichoderma harzianum* were selected, on the basis of their ability to produce toxins. The magnitude of toxin production was studied by measuring the extent of wilting of tomato seedlings dipped in the culture filtrates of the fungi listed above. In another trial, the inhibition of germination of tomato seeds, was tested by putting the seeds in petriplates moistened with culture filtrates of different fungi. The extent of wilting of tomato seedlings was measured after 48 hours. The inhibition of seed germination was observed after four days.

The study indicates that *Curvularia clavata, Fusarium moniliforme, Aspergillus flavus* and *Trichoderma harzianum* caused servere wilting of tomato seedlings. *Fusarium moniliforme* and *Fusarium solani* were found to reduce the germination of rice seeds effectively. *Trichoderma harzianum, Curvularia clavata* and *Fusarium solani* were efficient in restricting the growth of germinated rice seeds.

Etiology of root (wilt) disease

The root (wilt) is still considered to be a disease of unknown etiology, although viruses fungi, bacteria and nematodes have been implicated. Electron-microscopic studies have shown the presence of pleomorphic structures resembling mycoplasma like organisms (MLOs) in the sieve tubes of phloem tissues in coconut palms infected with root (wilt) disease. Mycoplasmas are, in general, sensitive to oxytetracycline and resistant to penicillin and the reaction of coconut palms to the bove antibiotics might provide indirect evidence on the etiology of diseases caused by mycoplasmas. Study of the various weed flora of the root (wilt) affected gardens would also be useful in the search for a possible collateral host for the mycoplasma like organisms. *In vitro* characterization of molecules associated with root (wilt) disease, if any, by culturing would also be a helpful step in the etiology of root (wilt) disease.

Chemotherapy

Field experiments were conducted at the Regional Agricultural Research Station, Kumarakom, Kottayam during the period from October 1983 and November 1985 using oxytetracycline and penicillin by two methods, viz., stem injection and foliar spraying. Before the commencement of thee xperiment, it was necessary to standardize the stem injection method to administer oxytetracycline.

The standardization was done between 6.30 am on September 1983 to 6.30 am on September 10, 1987 at the Research Station and Instructional Farm, Mannuthy, Trichur. The uptake, translocation and distribution of the tracer dye rhodamine B was studied by injecting 0.2 per cent aqueous solution of the dye by drip method. Samples of tender spindle leaf, old leaflets, fronds buttons and tender coconuts were taken at four-hour intervals. It was observed that the dye reached the fronds, tender nuts, buttons and spindle leaf after four hours of injection. The uptake was slow at the beginning and picked up speed after four hours. It reached the peak by 3.30 pm and then slowly reduced by 7.30 pm and continued thereafter at a more or less same rate till the end. The whole quantity of dye was absorbed into the system by 4 30 am next day.

Stem Injection

Stem injection was done at a height of 1.5 m above the ground level on the trunk of coconut palms. A small hole of 1.5 cm diameter was made on both the sides of the trunk with the help of a metallic punch developed by the Agricultural Enginnering Department of the Kerala Agricultural University. Deepening of the hole to 4 cm depth was done with the help of a breast hand drill. The hole was washed by a jet of water to remove the dust and fibre particles. Then the cork was plugged air tight·

The injection system consisted of a plastic bottle connected to a 'Y' connection through a dripping device. From the 'Y' connection two polythene tubes were connected to the wooden cork hole. The palms were given, 4, 6 and 8 g of the antibiotic in 500ml of distilled water. The minimum period required for the entire antibiotic solution to be absorbed into the palm was 24 hours. However, variation was noticed in certain palms, wherein the period was extended up to 48 hours.

In order to study the systemic and residual activity of oxytetracycline in coconut, leaf tissues were collected for bioassay using *Bacillus cereus* as the test organism. The organism was seeded in potato dextrose agar medium and crude extract of the sample was placed at the centre of pertiplates in filter paper discs. Inhibition of bacterial growth was observed after 48 hours.

Table 8.6. Chemotherapy of root (wilt) disease of coconut (stem injection), Kumarakom

Treatment (per palm)		Pre-treatment 10/'83	Mean disease index 4/'84	10/'84	4/'85	10/'85	Per cent reduction
Oxytetracycline	4 g	35.33	25.58	20.70	10.19	23.64	33.08
,	6 g	35.36	34.18	35.20	12.37	26.80	24 21
,,	8 g	34.71	28.02	28.29	10.55	20.63	40.56
Penicillin	4 g	35.79	33.60	37.62	14.98	22.58	36.91
,,	6 g	35.93	34.79	48.05	18.74	29.47	17.98
,,	8 g	33.45	31.00	32.30	11.00	14.28	57.31
Untreated control		31.58	26.02	19.48	6.14	19.18	39.29

Table 8.7. Chemotherapy of root (wilt) disease of coconut, (foliar spraying) Kumarakom.

Treatment	Pre-treatment 12/83	Mean Disease Index				Per cent reduction
		6/84	12/84	6/85	12/85	
Oxytetracycline						
2000 ppm	38.07	21.51	24.18	10.59	27.67	21.10
,, 3000 ppm	34.86	20.37	24.43	10.12	27.67	20.63
,, 4000 ppm	35.08	23.27	20.70	10.45	28.33	19.24
Penicillin						
2000 ppm	33 07	26.34	22.73	13 10	33.67	28.42
,, 3000 ppm	36.41	36.64	40.73	19.08	24.67	32.24
,, 4000 ppm	33.05	20.34	19.14	7.75	28.67	13.25
Untreated control	36.79	31.74	25.98	16.52	27.67	24.79

At the Regional Agricultural Research Station, Kumarakom, two independent experiments with different levels of oxytetracycline and penicillin were compared with an untreated control. In stem injection, the percentage reduction of disease index in oxytetracline at 4, 6 and 8 g were 33, 24 and 41 respectively. (Table 8.6). The percentage reduction with the same levels of penicillin were 37, 18 and 57, respectively. The reduction in the untreated control was 39 per cent. The foliar spraying of the antibiotics also, did not cause, any significant variation in disease expression by the palms. At Kayamkulam wherein only a single dose of oxytetracycline was compared with an untreated control, there was a small reduction in the disease index, due to the antibiotic. (Table 8.8).

Table 8.8. Chemotherapy of root (wilt) disease of coconut, with stem injection) Kayamkulam.

Period of observation	Disease Index	
	Treated palms	Untreated control
May 1985	30.90	33.60
September 1985	30.43	33.90
Percentage change	1.52	—0.89

The results of a bioassay with *B. cereus* as the test organism indicated that inhibition zone was clearly visible from samples collected up to one month of application of oxytetracycline. After two months, the inhibition zone appeared only in a few cases indicating that the antibiotic was not active in the plant system for more than a month.

A statistical analysis of the data on disease score gathered from two locations during 1983-88 showed no significant difference among treatments. The percentage reduction in disease intensity was also not indicative of the changes in the treatment palms as compared to the control. The results obtained in these trials do not help in the diagnosis of the possible involvement of mycoplasma like organisms in root (wilt) disease of coconut palms.

Further it may be seen that the disease intensity has come down in all the treatments including the untreated control with the passage of time. This indicates that a better management of the palms can reduce the severity or root (wilt) disease. The bioassay conducted from leaf tissues collected from palms treated with oxytetracycline indicated that the antibiotic was active for a period of one month only. The frequency of application of antibiotics was fixed at an interval of three months based on the results obtained under temperate conditions. It is likely that the degradation of antibiotics under tropical conditions occurs at a faster rate and hence a closer administration of oxytetracycline may be essential. In the light of the above observations, it may be concluded that the experiment does not support the possible mycoplasmal etiology of root (wilt) disease of coconut. The mycoplasmal etiology of coconut root (wilt) needs further scientific substantiation.

Survey of collateral hosts

A survey was conducted during the period June 1983 upto June, 1985 to identify and catalogue the collateral hosts of root (wilt) pathogen. The survey covered 54 locations in four districts, Quilon, Kottayam, Ernakulam and Alleppey. A total number of 171 herbaceous plants were catalogued by observing symptoms. The details of symptoms of suspected MLO affected plants were also recorded. Habitation of insects on the plants were studied in relation to the above plants. The adults of the white fly were found colonizing on *Ageratum conyzoides* plants occuring in the north-eastern boundary of Kottayam district. Nymphs of an unidentified aphid was seen in herbaceous plants like *Condiella nodiflora* and *Colocasia* spp. The adults and nymphs of an unidentified fulgorid bug were found in the crown of young palms at Erattupetta. The adults of lace wing bug were also noticed on coconut crowns in this locality and at Palai. The survey was also conducted in the other parts, viz., Ranny, Pathanamthitta, Punaloor, Karavaloor, Ayoor, Valakom and Kottarakkara. A summary list of herbaceous plants found in the areas surveyed is provided in Table 8.9.

Table 8.9. Catalogue of herbaceous plants in the root (wilt) affected districts of Kerala

District	Locations surveyed (No.)	Species catalogued (No.)	Families of plants involved (No.)
Quilon	18	65	18
Kottayam	11	21	9
Ernakulam	13	41	21
Aileppey	12	44	18
Total	54	171	66

It may be seen that the maximum number of species of herbaceous plants was recorded in Quilon district and the least number in Kottayam district. *Emilia* *sonchifolia* was recorded in all the districts. *C. nodiflora, A. conyzoides, Croton sparsiflorus, Stachytarpheta indica* and *Vinca rosea* were the predominant species in all the locations surveyed.

The herbaceous weeds in the root (wilt) affected areas showing yellowing symptoms were subjected to a special staining technique to test the possible presence of mycoplasma like organisms (MLOs) in them. The phloem of stem sections of all the samples remained unstained, indicating the absence of MLOs in them. Hence, none of the above plants could be presumed to contain MLOs. Therefore, it is unlikely that these plants serve as collateral hosts of the root (wilt) pathogen.

Meristematic tissues of roots and leaves and phloem sap of infected plants were used for *in vitro* characterization of molecules associated with root (wilt) disease. In addition, a host *Vinca rosea* growing in different coconut gardens was also utilised for the study. The samples were surface sterilized by using 0.1 per cent mercuric chloride solution before use. The traces of mercury adhering to the samples were removed by several washings in distilled water. Then the tissue was extracted in ^{34}C medium. The tissue homogenate was filtered and incubated by taking 1.6 ml in a test tube to which 0.1 ml of plant extract was added. The cultures were centrifuged and the supernatant was separated from which slides were prepared. Gram staining and giemsa staining were done and the slides were observed under oil immersion objective.

Small round particles were visible repeatedly in the various samples analysed. The identity of the organism could not be confirmed. Culturing was attempted in solid medium also, for which PPLO solid medium was used. Petri-dishes with media were inoculated with centrifuged liquid culture. But no success was obtained. The above studies were carried out at the College of Veterinary Science, Mannuthy and the College or Horticulture, Vellanikkara.

Varietal evaluation

A series of trials were carried out at the Regional Agricultural Research Station, Kumarakom, Rice Research Station, Moncompu and Rice Research Station, Vyttila to assess the reaction of coconut cultivars/hybrids to root (wilt) disease. The observations so far gathered reveal that none of the cultivars/hybrids possesses remarkable resistance or tolerance to the malady.

In a field trial initiated at Kumarakom in 1974, sixteen coconut hybrids were screened for their tolerance to root (wilt) disease (Table 8.10). The intensity of root (wilt) disease was recorded from 1979 onwards. The results gathered during the period 1979-'81 indicated that the intensity of root (wilt) incidence was significantly low in Fiji x Gangabondam followed by Gangabondam x West Coast Tall. The hybrid Malayan Dwarf yellow x West Coast Tall showed the maxi mum disease intensity.

Table 8.10 Reaction of coconut hybrids to root (wilt) disease.

	Hybrid	Root (wilt) disease index		Hybrid	Root (wilt) disease index
1	Fiji x GB	14.50	(9)	LM x SRM	37.78
2	Fiji x YD	30.66	(10)	SRM x LM	20.47
3	WCT x GB	24.24	(11)	AD x WCT	26.00
4	GB x WCT	17.94	(12)	AD x YD	20.82
5	WCT x GD	29.72	(13)	YD x WCT	27.45
6	GD x WCT	25.60	(14)	LO x GB x NG	21.78
7	WCT x MDY	28.50	(15)	LO x GB x YD	38.16
8	MDY x WCT	41.61	(16)	LO x GB x Spicata	18,14
		CD (0.05)	10.12		

GB. Gangabondam; YD, Yellow Dwarf; WCT, West Coast Tall; GD. Green Dwarf; MDY; Malayan Dwarf Yellow; LM, Lakshadweep Micro; SRM, San Ramon; AD, Andaman Dwarf, YD Yellow Dwarf; LO, Lakshadweep Ordinary; NG, New guinea

In another series (1976) fifteen accessions were tried for their tolerance to the disease. All the palms took infection on the third year of planting. In another series started at Kumarakom in 1975, all the hybrids were found susceptible to the disease. in the trials conducted at Moncompu and Vyttila also, the palms took infection in the fourth year.

During the period 1972-'81 the following varieties of coconut were tested in a completely randomised design at Kumarakom. The number of replications assigned to each cultivar is given in parenthesis: (i) Strait Settlement Green (9), (ii) Malayan Dwarf (9), (iii) Java (3), (iv) Cochin China (10), (v) Andaman Giant (10), (vi) Andaman Ordinary, (vii) (9), Dwarf x Tall (16), and (viii) West Coast Tall (16). The observations on root (wilt) and leaf rot were recorded from 1979 to 1981. The mean data on root (wilt) disease intensity (Table 8.11) indicated that Andaman Ordinary was the least susceptible cultivar to the disease, Strait Settlement Green and Cochin China also showed a fair degree of tolerance. Java and WCT were observed to be highly susceptible to the disease. The leaf rot intensity was significantly low in Cochin China and Andaman Ordinary when compared to West Coast Tall and Java (Table 8.11).

Table 8.11. Reaction of coconut varieties to root (wilt) and leaf rot diseases

Variety	Mean root (wilt) disease index	Mean number of leaves affected by leaf rot
1. Strait Settlement Green	23.96	2.44
2. Malayan Dwarf Yellow	31.98	2.78
3. Java	51.11	3.00
4. Cochin China	24.17	1.07
5. Andaman Giant	29.11	2.41
6. Andaman Ordinary	15.29	1.54
7. Natural Cross Dwarf	26.84	2.04
8. West Coast Tall	42.97	3.21
C D (0.05)	7.33	1.42

In another experiment laid out during 1974 in a compact family block design the following family groups were compared: i) Lakshadweep Ordinary ii) New Guinea iii) Cochin China iv) Philippines v) Andaman Ordinary vi) West Coast Tall. There were six progenies in each family. The observations on root (wilt) intensity were recorded at half yearly intervals from 1977 to 1983 (Table 8.12). The results indicated that the progeny of Cochin China x Green Dwarf recorded the lowest root (wilt) disease intensity (6.86) followed by Lakshadweep Ordinary x Yellow Dwarf (7-42).

Table 8.12. Root (Wilt) disease tolerance of progenies of Tall x Dwarf and Tall x Tall cross combinations

Designation	Mean root (wilt disease index (Pooled)
LO x MDY	18.38
LO x GB	23.07
LO x GD	16.33
LO x AO	12.72
LO x YD	7.42
WCT x GB	37.90
WCT x GB	26.23
WCT x T	27.80
WCT x YD	38.09
WCT x AD	33.10
AO x AO	34.92
AO x MDY	28.56
AO x GB	18.73
AO x AD	24.19
AO x YD	21.91
N x GB	14.21
NG x AD	15.63
NG x MDY	25.73
NG x GD	23.41
NG x MDY	23.51
NG x YD	27.64
CC x YD	26.16
CC x CC	21.64
CC x GB	13.66
CC x MDY	16.21
CC x AO	34.29
CC x GD	6.86
Philippine x MDY	13 14
Philippines x Philippines	24.69
C D (0.05)	7.82

LO, Lakshadweep Ordinary; GR, Gangabondam; GD, Green Dwarf; AO, Andaman Ordinary; MDY, Malayan Dwarf yellow; AD, Andaman Dwarf; YD, Yellow Dwarf; CC, Cochin China; NG, New Guinea.

A field trial with the following exotic cultivars of coconut from geographically distinct areas was laid out in a completely randomised block design during 1976 at Kumarakom. The replications of each test variety are given in parenthesis (i) San Ramon (12), (ii) St. Vincent (14), (iii) Jamaica (10), (iv) British Solomon Island (17), (v) Keniya (22), (vi) Guam (21), (vii) Strait Settlement Green (16), (viii) Federated Malayan States (26), (ix) Java (22), (x) Fiji (21) and (xi) West Coast Tall (WCT) (18).

All the exotic cultivars tested were found to be susceptible to the disease. However, the cultivar, San Ramon recorded significantly lower disease incidence followed by Guam, St. Vincent and Keniya. The other exotic cultivars like Strait Settlement Green, Federated Malayan States, British Solomon Island, Jamaica and Fiji were significantly superior to the local check variety, West Coast Tall. It was also found that West Coast Tall and Java were highly susceptible to root (wilt) disease (Table 8.13).

Table 8.13. Reaction of exotic cultivars of coconut to root (wilt) disease

Rank	Cultivar	Mean root (wilt) disease index
1	San Ramon	12.22
2	Guam	19.86
3	St. Vincent	22.64
4	Keniya	23.04
5	Strait Settlement Green	23.64
6	Federated Malayan States	25.45
7	British Solomon Island	25.99
8	Jamaica	26.51
9	Fiji	30.18
10	Java	30 91
11	West Coast Tall	39.81
	C D (0.05)	9.12

Stem bleeding

Stem bleeding of coconut is a very serious disease in the northern districts of Kerala. It is classified as a disease of unknown etiology at present. A few studies have been conducted at the Regional Agricultural Research Station, Pilicode on symptomatology, etiology and control of the disease.

Symptomatology

The first indication of the disease is the oozing out of a dark reddish brown fluid from cracks that may be found on the surface of the stem or bark. This reddish brown ooze turns black as it dries. In the early stages, the discolouration and decay of the tissue is localised and as the disease advances, a general decay of the internal tissue takes place. At this stage, the tree ceases to bear nuts, the crown dwindles and the palm dies. Generally, young palms are seldom affected. When young palms are affected at the base, the outer patches give no indication of the internal decay. The inner tissue rots and a cavity is formed along the central portion of the stem in which a thin yellowish fluid accumulates. If the decay extends downwards the stem becomes hollow.

General yellowing is the first symptom noticed on leaves. The size of the newly emerged leaves is reduced with shorter petioles. In advanced stages, the normal production of leaves is also delayed. Then the number of leaves in the affected palm gets gradually reduced. In certain cases the older leaves get dried up and hang from the tree.

The inflorescence bears a few female flowers and sometimes the husk of nuts gets shrinked and a circular depression is formed on the husk. In some cases, tapering of the trunk is observed. Formation of the kernal is also seen affected. In palms affected by stem bleeding, root decay is a common phenomenon.

Etiology

Stem bleeding disease was prevalent in Kerala from the very early day and its causal organism was reported to be *Theilaviopsis paradoxa* by Sundaram in 1922, the then Mycologist of Madras presidency. He reported that only when the surface was injured and wounds or cracks were formed, the fungus was able to infect the palms. However, studies conducted later by different workers failed to establish the above fungus as the causal agent. The fungus was considered as an associated organism and not as the primary cause of the disease. Application of heavy doses of fertilizers was also reported as a possible cause for disease incidence.

Studies conducted at Pilicode during 1984–87 revealed that apart from *Theilaviopsis paradoxa*, fungi like *Paecilomvces variotti*, *Philaphera* sp., *Trichoderma* sp., *Acremonium racifeii*, *Alternaria sp. Aspergillus* sp., *Botryodiplodia theobroma and Fomes lavegatus* were associated with the stem bleeding of foconut. Among these fungi, *Paecilomyces variottii* alone took infection on articicial inoculation.

The influence of season on the occurrence of the disease was also studied. Ten palms each at Pilicode and Nileshwar were selected for recording observations. The soil types were red laterite loam at Pilicode and sandy loam at Nileshwar. At Nileshwar, the palms were irrigated at the rate of 200 litres/palm/week during summer months from December to May while those at Pilicode were not irrigated. At Pilicode 13 percent of the palms showed symptoms in July and 20 percent showed symptoms in November. The symptom expression was noticed only during July to December at Pilicode. At Nileshwar, 16 percent of the palms showed symptoms in August, 30 percent during February, April, August, October and November and 36 per cent during June. The symptom expression was low in summer months at Nileshwar. This might be attributed to the effect of irrigation.

Varietal reaction

The reaction of different varieties in the germplasm collection of coconut at Pilicode to stem bleeding disease was studied during 1985 and according to the surface area of infection, they were classified into three groups (Table 8.14). The cultivars with a fair degree of tolerance included Lakshadweep Ordinary, Philippines Ordinary, Jamaica, Siam, Navasi, Ceylon, Kalibahim, Gangabondam, Omalur Indupali and Kulithalai.

Table 8.14. Reaction of coconut cultivars to stem bleeding disease

Group I (tolerant)	Group II (mildly susceptible)	Group III (highly susceptible)
Siam	Cochin China	New Guinea
Philippines Ordinary	St. Settlement	Java
	Apricot	Strait Settlement Green
Kalibahim	Philippines Laguna	Fiji
Jamaica	Lakshadweep Dwarf	Philippines Ordinary
Navasi	Kappadam	Seychelles
Ceylon	Bombay	Gon Thembli
Malayan Dwarf Green	Godavari	Thembili
Malayan Dwarf Yellow		Sanramon
Malayan Dwarf Orange		Andaman Ordinary
Lakshadweep Ordinary		Andaman Dwarf
Omalur		Andaman Giant
Kulithalai		Lakshadweep Small
Indupali		Bengal
Gangabondam		Mysore
		West Coast Tall

The loss in nut yield due to the disease was also estimated by studying the yield of the diseased and healthy palms (100 each) over a span of 10 years, using the formula $\frac{(X-Y)\ 100}{X}$ where, X=the yield of healthy palms and Y=the yield of the diseased palms. The yield loss was estimated as 23.6 per cent.

Disease control

Earlier studies on the control of the disease indicated that removal of the decayed tissues and application of coaltar or bordeaux paste in the affected area checked the spread of the disease. Sanitation of the coconut garden as a whole could also reduce the disease incidence. Studies on chemical control of the disease revealed that drenching one per cent calyxin (25 l per palm) reduced the disease intensity considerably and it was on par with bavistin, vitavax, coaltar and aureofungin sol. In farmers' fields also calixin drenching was found to reduce the disease (Table 8.15).

Another trial on disease control revealed that application of neem cake at the rate of 5 kg per palm and drenching the basin with one per cent Bordeaux mixture was effective in reducing the disease intensity.

Table 8.15. Influence of fungicides, neem cake and coal tar on stem bleeding disease (mean data of four years)

Treatments	Per cent increase in the area of infection (Transformed values *)
1. Bavistin	1.174
2. Calixin	0.513
3. Benlate	1.026
4. Vitavax	1.160
5. Aureofungin sol	1.689
6. Neem cake	1.223
7. Coaltar treatment	1.227
C D (0.05)	0.499

Bud rot

Another fatal disease on coconut palm is the bud rot of fungal etiology, reported as early as in 1913, by Fletcher, the then Government Entomologist of Coimbatore. The causal organism was reported by Shaw and Sundararaman (1914) to be *Phytophthora palmivora* Bull. The disease was widely spread in parts of Malabar district but was mild in other areas. The disease spread slowly, though persistently, by means of tappers, rhinoceros beetle and human agencies.

There was a controversial belief that the primary cause of bud rot was bacteria and *Phytophthora* was only secondary. Isolation studies were therefore, taken up with Potato Dextrose Agar, Peptone Dextrose Agar and Hutchinson Agar. The growth of the micro-organisms isolated was recorded and identified. Bacteria could be isolated only from the soft rot areas and the bacterial isolates when inoculated on young palms did not take infection and produce the typical symptoms of bud rot thereby ruling out the possible involvement of bacteria in the incitation bud rot disease.

Classification of infected plants according to their age showed that plants below three years and above 15 years were seldom affected. The percentage of infection was more from the fourth to the seventh year. The exotic varieties of coconut were found to be more susceptible to the disease than the West Coast Tall.

Control measures

From 1922 onwards, control measures were tried at Pilicode and Nileshwar. The affected portion of the trees were removed and Bordeaux paste was applied. Prophylactic spraying with one per cent Bordeaux mixture was given to coconut palms in May and June every year.

Studies on the incidence of the disease during the different months of the year revealed that the maximum disease was noticed in August followed by July.

An experiment was laid out in a cultivator's field during 1982 to assess the efficacy of newer fungicides against the bud rot disease of coconut. Five treatments were compared viz., Bordeaux paste 10 percent, Fycop 40 A 5 percent, Fytolan 10 per cent, Ridomil wp 25 0.2 per cent + Cuman L 0.08 per cent and Ridomil 0.2 per cent + Cuman L 0.08 per cent. There were four replications. The infected bud portions were thoroughly cleaned and the chemicals were applied. Among the treatments, Ridomil+ Cuman L and Bordeaux paste were the best (Table 8.16).

Table 8.16 Chemical control of the bud rot of coconut

Treatments	Palms treated	Mortality	Percentage of mortality
Bordeaux paste	4	Nil	0
Ridomil MZ 0.5 per cent + Cuman L 0 8 per cent	4	Nil	0
Fycop 40 A 5 per cent	4	1	25
Fytolan 10 per cent	4	1	25
Ridomil wp 25 0.2 per cent + Cuman L 0.08 per cent	4	1	25

Quick (Yellow) decline

In the root (wilt) affected areas of Kerala State, especially in Alleppey and Ernakulam districts, a peculiar type of disease—bright lemon yellowing of leaves—was noticed on a few scattered palms. The first symptom of the disease was bright yellow discolouration of one of the leaves in the middle whorl. Soon the yellowing was found to spread to the leaves just above and just below the discoloured leaf. Finally all the leaves in the middle whorl of the palm became bright yellow in colour. Along with the foliar symptoms, inflorescence necrosis and drying were also noticed. The symptomatology of the disease was studied by conducting periodical survey of palms in several farmers' fields in Muthukulam and Government farms (District Agricultural Farm, Mavelikkara and Kayamkulam Kayal Farm, Cheppad) in Alleppey district and in a few farmers' fields in Shertallai taking in Alleppey district.

In order to study the etiology of the disease, soil and leaf samples were subjected to chemical and microbial assay. No pathogenic fungi or bacteria were obtained in laboratory from any of the samples collected. The leaf and soil analysis indicated a possible deficiency of copper and manganese in the samples tested. Based on the laboratory studies, a field experiment has been laid out at Cheppad. Alleppey district with the following treatments:

T_1—Soil application of copper and manganese (250 g)
T_2—Stem injection of oxytetracycline 3 g ai/palm
T_3—Stem injection of penicillin 3 g ai/palm

T_4—Treatment 1 plus Treatment 2.
T_5—Untreated control.
The study is in progress.

Leaf rot

It is a common observation that leaf rot caused by *Bipolaris halodes* is often superimposed on root (wilt) affected coconut palms. Leaf rot, in fact, worsens the condition of the root (wilt) affected palm very seriously.

Etiology

During 1965, a detailed investigation on the etiology of leaf rot disease of coconut was conducted at the College of Agriculture, Vellayani by collecting diseased specimens from five southern districts of Kerala state where the disease was noticed. Isolation studies of the specimens showed that *Helminthosporium halodes* *Gloeosporium* sp., *Gliocladium roseum*, *Fusarium* sp., *Diplodia* sp., *Pestalotia palmarum* and *Thilaviopsis paradoxa* were present.

The pathogenicity of the organisms isolated, was tested on young healthy palms. Simultaneous inoculations were done on detached leaves and leaf bits also. It was found that *H. halodes*, was pathogenic either individually or collectively. The other fungi were not pathogenic.

Two field experiments were conducted at the Regional Agricultural Research Station, Kumarakom from 1981 to 1985 in order to find out whether the application of boron as root injection, foliar spray, crown filling or soil drenching could prevent the incidence of leaf rot disease on root (wilt) affected palms or could reduce the intensity of leaf rot disease on already diseased palms. In the first experiment using leaf rot disease free palms, all the experimental palms contracted the disease irrespective of treatments. In the second experiment consisting of already diseased palms, the application of boron could not significantly reduce the disease intensity. Hence, it was concluded that the application of boron was not effective in preventing the incidence of leat rot disease or in reducing the intensity of the disease in affected palms.

Control of leaf rot

The efficacy of some of the newer fungicides in controlling leaf rot disease was tested. As the first step, bioassay of the various fungicides against *Bipolaris halodes* was carried out at the College of Horticulture, Vellanikkara. Those fungicides which were found effective *in vitro* were selected for field evaluation on a multilocational basis.

in vitro studies

A total of fourteen fungicides, viz., Cupranik, Captaf, Bavistin, Kitazin, Hinosan, Foltaf, Thiride, Maneb, Panolil, Difolatan, Anthracol, Bayleton, Blitox and Aureofungin sol each at five different concentrations (100, 250, 500, 1000 and 2000 ppm) were used for bioassay studies against the leaf rot pathogen, *Bipolaris halodes* in both solid as well as liquid media. Bordeaux mixture one per cent was used as the standard check. The growth of the pathogen was evaluated by poison food technique also. Based on the results of solid and liquid media, it was concluded that Foltaf, Manzeb, Panolil, Captaf, Hinosan and Kitazin were effective in preventing the growth of the fungus under laboratory conditions. The above chemicals were also tested for their field performance.

Field trials were carried out at Regional Agricultural Research Station, Kumarakom, Rice Research Station, Vyttila and Rice Research Station, Kayamkulam for a period of three years (1982-1985) with Foltaf, Manzeb, Panolil, Captan, Hinosan, Kitazin and Bordeaux mixture as treatments. At each centre, two independent trials were carried out, the first set on coconut palms which were already infected by leaf rot and the second set on coconut palms which were apparently free from leaf rot when selected. The palms in different treatments were scored for the intensity of leaf rot before treatment application, viz., pre monsoon, monsoon break and post monsoon periods, using the score chart given in Table 8.17.

Table 8.17. Score card for leaf rot of coconut

Disease score	Disease Intensity (area affected in percentage)
0	Healthy (no infection)
1	Less than 10
2	10—25
3	25—50
4	50—75
5	More than 75

In the first experiment, the reduction in disease intensity in different fungicidal treatments varied from 22 to 43 percent. The disease intensity in the untreated control remained almost constant. Bordeaux mixture was the most effective treatment with 43 percent reduction. Next in the order of merit was Kitazin, in which 40 per cent reduction had occurred. The reduction in disease intensity in palms treated with Foltaf and Manzeb was 33 per cent and 29 per cent. respectively. The least reduction was noticed in palms treated with Panolil (22 per cent). The study indicated that Kitazin could be used in the place of Bordeaux mixture, without loosing much efficiency. Even with repeated thorough sprayings, the disease could be reduced to 22 percent of the original disease level. Obviously the frequency of spraying (once in four months) was insufficient to keep the new leaves (which emerged every month) free from infection. The observation that the disease situation did not develop further in the untreated control was possibly due to the fact that the inoculum density might have been reduced in the area through repeated sprayings.

In the second experiment, in which apparently healthy palms were sprayed with different fungicides, it was found that in plants sprayed with Bordeaux mixture or Hinosan, the disease intensity was as low as one per cent. In the palms treated with Kitazin or Manzeb, the intensity was two per cent. Foltaf and Panolil were not effective in preventing infection. In the untreated control, the intensity was 16 per cent.

On evaluating the merits of different fungicides in both the experiments, it could be concluded that Kitazin one per cent spray was almost as effective as Bordeaux mixture one per cent in leaf rot control. However, no fungicide tried had the ability to eradicate the pathogen from the infected area completely. But, one per cent Bordeaux mixture was more effective than the other fungicides.

Leaf blight

During 1986, a disease causing extensive damage to the foliage was found to occur in many parts of the northern Kerala. The disease symptom began from the tip or the margin of the leaflets and spread downwards in a concentric manner. Sometimes 10 to 17 leaves of a palm were seen affected. *In vitro* studies revealed that the causal organism was *Pestalosphaeria elaeidis*.

To find ound a suitable control measure for the disease, Bavistin (0.1 per cent) and Bordeaux mixture (one per cent) were sprayed after removing the infected leaves. In the control plants, the infected leaves were removed, but no spraying was given. It was found that the above fungicides were effective in checking the disease.

Association of *Fumago vagans*

An epiphytic association of the fungus *Fumago vagans* on the leaflets of a 15-year-old coconut palm in the Regional Agricultural Research, Pilicode was noticed. The Fungus was found to occur as a sooty growth covering the dorsal surface of the individual leaflets. Occurrence of the association before opening of the leaves resulted in webbing together of the leaflets by the fungal mycelia. The association persisted In the leaflets till the leaf matured. The fungi did not enter the host tissue to cause direct damage to the leaf. A preliminary study revealed that the extent of association varied from 0 to 40 per cent of the leaf area. There was a reduction in chlorophyll content due to this association and it varied from 3 to 30 per cent depending on the extent of association.

Immature nutfall

Shedding of female flowers (buttons) and immature nuts occur in coconut due to various reasons. The problem was first reported in 1922 from Perumbilau and Chalissery areas of the erstwhile Cochin state. Since it resembled the Mahali of arecanut in several respects, it was called as 'Mahali disease' at that time. After the unusual heavy rains in August 1923 reports of nutfall were received from various places in the Ponnani and Valluvanad taluks also. Nuts of all sizes were found to be shed. Their stalk end were discoloured. The discolouration extended upto the point of attachment of the inflorescence axis. Newly fallen nuts showed a whitish growth of the fungus over the brown patches. This growth consisted of the mycelium and sporangia of the fungus (*Phytophthora* sp) causing the disease. On breaking open a fallen nut, the husk was found soft and rotten in patches. The kernal of the affected fruit was also rotten. *Phytophthora* sp. was later isolated from the discoloured patches and inoculation trials proved that the fungus was identical with *P. palmivora* var. areca.

In order to identify the role of the fungus in causing immature button shedding, an experiment was conducted during 1979—80 at Pilicode. A total of 31 palms with severe button shedding was selected. The shed buttons were collected every day and pathogens isolated in P. D. A. and Hutchinson Agar. The isolated organisms were identified and inoculated for studying the symptoms During the course of study in 1985 *Pestalotia* sp. was constantly isolated from shed buttons of coconut cv New Guinea. Pathogenicity studies on different cultivars revealed that the pathogen could infect the host only through wounds and the spread of the disease was low. *Botryodiplodia* sp. was also isolated from shed buttons and tender nuts.

CHAPTER 9

Coconut Based Farming Systems

I. P. S. Nambiar, P. K. R. Nambiar and K. C. Rajan

Multiple cropping with coconut as the dominant component has a long tradition in Kerala State. However, only in recent years scientific investigations have been initiated on its ecological principles and ways of management and economic returns. The research work on multiple cropping carried out at the Regional Agricultural Research Stations Pilicode, and Kumarakom are presented in this chapter.

The earlier trials at Pilicode were mostly confined to screening cereals, millets and oilseed crops in the partial shade of coconut palms with the ultimate objective of increasing the net returns from the coconut gardens. Later, long season crops like cassava, banana, ginger and pineapple and perennial crops like pepper, cacao, and cinnamon were introduced in the system. All the crops were grown under rainfed condition.

Intercropping

In a feasibility trial undertaken during 1942–44, upland rice, cumbu, ragi, varagu, samai, and sesamum were grown in small plots in the interspaces of coconut cv. West Coast Tall and the yield data gathered. The performance of sesamum was poor (77 kg per ha) probably due to heavy rainfall during the growing season. The upland rice gave a grain yield of 780 kg per ha. The most promising intercrop was varagu with a grain yield of 1311 kg per ha. None of the millets recorded grain yields above 250 kg per ha.

In another trial conducted during 1943–44 three fodder grasses, thin napier, ordinary napier and guinea grass, were yield tested in the partial shade of a middle aged coconut garden. The best yielder was thin napier (20,260 kg per ha) and it was significantly superior to the other two grasses.

The economic feasibility of raising short and long season annual crops in a middle aged coconut garden (cv. West Coast Coast Tall) was investigated at Pilicode during 1978-79. The intercrops were elephant foot yam, turmeric, ginger, cassava, sweet potato and colocasia. All these crops were planted at the onset of the South-West monsoon (May-June). The yield performance of sweet potato and colacasia was poor. The other crops registered satisfactory yields. (Table 9.1). The maximum profit was received from turmeric (Rs. 2597 per ha) followed by cassava (Rs. 1200 per ha).

Table 9.1. Yield performance of intercrops in coconut gardens

Intercrop	Tuber yield (kg/ha)	Expenditure (Rs./ha)	Gross income (Rs./ha)	Net profit (+) or loss (—) (Rs./ha)
Elephant foot yam	5235	2683	3141	+458
Turmeric	4441	6285	8882	+2597
Ginger	2426	6679	7290	+ 611
Sweet potato	588	3235	147	—3088
Cassava	13823	2706	3906	+1200
Colocasia	338	3676	169	—3507

An investigation was conducted simultaneously at Pilicode (Lateritic loam soil) and Nileshwar (red sandy loam) during 1978-79 to identify the most suitable variety of banana for intercropping in coconut gardens. The varieties tried were robusta, nendran, nhalipoovan and palayamkodan. The best yielder at Pilicode was robusta (9.0 kg per bunch) fetching a gross income of Rs. 11.27 per bunch at the then prevailing price of Rs. 1.24 per kg of fruit. Palayamkodan topped the list of varieties in yield performance at Nileshwar (11.6 kg per bunch) closely followed by nhalipoovan (10.5 kg per bunch). But the highest returns were obtained from the variety robusta. The gross income from palayamkodan was Rs. 11.1 per bunch (Table (Table 9.2). The variety nendran failed to give any yield.

Table 9.2 Performance of banana varieties in the partial shade of coconut garden

Variety	Bunch weight (kg)		Gross income (Rs./Bunch)*	
	Pilicode	Nileshwar	Pilicode	Nileshwar
Robusta	9.0	9.9	11.3	12.1
Nendran	3 8	—	5.7	—
Nhalipoovan	3.7	10 5	4.6	9 6
Palayamkodan	8 0	11.6	8.0	11.1

* The sale price varied with variety

In a similar study conducted in the reclaimed alluvial soil of the Regional Agricultural Research Station, Kumarakom, Palayamkodan was found to be the most suitable variety for intercropping in coconut gardens. The trial comprised of four varieties (nendran, monthan, padathy and palayamkodan) and three ratooning systems (retaining one, two and three suckers per hill during the second and third years).

In the yield performance during the first year monthan and palayamkodan were on par and significantly superior to the other two varieties. This trend was followed by the ratoon crops also. Here, the maximum yields were recorded when three suckers were retained in each hill during the second (first ratoon) and third (second ratoon) years. (Table 9.3). Although the yield per unit area was the highest with the second ratoon (third year of planting), it led to a reduction in the fruit size thereby reducing the market value of the fruit. Therefore one ratoon of palayamkodan with three suckers per hill was adjudged as the best intercropping system for the reclaimed alluvial soils of Kuttanad.

Table 9.3. Bunch yield (kg/ha) of banana varieties as influenced by ratooning systems; alluvial soil, Kumarakom

Plant crop/ ratoon crop	Variety				C D (0.05)
	Nendran	Monthan	Padathy	Palayamkodan	
Plant crop (First year)	14996	35049	25813	32934	variety 6012
First ratoon crop (Second year)					variety
1 Sucker/hill	11591	29863	31604	34244	9048
2 Suckers/hill	20962	49406	54116	52400	Ratoon
3 Suckers/hill	34153	78445	59288	86893	7786
Mean of first ratoon crop	22235	52571	48336	57846	
Second ratoon					variety
1 Sucker/hill	9636	·16970	13061	22349	4476
2 Suckers/hill	12597	27322	23936	30631	Ratoon
3 Suckers/hill	16796	43867	33243	51394	3876
Mean of second ratoon crop	13010	29386	23413		

Mixed cropping

An experiment on the mixed cropping of cacao was initiated at Pilicode in the year 1970 to study its influence on the yield performance of coconut under rainfed conditions. The planting materials for the study were obtained from Londas Jerangau Estate in Malaysia. These were natural hybrids of Forestero and Criollo. The experiment was laid out in a randomized block design with three treatments and eight replications. The treatment-1 consisted of three single rows of eight seedlings (single hedge) each planted in the centre of two rows of coconut palms at a spacing of 3.65 m. There were 24 seedlings in this treatment. The treatment 2 had three double rows of eight seedlings (double hedge) each planted at a spacing of 3.65 m in the triangular system of planting. There were 48 seedlings in this treatment.

The cacao seedlings were planted in a 50-year-old coconut plantation (var : West Coast Tall) spaced at 9 m x 9m. The coconut and cacao were manured separately as per the package of practices recommendations:-

Coconut : 0.5 kg N, 0.32 kg P_2O_5 and 1.20 kg K_2O per palm per year.
Cacao : 0.10 kg N, 0.04 kg P_2O_5 and 0.14 kg K_2O per seedling per year.

There was no significant difference between the two systems of planting in the number of pods per plant (Table 9.4) obviously because the plants were well spaced. However, in per ha yield the double hedge system was significantly superior to the single hedge system owing to nearly double the number of plants in the former.

Table 9.4. Yield character of cacao planted as mixed crop with coconut

Year	Number of pods/plant		Weight of dry beans (kg/ha)		
	single hedge	double hedge	single hedge	double hedge	C D (0.05)
1976	17.1	19.4	146.9	334.1	140.8
1977	35.9	35.7	305.9	614.1	228.4
1978	21.9	21.2	186.8	314.0	150.8
1979	11.9	14.4	94.0	248.6	125.3
1980	18.2	20.4	163.8	435.4	201.9
1981	17.3	22.2	146.9	381.3	195.6
1982	15.9	18.9	135.1	323.5	147.1
1983	16.9	18.7	143.5	319.9	154.7
Mean	19.3	21.4	165.4	377.6	—

Table 9.5. Nut yield (per ha) of coconut cv. West Coast Tall as influenced by mixed cropping of cacao

	Year	System of mixed cropping with cacao		
		Single hedge	Double hedge	No cacao
Pre-treatment yield		7208	7484	7449
Post-treatment yield	1971	7800	7781	6817
	1972	9081	8922	8523
	1973	8344	9481	8423
	1974	7350	7408	8292
	1975	8439	8911	8273
	1976	7088	7386	6839
	1977	12126	9628	9373
	1978	8641	8261	10005
	1979	6820	7236	7019
	1980	6491	5769	8081
	1981	8614	9446	9441
	1982	6173	4475	6247
	1983	8203	6610	8076
Mean		8090	7800	8108

The net returns from cacao worked out to Rs.2542 and Rs. 5880 per ha under the single hedge and double hedge systems respectively. The latter system thus proved to be more efficient in the utilization of available space and sunlight in the coconut gardens.

The data on the pre-treatment yield of coconut from 1965-70 and the post-treatment yields of coconut and cacao during 1971-'83 were recorded. The results showed that there was no marked variation in the yield performance of coconut over these thirteen years due to mixed cropping of cacao indicating the compatibility of cacao as a mixed crop with coconut (Table 9.5).

Multistoreyed Cropping:

An experiment on multistoreyed cropping was laid out in 1970 at Pilicode. The crops included coconut, cacao, black pepper and pineapple (Table 9.6). Cacao was planted under the double hedge system. Two rooted cuttings of black pepper were planted in the coconut basin, 60 cm away from the bole and later the vines were trained on to the coconut trunk. Three rows of pineapple were planted in between palm rows. The different crop species were fertilized as per the package of practices recommendation.

The results showed that a maximum profit of Rs. 17,430 per ha could be generated from the multistoreyed cropping system involving coconut, pineapple, cacao and black pepper. The coconut+cacao cropping system was also almost equally productive, yielding a net return of Rs. 14300 per ha. Against this, the monocrop of coconut registered a net profit of Rs. 6050 per ha only (Table. 9.6)

Table 9.6. Economics of multistoreyed cropping

Crop combination	Mandays per year	Total expenditure on cultivation (Rs per ha)	Net profit (Rs per ha)
Coconut monocrop	220	3500	6050
Coconut + cacao	300	6200	14,300
Coconut + cacao + pineapple + pepper	360	7520	17,430

The multistoreyed system represents the most intensive type of land management in coconut gardens. Its success depends, however, on the timely availability of inputs and other resources.

CHAPTER 10

Economics of Production and Marketing of Coconut

V. Radhakrishnan, S. Rajina and P. Premaja

Coconut is grown in almost all the small and tiny holdings throughout the length and breadth of Kerala. Even in tiny holdings, it is grown as a commercial crop. The economics of production and marketing aspects of coconut therefore assume importance. However, not much studies have been made with respect to these aspects in Kerala.

Economics of production

A study on the costs and returns in coconut cultivation in Calicut district was undertaken at the College of Horticulture, Vellanikara during the year 1985-86. The data for the study were collected by personal interview method based on a well structured interview schedule from a sample of 120 coconut cultivators. The sample was selected by three-stage random sampling with panchayat as first stage unit, panhayat ward as second stage unit and coconut cultivators as third stage unit. The panchayats selected were Quilandy, Chengottukavu, Feroke, Balussery, Unnikulam and Omasery. From each panchayat, two wards were selected at random and ten cultivators were selected from each ward. The average size of the sample family was 6.6 and 60.8 per cent of the sample farmers had 5 to 7 members in their families. Almost all the sample farmers were literate. Most of the families in the sample had more than one occupation. Only 25.1 per cent of the total respondents were pure agriculturists. The total family income per annum of most of the respondents came in the range of Rs 5000/- to Rs 15000/-. An analysis of the cropping pattern revealed that a major percentage of the cropped area was devoted to the cultivation of coconut. The other crops of importance were rice, arecanut and banana. Most of the coconut holdings were rainfed and only 7 per cent of the gross area under this crop was irrigated.

The data on costs and returns on coconut cultivation were collected for a period of 16 years from the year of planting as sixteenth year was regarded as the period of yield stabilisation. The cost of cultivation per hectare was calculated based on 1985-86 prices.

The total cost of cultivation for 16 years was estimated to be Rs. 91, 311/- for the district (Table 10.1). The major item of expenditure was human labour constituting about 50.5 per cent (Rs 46,100/-) of the total cost. Maximum number of labourers were engaged during the first year of the crop. The total labour requirement for 16 years was 1844 man days per hectare. During the steady bearing stage labour contributed by family members came to about 41.8 per cent of the total labour requirement.

The expenditure on seedlings was Rs 1918/- The materials for fencing, shading and mulching accounted for 4.1 per cent (Rs 3767/-). The expenditure on fertiliser including farm yard manure accounted for 24.2 per cent (Rs.22058/-) while that of plant protection was 5.1 per cent (Rs.4636/-).

Harvesting charges were incurred from the eighth year onwards and these amounted to 9.9 per cent (Rs.9040). The cost for various tools and implements including replacement and maintenance charges accounted for 0.71 per cent of the total cost. Land tax accounted for 0.18 per cent (Table 10 2). The cost of bringing the plantation upto bearing stage or the total investment cost came to Rs. 38,773/-per ha and the expenditure from the eighth year onwards or the maintenance cost came to Rs 5853/- per ha per year.

Coconut starts yielding from the eighth year and the yield gets stabilised by the sixteenth year of planting. Steady yield would continue upto 50 years and thereafter nut yield may decline. The average annual production of nuts per hectare during the stabilised period was estimated as 10,049. The cost of production per nut worked out to Rs. 1.02 (Table 10.3).

For estimating the returns from coconut cultivation, the average farm gate price for nuts during the year 1983-84 was considered due to the fact that the farm gate prices of nuts for 84-85 and 85-86 were highly unusual. The estimated net returns on investment per ha per year came to Rs. 13835/- (Table 10.4) leading to a benefit cost ratio of 1.4.

The resource use efficiency of yielding coconut plantation was studied by fitting a multiple liner production function. The results showed that the age of trees, labour mandays, fertilisers and plant protection were the factors influencing the gross income from a coconut garden.

Table 10.1. Estimated cost of cultivation of coconut per ha in Calicut district

Year	Stage of the crop	Cost (Rs.)	Percentage to total
1	2	3	4
1	Planting	11940	13.08
2		3365	3.69
3		3518	3.85
4		4608	5.05
5		5114	5.60
6		5114	5.60
7	Flowering	5114	5.60
8	Yielding	5730	6.28

Table 10.1 Contd:

(1)	(2)	(3)	(4)
9	Yielding	5779	6.33
10		5814	6.37
11		5823	6.38
12		5864	6.42
13		5882	6.44
14		5882	6.44
15	Steady bearing	5882	6.44
16		5882	6.44
	Total	91311	100

Table 10.2 Break up of the total cost of cultivation for 16 years in Calicut district

Item of expenditure	Cost (Rs.)	Percentage to total
Human labour	46100	50.49
Materials for fencing, shading and mulching	3767	4.13
Seedlings	1918	2.10
Fertilizer including farm yard manure	22058	24.16
Plant protection chemicals	4636	5.08
Harvesting charges	9040	9.90
Tools and implements	650	0.71
Land tax	160	0.18
Miscellaneous	2982	3.27
Total.	91311	100

Table 10.3 Estimated cost of production of coconut (Rs/ha) in Calicut district

Sl. no.	Particulars	Cost (Rs)
1	Investment during establisment of plantation upto bearimg	38773
2	Compound interest on investment at 11% (1-7 years)	24199
3	Total investment	62972
4	Annuity value (share of total investment to be adjusted over a period of 48 years)	6793
5	Annual maintenance cost	5853
6	Total cost per hectare per year	12646
7	Income from dry leaves and petioles per year	1374
8	Net cost of production of nuts per hectare per year	11272
9	Average production of nuts per hectare per year	10049
10	Cost of production per nut	1.12

Table 10.4. Estimated returns from coconut cultivation, Calicut district (Rs/ha/year).

Sl. no.	Particulars	District
1	Farm-gate price of coconur per nut	2.36
2	Cost of production per nut	1.12
3	Ner return per nut	1.24
4	Average production of nuts	10049
5	Net return from nuts	12461
6	Income from dry leaves and petioles	1374
7	Net return on investment per hectare	13835

Marketing

Only two studies have been undertaken in the Kerala Agricultural University with respect to marketing of coconut. The first study was conducted during the period 1984–'86, using primary data collected from a sample of 150 coconut farmers in Calicut district, village traders, traditional millers, market intermediaries and all major oil mills in the district.

The study revealed that almost all the farmers sold the nuts as such on the farm itself, to copra markers in the locality. As much as 90 per cent of the farmers felt that the price they received was commensurate with the ruling wholesale prices. The following four marketing channels were identified:

1. Farmer—copra maker—oil miller—retailer—commissioner
2. Farmer—copra maker—oil miller—commission agent—wholesaler—retailer
3. Farmer—copra maker—oil miller—commission agent—industrial user
4. Farmer—oil miller—wholesaler—consumer

The study showed the markets for coconut and oil to be very well integrated and the structural characteristics of the market, were not likely to adversely affect market conduct to the detriment of the farmer.

During the period 1984-'87, a comprehensive study covering the entire state was undertaken. The objectives of the study were to investigate the marketing practices and problems, structural characteristics of the market. marketing costs and margins, market integration, spatial price differences, temporal price differences etc.

Farmers harvested mature nuts and sold them in the form of nuts. Only 2.5 per cent of the total marketable surplus was converted into copra by the sample farmers themselves. Exceptions to the practice of selling unhusked nuts was noticed in Trichur and Ernakulam districts. The predominant method of selling nuts was disposing them off at the farm itself, convenience being the main reason attributed to this.

The predominant first buyers of coconuts were copra makers. who bought from 80 per cent of the total sample farmers. The other buyers were oil millers, village merchants, co-operatives etc. The price for nuts, in the majority of cases, was arrived at, based on the wholesale market prices of oil and copra.

Four main marketing channels were identified for coconuts in the state. They were:

1. Farmer—copra maker—oil miller—industrial use
2. Farmer—copra maker—oil miller wholesaler—consumer
3. Farmer—copra maker—oil miller—retailer—consumer
4. Farmer—oil miller—retailer—consumer

The study showed that the major coconut markets outside the state, viz. Bombay, Calcutta and Madras were very well integrated. Near perfect integration could be observed among the markets in Kerala also, viz. Cochin, Alleppey and Calicut. At the retail level and at the village level also coconut prices were observed to be well integrated with the wholesale prices. The changes in Bombay market price very well reflected in the major Kerala markets, which in turn reflected down the line to the farmer's and to the retail level.

Marketing costs and margins

The district-wise data on marketing cost and margin are shown in Tables 10.5 a, 10.5 b, and 10.5 c. The margins for sales within the state ranged from Rs. 30 to Rs. 81 per 100 nuts. Total margins as proportions of realization from wholesale price of husk, shell, oil and oil cake ranged from 10.8 per cent in Alleppey district to 28.0 per cent in Cannanore district. The average marketing cost of buyers of coconut was around Rs. 12 to Rs. 13. The copra crushing charges ranged from Rs. 0.16 per kg to Rs. 0.20 per kg of copra.

Table 10.5 a. Average marketing costs and margins for coconut (Rupees per hundred) upto the stage of wholesale of oil locally in the districts of Alleppey, Ernakulam and Trichur during March-April 1984

Sl. no.	Particulars	District		
		Alleppey	Ernakulam	Trichur
1	2	3	4	5
1	Cost of coconuts paid to farmer	311.36	305.32	304.37
2	Marketing costs of buyer	12.58	13.02	13.33
3	Total outgo of buyer (1+2)	323.94	318.34	317.70
4	Total realisation of buyer from copra, husk and shell	351.52	368.70	372.77
5	Net margin of buyer (4-3)	27.58	50.36	55.07
6	Cost of copra to miller	329.07	355.60	366.47
7	Marketing costs of miller	2.72	2.96	3.68
8	Total outgo of miller	331.79	358.56	370.15
9	Total realisation of miller from oil ane cake	326.69	364.96	378.97

Table 10.5 a. Contd:

(1)	(2)	(3)	(4)	(5)
10	Net margin of miller (9-8)	—5.10	6.40	8.82
11	Total (gross) marketing margin	37.78	72.74	80.97
12	Percentage margin (item 11 as percentage of value of husk, shell, oil and cake)	10.82	19.24	21.00
13	Total net margin (item 13 as percentage of value of husk, shell, oil and cake)	6.44	15 01	16.58
15	Farmers share (per cent)	89.18	80.76	79.00

Table 10.5 b. Average marketing costs and margins for coconut (Rupees per hundred) upto the stage of wholesale of oil locally in the districts of Malappuram, Calicut and Cannanore during March-April 1985

Sl. no.	Particulars	District		
		Malappuram	Calicut	Cannanore
1	Cost of coconuts paid to farmer	215 93	229.21	189.61
2	Marketing costs of buyer	16.20	17.13	12.93
3	Total outgo of buyer (1+2)	232.13	246.34	202.54
4	Total realisation of buyer from copra. husk and shell	257.38	286.67	244.75
5	Net margin of buyer (4-3)	25r25	40.33	42,21
6	Cost of copra to miller	236.71	269.34	230.00
7	Marketing costs of miller	2.53	3.39	3.19
8	Total outgo of miller	239.24	272.73	233.19
9	Total realisation of miller from oil and cake	247.48	278.72	248.80
10	Net margin of miller (9–8)	8.24	5.99	15.61
11	Total (gross) marketing margin	52.22	66.84	73.94
12	Percentage margin (item 11 as percentage of value of husk, shell, oil and cake)	19.47	22.58	28.06
13	Total net margin	33.49	46.32	57.83
14	Percentage net margin (item 13 as percentage of value of husk, shell, oil and cake)	12.49	15.65	21.94
15	Farmer's share (per cent)	80.53	77.42	71.94

Table 10.5 c. Average marketing, costs and margins for coconut (Rupees per hundred) upto the stage of wholesale of oil locally in the districts of Trivandrum, Quilon and Kottayam during March-April, 1986.

Sl. no.	Particulars	District		
		Trivandrum	Quilon	Kottayam
1	Cost of coconuts paid to farmer	155.91	149.64	182 63
2	Marketing costs of buyer .	16.31	12 70	12.37
3	Total outgo of buyer (1+2)	172.24	162 34	194.34
4	Total realisation of buyer from copra, husk and shell	188.75	190.50	202 80
5	Net margin of buyer (4-3)	16.51	28.16	8.46
6	Cost of copra to miller	168.75	163.50	187.72
7	Marketing costs of miller	2.63.	3 37	3.26
8	Total outgo of miller	171.38	166.87	190.98
9	Total realisation of miller from oil and cake	169 08	168.12	197.41
10	Net margin of miller (9–8)	–2.25	1.25	6.43
11	Total (gross) marketing margin	33.20	45 48	30.52
12	Percentage margin (item 11 as parcentage of value of husk, shell oil and cake)	17.56	23.31	14.36
13	Total net margin	14.26	29.41	14.89
14	Percentage net margin (item 13 as percentage of value of husk, shell, oil and cake)	7.54	15 07	7.05
15	Farmer's share (per cent)	82.46	80.83	85.91

The sale price ranged from 71.9 per cent in Cannanore to 89.2 per cent in Alleppey. Marketing margins for sales of oil outside the state showed net margins of millers to be very high. The farmers. share, however, got reduced to 71.99 per cent in this case.

There existed a good deal of seasonality in coconut production, with the peak level of production in Meenam (mid March to mid April) and a trough in Karkitakom (mid July to mid August). Coconut prices also showed a seasonal pattern with the trough in prices coinciding with the peak in production. Coconut oil prices in Kerala, also showed a good deal of year to year fluctuations. The estimated net returns from storage of coconut oil were negative in some years and positive in most of the years during the 10 year period ending 1984. Both negative and positive returns were fairly high percentage of purchase price. This was a sign of inefficiency in pricing. However, average net returns from storage losses for the 10 year period 1975–'84 were not excessive.

One of the major inefficiencies noticed in the marketing system was the existence of fairly high net margins. One method to rectify this defect was the involvement of farmers themselves in marketing, by taking up the primary processing activity of copra making.

Another problem adversely affecting coconut economy is the uncertainties created by wide fluctuations in prices. Measures for stabilization of coconut and coconut oil prices need to be adopted so that the uncertainties created by the wide fluctuations in prices can be reduced.

One serious hindrance to marketing studies on coconut, or for that metter any agricultural produce is the absence of reliable primary and secondary data. Educating and encouraging the farmers to maintain farm records and systematic generation of secondary data on quantities handled during different months in different markets, number and kinds of intermediaries and their market share etc, through suitable marketing institutions and infrastructure may be of help.

Generally speaking coconut oil has been a premium oil. With an increase in production of various oil seeds in the country in the near future, it is doubtful whether this position can continue for long. As consumers of coconut oil, even coconut cultivators have developed price resistance. Therefore, in the emerging situation, the major factor which could save coconut economy from serious problems seems to be the development of high valued coconut based products.

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