

STUDIES ON THE WILT (ROOT) DISEASE OF THE COCONUT PALM

A comparative study of the rhizosphere microflora of coconut from diseased and healthy areas

K. RADHA AND K. P. V. MENON

(Central Coconut Research Station, Kayangulam)

DURING the course of investigations on the "Wilt or root" disease of coconut in Travancore-Cochin it was observed by Menon and collaborators (1949; 1950) that three soil fungi, *Rhizoctonia bataticola*—[*Macrophomina phaseoli* (Maubl) Ashby], *Rhizoctonia solani* and *Botryodiplodia theobromae* were intimately associated with the disease. (Menon and Nair, 1949). A knowledge of the soil conditions is of prime importance in studies of plant root diseases, particularly so when organisms of soil origin are suspected to be causative agents as in the case of this coconut disease. The need for a proper understanding of the non-living factors of the soil environment, namely moisture, temperature, aeration, reaction, fertility, etc., which materially affect plant growth and its metabolic processes was recognised early enough by plant pathologists. Of late, interest has shifted to the living factor of the soil, to the microflora that inhabit it. The interactions of higher plants and soil micro-organisms or in other words the study of the rhizosphere of plants has now assumed importance (Timmonin 1940; Katznelson, 1946; Agnihotrudu, 1953). "Rhizosphere" is that zone of influence next to the root of the plant, where certain micro-organisms are more abundant than in the soil beyond. Interesting relationship between the microbial population of the rhizosphere

and resistance of plants to soil-borne diseases has also been reported. (Timmonin, 1940; Lochhead *et. al.*, 1940). Results on the investigations of the microbiological status of the rhizosphere of coconut palms in different soil types from healthy and diseased areas are presented in this paper.

Materials and methods

Root and soil samples were collected from:—

1. Adoor—diseased area, laterite soil.
2. Kayangulam—diseased area, sandy soil.
3. Quilon beach—healthy area, sandy soil.
4. Quilon—Kuriyapuzha—healthy area, sandy soil and
5. Varkala—healthy area, laterite soil from depths of 1, 2, 4 & 6 ft. by opening pits 3 to 5 ft. away from the bole of palms. Roots (about 10 g) with the adhering soil were used for the estimation of the rhizosphere microflora and 10g. soil for the control soil. The microflora were estimated by the dilution plate method of Waksman and Fred (1922) using the fungal and bacterial media advocated by them. The weight of the rhizosphere soil was determined by transferring the contents of the flasks where

the first dilution was prepared to a previously weighed Petri dish after removing the roots, evaporating the water and drying the soil residue to constant weight at 105°C. The numbers of fungi, bacteria and actinomycetes are expressed on the basis of 10 g. moisture free soil. Root pieces used for dilution were surface sterilized with an aqueous solution of calcium hypochlorite (1/14) washed in several changes of sterile tap water and plated on potato dextrose agar to isolate the fungi. Percentage occurrence of fungi were calculated on 20 root piece basis.

Results

Quantitative nature of the microflora

1. Significantly higher numbers of fungi, bacteria and actinomycetes were observed to exist in the rhizosphere than in the control soil.

2. The rhizosphere microflora in the laterite samples was at its highest nearer the surface (1 ft.) and it steadily decreased with increasing depth. The rhizosphere flora of sandy samples was not correlated with the sampling depth (Table I)

TABLE I

Numbers of fungi, bacteria and actinomycetes in the rhizosphere

(Fungi, in thousands, Bacteria and Actinomycetes in millions per 10 g. moisture free soil.)

Samples collected from	Depth of sampling in feet	Fungi	Bacteria	Actinomycetes
Adoor	1	1240.0	1780	60
	2	252.0	664	12
	4	105.0	265	15
	6	25.0	32	5.76

Samples collected from	Depth of sampling in feet	Fungi	Bacteria	Actinomycetes
Kayangulam	1	650	500	65
	2	529.4	135.2	17.7
	4	345.4	54.5	4.4
	6	450	80.0	3.0
Quilon beach	1	336.5	665	23.3
	2	363.0	366	21.7
	4	247.5	165	19.8
	6	226.0	150	17.2
Quilon	1	550.0	600	16.65
	2	456.0	300	16.65
	4	406.0	66	13.3
	6	446.0	66	13.3
Varkala	1	640.0	166	40
	2	300.0	83	16.65
	4	283.0	13	2.66
	6	202.0	1.1	2.43

3. Higher numbers of fungi, bacteria and actinomycetes were recorded in the rhizosphere of diseased palms than that of healthy ones from laterite soils. Similar variation between the samples from diseased and healthy palms was not significant in sandy soils (Table I).

4. "Rhizosphere effect", rhizosphere-soil ratio, in the decreasing order was as follows:—fungi > bacteria > actinomycetes (Table II).

STUDIES ON THE WILT (ROOT) DISEASE OF THE COCONUT PALM

TABLE II

Rhizosphere effect—Rhizosphere: Soil Ratio

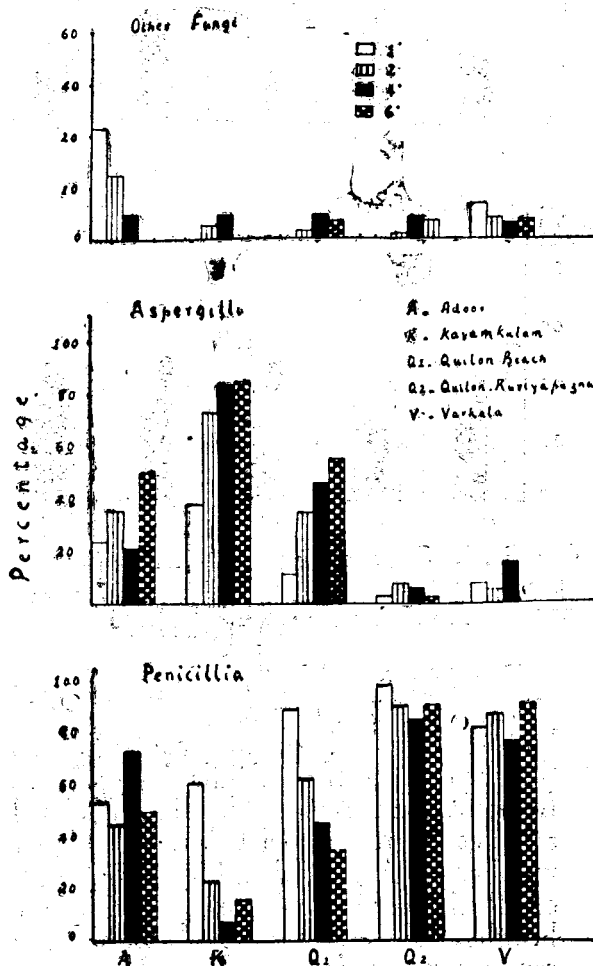
Samples collected from	Depth of sampling in feet	Fungi	Bacteria	Actinomycetes
Adoor	1	147.6	118.2	34.49
	2	90.65	62.5	8.63
	4	69.55	23.52	10.62
	6	23.36	5.623	9.568
Kayamkulam	1	51.58	34.34	12.7
	2	40.72	16.29	11.3
	4	47.32	7.46	3.3
	6	26.35	10.0	3.2
Quilon Beach	1	210.3	67.01	6.413
	2	279.2	99.71	6.782
	4	227.1	49.56	7.333
	6	371.7	22.06	8.191
Quilon Kuripuzha	1	105.7	36.81	4.548
	2	99.1	97.7	5.741
	4	135.3	63.46	8.212
	6	104.2	62.85	12.91
Varkala	1	188.2	73.13	28.58
	2	97.87	42.13	16.65
	4	101.0	10.8	4.031
	6	8.418	2.736	4.5

5. The rhizosphere effect of fungi was lower in the diseased than in the healthy in all the samples, this variation being more perceptible in the sandy soil than laterite. (Table II).

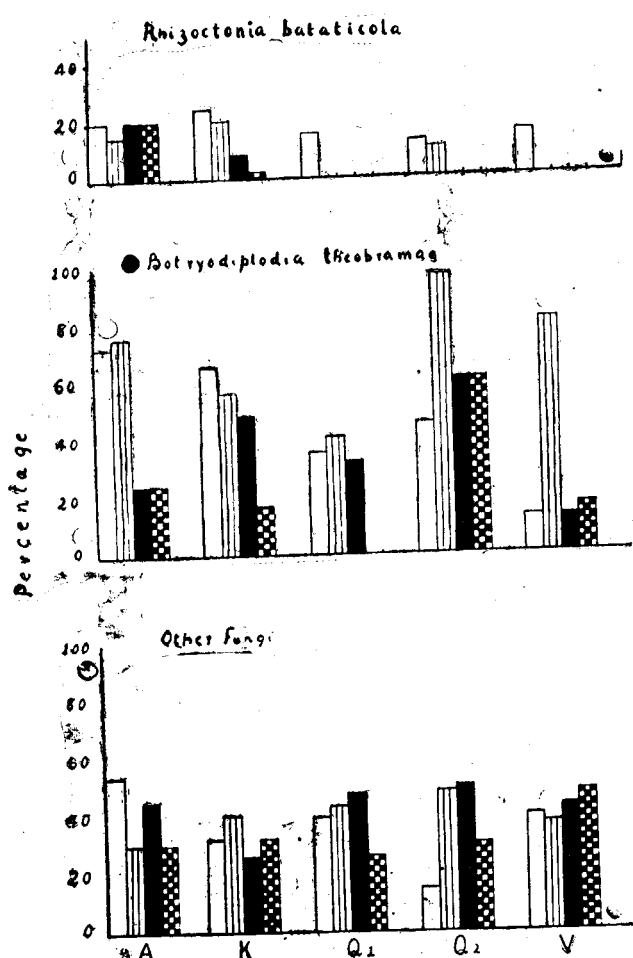
6. The rhizosphere effect of bacteria was higher in the diseased as compared to the healthy in samples from the laterite area whereas it was lower in samples from the sandy areas. (Table II).

7. The rhizosphere effect of actinomycetes was higher in the diseased than in the healthy in both the soil types—however the difference was negligible. (Table II).

Quantitative nature of the rhizosphere fungal flora.—The fungal colonies in the dilution plates and the root plantings were identified to the genus and the percentage occurrence of penicillia, Aspergilli, *Rhizoctonia Botryodiplodia*, etc., are presented in Text Figures 1 and 2.



Text Fig. I. Showing the percentage-occurrence of Aspergilli, Penicillia and other fungi in dilution plates.



Text Fig. 2. Showing the percentage occurrence of *Rhizoctonia bataticola*, *Botryodiplodia theobromae* and other fungi in root plantings.

Fungi in the dilution plates.—*Aspergilli* and *Penicillia* were predominant in both the rhizosphere and control soils, the occurrence of *Penicillia* being more frequent than *Aspergilli*. The diseased samples were associated with higher numbers of *Aspergilli* and lower numbers of *Penicillia* in comparison with the healthy. *Fusaria* and *Diplodia* were of rare occurrence in the rhizosphere dilutions and absent in the soil dilutions. *Rhizoctonia* spp. also were significant by

their absence in the rhizosphere and soil dilutions.

Root plantings.—*Botryodiplodia theobromae* was the most dominant fungi harboured in the roots. This fungus was isolated from a majority of the roots examined irrespective of the soil type and sampling depth. *Rhizoctonia bataticola* was present in all the five areas, being more frequent in diseased areas and at shallow depths.

***Rhizoctonia solani*.**—Two strains of *R. solani* were isolated from the roots from the diseased areas. (1) with abundant, white aerial mycelium having no sclerotia and (2) with sparse aerial mycelium and brown sclerotia. Both these strains of *R. solani* were not encountered in the healthy soils.

Other fungi which were of frequent occurrence were *Neocosmospora vasinfecta*, *Gloeosporium*, *Gliocladium*, *Pestalotzia*, *Fusaria*, *Curvularia*, *Chaetomium*, *Trichoderma* and *Mucor*.

Rhizosphere microflora as related to the stage of disease. The data presented earlier indicated that the diseased condition of the coconut palm growing in sandy soil is associated with a decrease in the rhizosphere effect of the microflora. The correlation between the rhizosphere effect and disease incidence, the degree of infection based on visual symptoms, was next investigated. Samples for this purpose were collected from the garden of the Central Coconut Research Station, Kayamkulam.

Coconut palms were classified as (1) in the early stage of wilt disease, where the characteristic symptoms of the disease namely flaccidity of the leaves, ribbing and puccering of the leaflets and the drying of the leaf tips appear on the leaves

STUDIES ON THE WILT (ROOT) DISEASE OF THE COCONUT PALM

of the middle group or occasionally on the entire crown in a mild form, (2) in the advanced stage of disease, where the above symptoms are intense and the tapering of the stem and coppering of the leaves have also set in and (3) healthy, where none of the disease symptoms are present and the tree looks normal. Samples were collected by removing a crust of soil with roots up to 2 feet depth by means of an iron pipe 1 inch in diameter. 3 samples were collected per tree 3 feet away from the bole and 4 trees for each category.

significant variation in the rhizosphere effect of the different categories of palms. Numbers of the rhizosphere flora as well as the rhizosphere effect were the highest in healthy trees, the lowest in the case of palms in the advanced stage of disease with the palms in the early stage of disease taking an intermediate position. It is interesting to note that when the numbers of the rhizosphere flora of the different categories of trees presented a significant variations, the control soils, collected from the base of the very same trees had no appreciable difference in their microbial population.

TABLE III
Rhizosphere flora of diseased and apparently healthy palms

Condition of trees	Numbers of			Rhizosphere effect on			
		Fungi	Bacteria	Actinomycetes	Fungi	Bacteria	Actinomycetes
Healthy	R	375	530	2.5	63.98	252.6	4.16
	S	5.86	2.1	0.6			
Early stage of disease	R	250	620	1.5	51.64	258.3	3.0
	S	6.03	2.4	0.5			
Advanced stage of disease	R	137.5	340	0.8	30.09	120.4	1.6
	S	4.57	2.8	0.5			

R=Rhizosphere,

S=Soil.

Results presented in Table III show

Qualitatively the rhizosphere flora of the different palms and the control soils were similar. Fungi isolated from the dilution plates included *Penicillia*, *Aspergilli*, *Fusarium*, *Gliocladium*, *Gloeosporium*, *Pestalozzia*, *Neocosmopora vasinfecta* and *Mucor*. *Botryodiplodia theobromae*, *Rhizoctonia bataticola* and *Rhizoctonia solani* were isolated from the roots of all the palms and numerically their variation was not significant.

Rhizosphere flora of the diseased and healthy trees at different depths.—Samples were collected at depths of 1, 2, 4 and 6 feet as before from the base of the three categories of trees, healthy, early stage of disease and advanced stage of disease.

TABLE IV

Rhizosphere flora of diseased and healthy palms at different depths of the rhizosphere

Condition of tree	Depth of sampling in feet	Numbers of		
		Fungi	Bacteria	Actinomycetes
Healthy	1	546	130.6	12.0
	2	171	435.7	2.8
	4	22.2	183.3	1.6
	6	45.6	43.02	0.4
Early stage of disease	1	466	340	0.5
	2	100	309	1.8
	4	81	256	0.8
	6	50	215	0.6
Advanced stage of disease	1	38	135.08	2.4
	2	75	114.28	2.1
	4	14	125	2.5
	6	50	34.3	0.3

Results presented in Table IV support the earlier observation that the rhizosphere flora is correlated with the condition of the roots, the healthy roots had the highest numbers of microflora and the fungi and bacteria dwindled with the intensity of disease. Actinomycetes were present in large numbers in palms in advanced stage of disease than in palms in the early stage of disease. In general, with increase in depth of sampling there was a corresponding decrease in numbers of the microflora. Qualitatively there was no apparent variation in the occurrence of fungi at different depths.

Discussion

Starkey (1929), Timmonin (1940), Katznelson (1946) and Agnihothrudu (1953) have demonstrated the influence exerted by the roots of several plants on the rhizosphere microflora. A similar rhizosphere effect, that of accumulation of fungi, bacteria and actinomycetes in the rhizosphere of a perennial crop has been recorded here.

No consistent variation of the rhizosphere effect between the soil types, sandy and laterite or between samples from diseased and healthy areas was observed. However considering the two types of soils independently, considerable difference in the rhizosphere effect of fungi, bacteria and actinomycetes was recognized between the healthy and diseased samples, the variation in the sandy soil being more noticeable (Table II). The rhizosphere effect is probably related not only to the diseased or healthy condition of the plant but also to the nature of the soil. Further evidence of the correlation of the rhizosphere effect and disease incidence and the progressive reduction of the rhizosphere effect with the severity of disease was demonstrated (Tables III and IV). This is comparable to the observations of Eaton and Rigler (1946) who stated that an abundance of saprophytic micro-organisms in the rhizosphere tend to increase the resistance of maize to *Phymatotrichum omnivorum*.

The presence of *B. theobramae* in large numbers in healthy palms is noteworthy since this organism has been associated with the wilt disease of coconut. *R. bataticola*, another of the suspected coconut pathogen was also present in samples collected from both healthy and diseased areas. However fewer numbers were isolated from the healthy than from the diseased samples. (Text

Fig. 2). *R. Solani*, yet another of the suspected coconut pathogen was isolated only from the diseased samples. These results, when viewed with the observations of Hildebrand and West (1941) that the incidence and severity of strawberry root rot is related to the relative incidence of the "harmful" organism in the rhizosphere, probably indicate the possibility that *B. theobromae* is innocuous as far as coconut wilt is concerned. Based on a similar assumption the role of *R. bataticola* and *R. Solani* necessitates further clarification. Perhaps these soil fungi may exist in the roots of healthy palms in a mycorrhizal state, and their pathogenic activity is dependant on conditions adverse to the host as suggested by Park (1928) and hence may be termed as "Weak parasites" according to Samuel & Greaney (1937).

Summary

1. Importance of the study of rhizosphere microflora and rhizosphere effect as related to plant disease has been emphasized.
2. Investigations of the rhizosphere microflora and the rhizosphere effect in five coconut samples representing healthy and diseased in sandy as well as laterite soils indicated that the nature of the soil

and the condition of the palms influence the rhizosphere microflora. An accumulation of fungi, bacteria and actinomycetes in the rhizosphere was evident in all samples.

3. The rhizosphere effect steadily decreased with increase in depth in laterite soil but was inconsistent in sandy soil.

4. A consistent reduction in the rhizosphere effect of the diseased palms as compared to the corresponding healthy palms in sandy soils was recorded. The rhizosphere effect was correlated with the severity of disease.

5. A decreasing order of rhizosphere effect as follows was noticed: fungi > bacteria > actinomycetes.

6. Role of the three soil fungi hitherto associated with the wilt disease of coconut has been discussed in view of their relative occurrence in the rhizosphere of coconut.

Acknowledgment

We are thankful to Mr. C. M. John, Director, Central Coconut Research Station, Kasaragod for his interest in this investigation.

REFERENCES

- AGNIHOTHRUDU, V. "Soil conditions and root diseases, VIII. Rhizosphere microflora of some of the important crop plants in South India". Proc. Ind. Acad. Sci.—1953, 36: 1—13.
- EATON, E. M. & N. E. RIGLER. "Influence of carbohydrates levels and root surface microfloras on *Pymatotrimum omnivorum* root rot in cotton and maize plants". J. Agric. Res. 1946, 72: 137—161.
- HILDEBRAND, A. A. & P. M. WEST. "Strawberry root rot in relation to microbiological changes induced in root rot soil by incorporation of certain cover crops" Canad J. Res. C. 1941. 19: 183—198.
- KATZNELSON, H. "The rhizosphere effect of mangels on certain groups of soil microorganisms. Soil Sci. 1946, 62: 343—354.

- LOCHHEAD, A. G., M. I. TIMMONIN & P. M. WEST. "The microflora of the rhizosphere in relation to resistance of plants in soil borne pathogens" *Sci. Agr.* 1940, 20: 414—418.
- MENON, K. P. V. & U. K. NAIR. "The Wilt disease of coconut in Travancore and Cochin" *Indian Coconut Journal* 1949, 3: 5.
- MENON, K. P. V., SANKARASUBRAMONY, H. & PANDALAI, K. M. "Investigations on the disease of coconut palms in Travancore-Cochin". *Indian Coconut J.* 1950, 3: 81.
- PARK. "Report of the Mycological division" Ceylon Dep. Agr. Tech. Rept. 1928. 1—9.
- SAMUEL, G. & F. J. GREANEY. "Some observations on the occurrence of *Fusarium culmorum* in wheat". *Trans. Brit. Mycol. Soc.* 1937, 21: 114—117.
- STARKEY, R. L. "Some influences on the development of higher plants upon the micro-organisms in the soil—1 Historical and Introductory". *Soil Sci.* 1929, 27: 319—334.
- TIMMONIN, M. I. "The interaction of higher plants and soil micro-organisms. I Microbia population of rhizosphere of seedlings of certain cultivated plants" *Canad. J. Res. C.* 1940 18: 307—317.
- "The interaction of higher plants and soil micro-organisms II Study of the microbial population of the rhizosphere in relation to resistance of plants to soil borne diseases", *Canad. J. Res. C.* 1940, 18: 444—455.
- WAKSMAN, S. A. & E. B. FRED. "A tentative outline of the plate method for determining the number of micro-organisms in the soil". *Soil Sc.* 1922, 14: 27—28.

OBSERVATIONS ON THE SUDDEN WILTING OF COCONUT PALMS AT THOTTAPALLY SPILL WAY AREA IN TRAVANCORE-COCHIN

BY K. M. PANDALAI, H. SANKARASUBRAMONY AND K. P. V. MENON

(Central Coconut Research Station, Kayangulam)

Introduction

THE village of Thottapally lies on the road side between the 38th and 40th miles on the Quilon-Alleppey main road. A spill way is being constructed by the Government of Travancore-Cochin at Thottapally in connection with the Kuttanad Development Scheme. It was necessary for this purpose to dredge out soil from the channel sites leading to the spill way and dump it on both the sides to raise the level of the land. The entire area, where, the dredged material has been dumped contained many healthy and well bearing coconut palms. Soon after the dredgings began to be dumped to the bases of these palms it was observed that the trees developed symptoms of wilting which progressed in rapid strides and caused their death within the course of six to eight weeks. The intensity of wilting appeared to be a factor which depended upon the quantity of dredged material received on the spot as well as on the period during which the root system of the palm was in contact with it. This observation pointed to the conclusion that the cause of the wilting could be a factor or set of factors associated with the changes in the soil conditions brought about by the dumped material. The changed soil conditions possibly interfered with the functions of the

conducting system in the palms consequent upon the initial root injury. In this paper the results of investigations carried out to trace the exact cause of the wilting are described and discussed.

The Wilting Symptoms

The first visible symptom was the browning and drooping of the outer most leaves which started from the leaf tip and proceeded rapidly to the leaf stalk. The affected leaves soon dried up. This condition proceeded rapidly to all the leaves in the crown of the palms. Within three to four weeks of the occurrence of the first symptoms all the leaves dried up and soon the dried and the desiccated crown broke off from the stem and fell down. The different stages in the wilting process can clearly be seen in the illustrations given on the next two pages.

W. Nowell (1924) was the first to give the name of "wilt" to a condition of the palms which showed the above type of symptoms. Although some similarity exists between the symptoms described above and those exhibited by palms suffering from the bronze leaf wilt disease at Trinidad as described by F. M. Bain (1937) and H. R. Britton Jones (1940) it may be mentioned that unlike the bronze wilt, there is practically no yellowing or bronzing of the leaves in the case of the

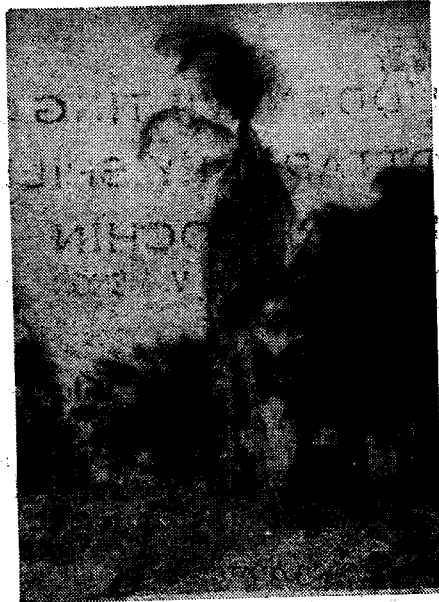


Fig: 1.—First stage of wilting. Note the drooping of the outer whorl leaves. Note also trees in background not wilted since no dredged material has been dumped there.

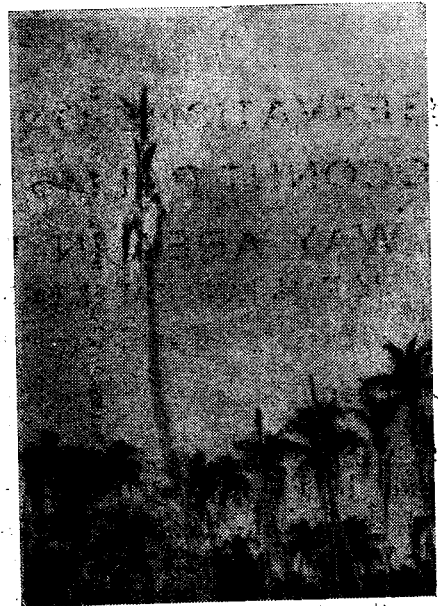


Fig: 3.—Third stage of wilting. Note only topmost crown leaves living.

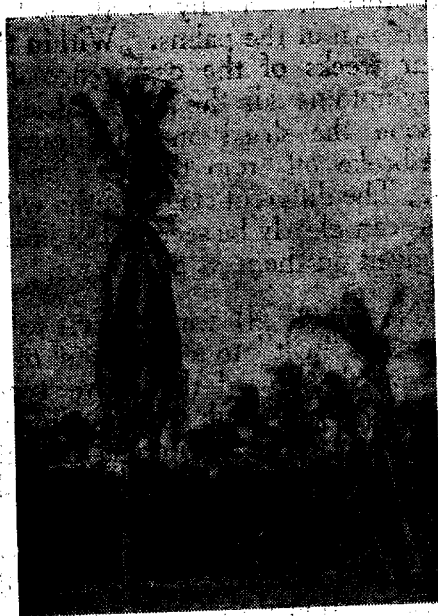


Fig: 2.—Second stage of wilting. Note almost all leaves wilted and drooping.

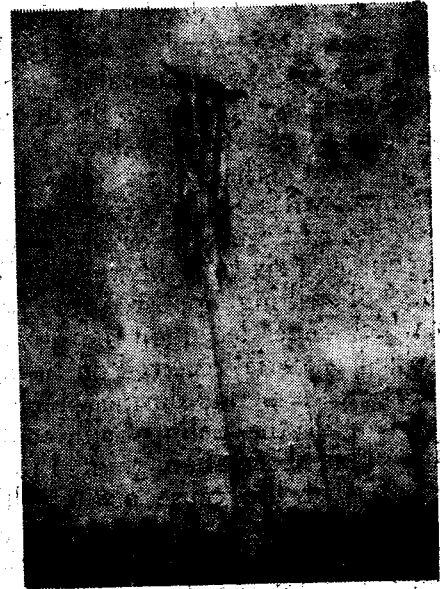


Fig: 4.—Fourth stage of wilting. Even the crown leaves have wilted.

OBSERVATIONS ON THE SUDDEN WILTING OF COCONUT PALMS AT THOTTAPPALLY
SPILL WAY AREA IN TRAVANCORE-COCHIN



Fig. 5.—Fifth and the final stage of wilting. Only the bare trunk remains.



Fig. 7.—Healthy coconut palm standing in the adjacent area which does not receive any sub-soil dumping.



Fig. 6.—A general view of the palms in the area.

trees wilting at the Thottappally area. More over, it has been reported that the death of the affected palms at Trinidad finally occurs due to a soft rot attacking the crown during its weakened state. In the case of the palms at Thottappally there was definitely no evidence of any bud rot. The end got simply dried up as a result of complete deprival of available moisture and the whole crown dropped down. Bunches of immature nuts and opened and unopened spadices hang on to the palm till they are completely dry and then fall down. The dropping down of the crown, the leaves or the bunches was not found to be associated with any organism causing decay, and the symptoms were almost similar to those shown by palms subjected to desiccation by severe drought conditions or to those shown by palms whose root systems got severely damaged. Nuts, spadices, etc., could be seen to be adhering to the palm till the last stage of death but with the obvious sign of drying out. The whole crown later falls down as a completely dried up debris.

From the above considerations the indications are that the wilting is the result of a nutritional or physiological

malady similar to the one described by F. Stell (1930) in Trinidad. That it is not merely a moisture factor is certain on account of the fact that the whole area is a low lying coastal region with the water table only about two to three feet below the ground level. Further, the palms in the adjacent vicinity which have not received any dredged material are in quite good condition. The abundant growth of coconut palms in this locality warrants the conclusion that there is good sub-soil water seepage and consequent good drainage. Want of these cannot therefore be the cause of the wilting. The problem of wilting, thus appears to centre round the change in the soil conditions brought about by the peaty sub-soil. The examination of the root systems of affected palms revealed that almost all the roots were in a dead

or dying condition. The more advanced the stage of wilting of a tree, the more dried up were its roots. Indeed the roots of the different trees given in the photographs to illustrate the different stages of the wilting showed drying up of the roots also in the same progressive order. Microscopic examination of the roots in the different stages of drying up failed to reveal the association of any parasitic organisms. It was thus quite obvious that the derangement was purely a physiological one.

Experimental

A comparative qualitative study of the dredged soil and sub-soil water from the affected areas was carried out with a spot test unit. The results obtained are recorded in Table I.

Table I showing the results of the qualitative spot test

Description of sample	Description of source	Reaction	Iron	Aluminium	Chloride	Sulphate
Soil	Wilted area	Highly acidic	High	Trace	Moderate	Moderate
	Normal healthy area	Slightly acidic	Trace	Nil	Trace	Trace
Sub-soil water	Wilted area	Nearly neutral	High	Trace	High	High
	Normal healthy area	Acidic	Trace	Nil	Trace	Nil
Root	Wilted tree	..	Trace	Nil
	Normal tree	..	Nil	Nil
Fresh dredged water	From an area where this has fallen recently. Trees not yet wilted	Alkaline	Trace	Nil	Trace	Nil

OBSERVATIONS ON THE SUDDEN WILTING OF COCONUT PALMS AT THOTTAPALLY
SPILL WAY AREA IN TRAVANCORE-COCHIN

From these results it may be seen that the low pH of the soil, the presence of soluble iron and aluminium and appreciable amounts of chlorides and sulphates in the dredged material are among the main factors which appear to be the cause of the sudden wilting of the palms. Such a high concentration of salts in the subsoil may be expected in this area since it is just on the sea coast and subject to water-logging by tidal waters, especially during the monsoons. The presence of considerable amounts of soluble salts in the

acid peaty soil due to the organic acids produced during the course of decomposition of the organic matter which constitutes about 60 per cent of this soil has already been observed by K. R. Narayana Iyer (1923). An examination of the dredged soil as well as surface soil from adjacent sites, where, trees were growing quite normal and healthy was therefore thought worth while. Accordingly the different samples described in table II were examined carefully to verify the results of the spot tests.

Table II giving the description of the samples examined

No.	Description of Sample
1.	Dredged soil dump. 4 feet deep. Trees wilted completely. Surface layer 2 feet
2.	Sub layer from the above 2—4 feet.
3.	Dredged soil dump. 3½ feet deep. Trees just started wilting.
4.	Dredged material from a dump 1½ feet deep. Trees completely wilted. Surface layer 0—9".
5.	Sub layer from above 9"—18".
6.	Dredged soil dump 2 feet deep. Trees partly wilted and the wilting in slow and steady progress
7.	Healthy surface soil from a bund adjacent to the wilting area 0—12"
8.	Sub soil from the above bund 12—24."
9.	Healthy surface soil from another bund on another side of the affected area. Trees in very healthy and bearing condition 0—12".
10.	Sub soil from above 12—24".

Only those factors which are known to have immediate significance with regard to the normal growth of the palms were determined in the above samples. The results are presented in table III.

Table III showing the major nutrient contents of the two sets of samples examined

No.	CaO %	MgO%	P ₂ O ₅ %	K ₂ O%	N%	C%	C/N
1	0.045	0.044	Trace	0.054	0.024	0.688	28.7
2	0.031	0.036	..	0.038	0.024	0.260	10.8
3	0.028	0.034	..	0.028	0.050	2.120	40.4
4	0.134	0.192	..	0.085	0.154	2.074	13.5
5	0.062	0.068	..	0.021	0.084	1.044	12.4
6	0.037	0.392	0.029	0.113	0.190	10.14	53.4
7	0.050	0.144	0.044	0.090	0.210	3.255	15.5
8	0.100	0.188	Trace	0.136	0.204	4.697	23.0
9	0.020	0.048	0.017	0.186	0.032	2.623	82.0
10	0.028	0.058	Trace	0.197	0.137	0.056	0.41

These figures show that there is very little difference in the major nutrient contents between dredged soil material and the soils collected from the base of the palms which have not received any addition on the surface by way of dredged material dumping. The results also show rather low nutrient contents in the dredged material, its carbon / nitrogen ratio being rather high. Exactly similar conclusions were reported by C. K. Narayanan Nair (1943). The rather high percentage of carbon in some of the samples appears to be due to the presence in them of large amounts of organic matter due to the existence of the woody residues and the decaying of aquatic vegetation as suggested by K. Parameswaran Pillay (1924). It has been shown by V. Subrahmanyam (1929) that in submerged soils containing large amounts of organic matter in readily decomposable forms the dissolved oxygen of the surface water is rapidly utilised and considerable amounts of

organic acids chiefly lactic, acetic and butyric are produced. It may be expected that the acids thus produced will react with the soil minerals and bring them in increasing quantities into solution. Indeed it is often found that the dredged material contains a high clay fraction and partially decomposed logs of wood long submerged under the soil. This clay material also effectively helps to cover off the surface of the soil.

In order to obtain a knowledge of the exact nature and extent of the oxidative changes in the dredged material after exposure to air, samples of these when freshly collected and after air drying were examined. Determinations of pH and the sulphate content of all the six samples given in table II together with the samples 7 to 10 from the non-wilted areas were carried out. These results as well as the results of determination of moisture and chloride in all these samples are given in table IV.

Table IV showing the moisture, chloride, sulphate contents and pH of the different samples

Sample	Moisture % when fresh (Oven dry basis)	Chloride p. p. m.	Sulphate p. p. m.		pH.	
			Fresh	After air drying	Fresh	After air drying
1	51.9	5946	2229	21417	3.10	3.05
2	87.3	1331	1094	12544	4.75	3.75
3	204.2	1598	579	14533	6.90	4.66
4	89.8	1509	1505	14574	3.80	4.05
5	172.1	2308	785	17291	6.20	4.70
6	187.0	3834	1865	35473	6.00	3.80
7	9.5	444	741	742	4.10	4.00
8	7.8	888	334	334	4.00	4.00
9	3.6	266	Trace	Trace	6.20	6.20
10	5.1	888	Trace	Trace	5.40	5.30

Some very interesting observations emerge from these results. It is seen that the dredged material contains an unusually high percentage of moisture, often

rising up to 200 per cent of its dry weight. Evidently this moisture appears to be unavailable for plant growth since it is held in a sort of colloidal combination by the clay fraction of the dredged material. The clay content of a soil imparts to it colloidal properties. The dumps therefore, shrink on drying and form large gaping cracks very wide and often more than a foot deep. This causes damage to the roots. The absorbed water is also held up even when the soil apparently appears to be dry. In this connection the observations made by T. R. Narayana Pillai and V. Subrahmanyam (1931) that the high moisture content of these soils is due to the presence of certain resins which form protective coats around the soil particles preventing water movement is very interesting. On the same account nutritive factors present in these soil particles are prevented from getting released out into the soil solution. It may thus be seen that a coconut palm whose root system happens to be covered by such a material will not be able to take up water or nutrients for its sustenance. The initial reaction to such a state of affairs would be the drying up of the roots followed by complete failure of root function and consequent wilting up of the aerial parts of the palm. Not only is there no moisture supply to counteract transpirational losses, but there is also no moisture available to the roots for nutrient absorption. It can also be seen that the dredged material when collected fresh contains moderate amounts of sulphates and gives a reaction in the range of neutral to slightly acid. The same samples after air drying give much higher values for the sulphate content and shifts the reaction more to the acid side. This is not the case with the samples from the non-dumped areas. This can be explained only by the

assumption that the fresh dredged material contains some reducing compounds such as sulphides which, on air drying and consequent oxidation, become converted into sulphates. There is in fact considerable evidence of the fresh dredged material and the sub soil water in the sites where the material was dumped being very heavily charged with hydrogen sulphide. After exposure to air, sulphates are progressively formed and there was also evidence of the formation in certain sites of free sulphuric acid. Hydrochloric acid also would be formed by the hydrolysis of the iron and aluminium chlorides. Similar observations have been recorded previously by T. R. Narayana Pillai and V. Subrahmanyam (loc cit). In sharp contrast to the above are the samples from the adjacent sites which do not receive any sub soil dumping. These did not show any fluctuation in their reaction or sulphate content; nor had they any abnormal content of moisture in them. The high concentration of chlorides in the dredged material is only due to the saline nature of the soil and sub soil water in the locality which lie often submerged under tidal waters containing a high chloride and sulphate concentration.

The effect of soil acidity on plant growth has been shown to be mainly secondary and this manifests itself in the shortage of available calcium and phosphates on the one hand and excess of soluble manganese, aluminium and other metallic ions on the other (E. J. Russel 1950). "The pH of the soil affects the root system mainly indirectly, for, the root or plant suffers from consequences of pH before the actual hydrogen or hydroxyl ion, concentration has any harmful effect (E. J. Russel, loc cit page 590). Thus it is well known that

the root system can get poisoned by soluble aluminium and manganese ions on the one hand and from a shortage of available calcium on the other before the hydrogen ion concentration itself begins to be harmful. Since the results given in table II have shown that iron and

aluminium are among the ions present in the subsoil it was necessary to make quantitative estimations of these and the condition in which the iron was present. This was, therefore, done and the results are shown in table V.

Table V showing the iron and aluminium contents of the different samples

Sample No.	Water soluble reducing compounds as ferrous iron p.p.m.	Water soluble iron p.p.m.	Water soluble iron and aluminium p.p.m.	Water soluble aluminium by difference p.p.m.
1	4176	5711	5744	33
2	14460	8345	8484	139
3	7319	9335	10322	987
4	9312	5676	5676	..
5	7582	9679	9691	12
6	1370	624	1351	727
7	Trace	Trace	Trace	..
8	do.	do.	do.	..
9	do.	do.	do.	..
10	do.	do.	do.	..

These results show that the dredged material contains ferrous iron in fair amounts and aluminium in small, but toxic amounts. Excess of soluble aluminium when present in the soil solution is known to accumulate in plant roots (G. E. Hutchinson 1943) and thus reduces the power of the roots to translocate phosphates from the soil to the vascular system (A. W. Blair and A. L. Prince 1923, K. E. Wright 1943, E. J. Hewitt 1948). Besides these, the dredged material also contains reducing agents such as sulphides and it would be exceedingly difficult for the root system under these conditions to get water or nutrients from the soil. Ferrous iron itself is highly toxic to plants. (H. O. Buckmann and N. C. Brady 1952). This is especially true if poor aeration occurs

in an acid soil. In the present case this is coupled with the presence of other reducing compounds which constantly use up all available oxygen for their oxidation or at any rate maintain a reducing environment to the root system. The results of table IV have shown that there is a colloidal factor in the dredged material which in certain sites have attained a thickness of three to four feet. Complete absence of air in the root rhizosphere results under these conditions and causes the suffocation of the entire root system. For entry through the roots water has to pass through a thick layer of cortical cells before reaching the conducting vessels, the xylem. It is probable that resistance to water passage through roots is brought about by the reducing conditions caused

t by the presence of ferrous iron. This
e indeed appears to be among the primary
e causes of the damage and death of the
. roots, the effect of which finally causes
3 complete wilting and death of the palms.
Besides lack of air, there is also
lack of available moisture, high
acidity, presence of reducing agents
like ferrous iron, sulphides, toxic agents
such as aluminium, sulphides, ferrous
iron, etc., as well as lack of essential
nutrients such as phosphates and available
calcium (vide table III). All these factors
contribute collectively to impair the
normal plant processes resulting in the
ultimate death of the plant. Even though
manganese is also usually among the
soluble ions present under the conditions
when soluble iron and soluble ammonium
are present, this element could not be
detected in the soil or sub soil water.
Manganese thus does not appear to play
any part in the sudden wilting of the
palms described in this paper. The
increased acidity due to the oxidative
changes in the exposed dredged material
and the formation of free acids by hydro-
lytic reactions are found to progressively
bring more of iron and aluminium into
the soil solution. In this connection the
findings of N. Subramoney (1951) is
interesting and noteworthy. He has
recorded in his studies on the kari soils
and measures for their reclamation for
paddy cultivation that the amount of free
sulphuric acid formed on such soils often
amounts up to even 2 per cent of the total
weight of the soil. He also noted the
presence of yellow patches consisting
mostly of iron and aluminium sulphates
on these soils. Such crusts were observed
also by the present writers on the dumps
of dredged material at Thottapally. Soon
after the surface of the dumps begins to
dry up, yellow incrustations were seen to
be formed, and on analysis these were
shown to be essentially mixtures of iron

and aluminium sulphates. The concen-
tration of ferrous iron and ferric iron in
the yellow material was found to be 5500
p.p.m. and 4600 p.p.m. respectively.
This material can further act as a source
of free sulphuric acid due to hydrolytic
changes.

Discussion

The problem of the acid peaty or kari
soils of Thottapally has been the subject
of a certain amount of work notably by
Parameswaran Pillay (loc cit) Narayana
Pillay and Subrahmanyam (loc cit)
Narayana Iyer (loc cit) Narayanan Nair
(loc cit) and Subramoney (loc cit). At
Thottapally the surface soil is almost a
normal sandy type while the subsoil is
of the acid peaty type consisting of a
colloidal mixture of clay, silt and partially
decomposed organic matter. It is this
mixture that is being dredged out and
dumped on the base of the healthy
coconut palms in the surrounding gardens.
From the foregoing considerations, the
undesirable effects of this dredged
material could be easily understood.
This acid peaty soil differs in properties
from the backwater, canal or river silts
which are with great advantage applied
to the sandy coconut tracts of the coast
as an ameliorant and the scientific
rationale of the application of which we
have recently elucidated. (H. Sankara-
subramoney et al 1952). The wilting of
the palms which soon follow the dump-
ing of the peaty subsoil appears to be an
immediate and direct consequence of the
changes in the soil conditions. The
material on exposure undergoes oxidation
with the formation of free acid and
consequent solubilisation of increasing
quantities of iron and aluminium. All
these factors viz. the lowered pH, the
increased iron and aluminium contents
of the soil solution reaching toxic concen-
trations, and the anaerobic environment

cause intense root injury in more than one way. Moisture present in the soil drains off and the combined water of the peaty soil is unavailable. This condition causes water scarcity and, therefore, desiccation of the root system. A strong reducing environment due to the presence of sulphides, ferrous iron and the sealing off of the surface soil by the dredged material causes intense root suffocation and puts them completely out of function. A desiccation of the entire aerial parts of the palm results and the wilting and death of the palm is complete. The death of the root system and the wilting of the palms appear to be purely a physiological factor since no organism could be isolated from either the roots or any other part of the palm. The appearance of the wilted palms was similar to palms which get wilted as a result of drought conditions.

Summary

1. The cause of the sudden wilting of coconut palms in the Thottapally Spillway area, where, peaty subsoil has been dredged out and dumped on to the bases of healthy palms has been investigated and described.

2. The wilting of the palms appears to be due to their desiccation and root injury as a result of the change in the soil conditions caused among other factors *viz.*

(a) the high acidity of the dredged subsoil and subsoil water.

(b) the presence in it of readily oxidisable agents such as sulphides, ferrous iron etc.

(c) the presence in it of toxic agents such as soluble ferrous iron and soluble aluminium

(d) potential capacity of the subsoil for the formation of free mineral acids by hydrolytic changes as well and

(e) complete anaerobic condition in the root rhizosphere causing intense root suffocation.

3. The cause of the wilting has been shown to be purely a physiological factor.

Acknowledgment

Our thanks are due to Shri C. M. John, Director, Central Coconut Research Station, Kasaragod for his keen interest and helpful suggestions during the progress of this work.

REFERENCES

1. Nowell W. (1924) Rep. Proc. Imp. Bot. Conf. London 161—162.
2. Bain F. M. (1937) "Bronze leaf wilt disease of the coconut palm" Department of Agriculture, Trinidad.
3. Britton Jones H. R. (1940) "The Diseases of the Coconut Palm" Baillere Tindall & Cox, London.
4. Stell F. (1930) Bulletin, Department of Agriculture, Trinidad and Tobago. 1 (R. A. M. 8, 714)
5. Narayana Iyer K. R. (1923) Department of Agriculture, Travancore, Leaflet No. 126.
6. Narayanan Nair C. K. (1943) Proceedings of the 30th Ind. Sci. Congress III. 96.
7. Parameswaran Pillay K. (1924) Department of Agriculture, Travancore Bulletin No. 9.
8. Subrahmanyam V. (1929) J. Agric. Science 19, 627.
9. Narayana Pillay T. R. N and Subrahmanyam V. (1931) Jour. Ind. Inst. Sci. 14, A. 99.
10. Russell E. J. (1950) "Soil Conditions and Plant Growth" Longmans Green and Co., London, 8th Edition, P. 473, 590.
11. Hutchinson G. E. (1943) Quart. Rev. Biol. 18. 128.
12. Blair A. W. and Prince A. L. 1923. Soil Science 15, 109.
13. Wright K. E. (1943) Plant Physiol. 18. 708
14. Hewitt E. J. (1948) Long Ashton Res. Station, Annual Report 58.
15. Buckmann H. O. and Brady N. C. 1952. "The Nature and Properties of Soils" Mac. Millan & Co., New York p. 284.
16. Subramony N. (1951) Bull. C. R. Institute. Travancore University. 2A. 1.
17. Sankarasubramony H. Pillay N. G., Pandalai K. M., and Menon K. P. V. 1952. Ind. Coconut Journal. 5, 141.