PHYSIOLOGY OF WILT DISEASE IN COCONUT PALM

by

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In coconut palm, 'wilt' is an important malady that has caused serious damage to the coconut industry in many major coconut growing countries. However, very little is known regarding the physiological nature of these diseases in order to help us evolve any effective control measures. This is mainly because special research methods have to be employed while dealing with the problems of coconut palm, due to its large size, perennial nature and multiyear period of fruit bearing. The present paper deals with a discussion on this subject.

AETIOLOGY OF WILT DISEASES :

Wilt diseases of coconut palm have been recognised under two categories viz., wilt diseases of known and unknown aetiology (Menon, 1963). The important diseases of cocohut palm reported from various parts of the world in which 'wilt' is an important symptom are given in Table 1.

"Bronze leaf wilt" disease is known to be caused by a combination of adverse soil conditions including insufficient moisture. Almost similar causes have been accounted for "tapering stem wilt" disease also. Besides, nutritional deficiency is another factor associated with "tapering stem wilt" which has been referred to as 'starvation of palms' (Briton Jones, 1940). "Wilt" in these cases is, thus, obviously the ultimate result of drought and nutritional deficiency which are purely of physiological origin.

In the case of wilt diseases of unknown origin the situation is much more complex. Although it is interesting to note that yellowing and wilting of leaves are reported as a common feature of many of these diseases, very little is known regarding the nature of these wilts.

The parasitic nature of "cadang cadang" of Philippines has not been conclusively proved although virus origin has been suggested (Ocfemia, 1937; Celino, 1947; Kent, 1953). Martyn (1949) indicated the infectious nature

of "lethal yellowing" or "unknown disease" of coconut palms in Jamaica and he suspected this to be caused by a virus. Micronutrient deficiency was suggested as a cause of this disease (Leach, 1946) although this has not been confirmed (Innes, 1949).

The root (wilt) disease prevalent in South India, has been the subject of detailed studies during the recent past at the Central Coconut Research Station, Kayangulam. The parasitic nature of this disease was indicated very early (Butler, 1908) while its complexity was also indicated later (Menon and Nair, 1951). Strong evidence has been obtained indicating the involvement of a virus in this disease complex (Nagaraj and Menon, 1956; Shanta et al, 1960; Menon and Shanta, 1962; while fungi were reported as secondary invaders of root system (Radha and Menon, 1954). In an exhaustive discussion on the wilt disease of unknown aetiology, Menon (1963) has drawn attention to the similarities among the "lethal yellowing", "bronze leaf wilt", "cadang-cadang" and the root (wilt) disease. Wilting of the crown, yellowing, necrosis and extensive root damage are the important common symptoms reported for these diseases of coconut palm. In the case of "cadang cadang" stiffening and shortening of leaves are characteristic while recently wilt is also reported to appear in later stages in certain cases. An important observation made in the case of root (wilt) disease is that this wilt disease is not caused by adverse soil conditions such as inadequate soil moisture or nutrient deficiency, although such factors may act as predisposing factors for the disease. Wilt of the palm in this case is thus not of purely physiological origin (Menon, 1963). This view is further strengthened by the pathogenic nature of the disease.

NATURE OF WILT :

Wilt in plants is the obvious result of an unfavourable water balance in them. Thus, any derangement in the absorptive unit or excess of transpiration would lead to internal water deficit culminating in wilt. Viewed from this angle the extensive root damage reported for all wilt diseases attains topical importance.

In the case of root (wilt) disease of South India a higher percentage of root decay has been reported (Nagaraj and Menon, 1955). A detailed study of the root system of 5 year old healthy and diseased palms was conducted recently (Table 2). It was observed that in their lateral spread or downward penetration, the root systems of healthy and diseased palms do not vary much. However, in other characters namely the circumference of the bole and the total number of roots, the diseased palms have lower values than the healthy (Michael, 1964). This apparently would show that the absorptive area of a diseased palm is considerably reduced, thus probably robbing the palm of its capacity to absorb enough water, drawing a parallel to the suggestion of Oraton (1902). Root damage resulting in reduction in their efficiency as

absorbing organs has been reported for root rots (Simmonds, 1939) and virus diseases (Stubbs, 1947). However, it is now known that absorption is not always limited by the root surface in contact with the external medium, since internal factors such as permeability of root cells, the metabolism of root tissues and consequently the capacity of xylem to conduct water are influencing factors (Kramer, 1956). That the crippled root system by way of root damage may not affect the uptake of water by a diseased palm, has been indicated by further observation. 50% root decay has been found to be common in comparable healthy and diseased palms in the early stage of disease (Menon, 1963). On the other hand 70 or 80 year old healthy palms always possess a very high percentage of decayed roots. The logical conclusion from these observations is that in the case of root (wilt) disease, (a) root decay need not be a prerequisite for wilt (b) root decay may be a secondary feature caused by secondary invaders of the unhealthy palm and (c) uptake of water is not affected appreciably although the root system is crippled.

The plant cell is known to undergo a series of physiological derangements prior to death (Guilliermond, 1941). Under pathogenesis, collapse of protoplasm and cytoplasmic disintegration are some such physiological derangements preceding death of cells (Braun and Pringle 1959). It is quite probable that in the case of root (wilt) disease of coconut palm such derangements at the subcellular level in the root tissue must precede the death and decay of the root system. However, this is a subject for detailed investigations in future. On the other hand, it is logical to envisage that the damaged root system of diseased palm would have resulted in an indiscrimate entry of minerals and other toxic materials through them leading to t heir accumulation in the leaves. That loss of selective permeability of root cells by way of root damage and consequent loss of functional balance of root system could lead to an indiscriminate entry of minerals and other toxic substances into the roots, has been observed by Kramer (1951). In a recent study, an analysis of the root sap collected from the healthy and diseased palms of comparable age group showed that the total inorganic as well as organic content of the diseased sap is generally higher than that of the corresponding healthy sap (Michael and Ramadasan, 1964). Accumulation of major nutrients such as nitrogen, phosphorus, potassium, calcium and magnesium in the diseased leaves has been reported (Sankarasubramony et al, 1952). Micronutrients such as manganese, boron and zinc have been shown to be in higher levels in the diseased leaves than in the healthy (Table 3, Pillai, 1959). Leaves of diseased palms growing in sandy, loamy, clayey and lateritic soils have been observed to contain higher quantities of silica than that in the corresponding healthy palms (Table 4). Accumulation of nutrients in the leaves has been reported in the case of 'cadang cadang' disease also (Yualvez et al,1958). An indiscriminate absorption of minerals resulting in ionic imbalance could very well lead to the damage of leaf cells, as is known in the case of citrus (Sokoloff et al, 1943) and complete derangement in the leaf metabolism. Ionic

imbalance has been shown to influence permeability of cells to water, their osmotic pressure and protoplasmic shrinkage resulting in loss of water. (Osterhaut 1916, 1956). Indeed, increased loss of water from diseased leaf has been observed in the case of root (wilt) disease of coconut palm (Lilly and Ramadasan, 1964). All these conditions induced by the pathogen and later aided and perpetuated by unfavourable conditions could, thus, ultimately lead to a progressive increase in the internal water deficit. Disruption and disintegration of chloroplastids in the diseased leaves, probably due to the accumulation of some toxic substances, has been envisaged by Menon (1963), while the possible phyto-toxic effect of unbalanced nutrition has been indicated by Pandalai (1959). The nature of such physiological derangements in the leaves of wilted coconut palms, if any, is the subject of detailed investigations presently at the Central Coconut Research Station, Kayangulam.

What the role of pathogens could be in inducing physiological derangements in the case of wilt diseases of coconut palm has not been investigated. Since pathogens, viruses or fungi, have been associated with the root (wilt), "cadang cadang" and "lethal yellowing" disease of coconut palm, the possible role of these organisms in causing "wilt" warrants a close examination.

THE ROLE OF FUNGI AND TOXINS

The toxin concept in wilt diseases has been the subject of recent discussions by eminent pathologists, especially in relation to fungal diseases of plants (Braun and Pringle, 1959; Gaumann, 1954; Ludwig, 1957). These investigators have given ample evidence to show that toxins and other metabolites could very well damage the conducting elements variously, causing acute internal water deficit. In this connection the increased rate of loss of water observed in the case of root (wilt) diseased palms is noteworthy. The nature and significance of enhanced transpiration in wilt diseased plants have been amply discussed by Sadasivan (1961). Many fungal toxins and other metabolites have been shown to impair permeability of cells (Gaumann et al. 1950). Gaumann and Jaag (1947) have discussed in detail how toxins in the sap stream could lead to damage to osmoregulatory functions of cells. How such an event could lead to release of cellular components leading to wilt has also been reported (Gaumann, 1951). The role of pectic enzymes released by pathogens causing reduction of sap flow in the xylem vessels, release of high molecular weight polyuronides, phenols and other substances leading to wilt in plants has been discussed in detail by Wood (1959). The possible role of toxins in the root (wilt) disease, "cadang-cadang" and "lethal yellowing" has been suggested (Martyn, 1949; Varghese, 1959; Velasco, 1961) although this has not been substantiated by enough data. Fungal parasites, although secondary in nature, may have also been associated with "cadang-cadang" (Ordonia, 1937; Price, 1958) and root (wilt)

disease (Radha and Menon, 1954). These observations warrant detailed investigations on these aspects in the coconut wilt diseases.

THE ROLE OF VIRUS :

Of particular interest is the fact that viruses have been associated with the "cadang-cadang", lethal yellowing and root (wilt) diseases. Viruses are known to cause a variety of symptoms in plants viz., mosaic, hypertrophy, necrosis, stunting. curling, yellowing, dwarfing of leaves etc. However, the physiological nature of symptom production is still not known. It is pertinent to recall in this context that the disease syndromes of "cadang-cadang", "root (wilt)" and "lethal yellowing" diseases of coconut palm have close similarities with the symptoms picture of virus infection in plants. The association of virus with the water conducting tissue in the case of Pierce's disease in grapevine and the dwarf disease in alfalfa, in which wilt is an important symptom, has been discussed recently by Esau (1948; 1956). John (1963) however reports that wilting due to virus infection is rare.

Joseph and Shanta (1963) have reported considerable changes in the epidermal, mechanical and conducting tissues in the leaves of root (wilt) diseased palms. Reduction in the cuticular thickening on the upper surface, reduction in the longitudinal division in the cells of upper epidermis during development, decrease in the thickening of the walls of sclerenchymatous cells in the hypodermis and reduction in the lignification of the bundle sheaths are the important observations made in the leaf tissues of diseased palms. The gross physical damage in the diseased leaf tissue reflects the disruption and retardation of all those physiological processes connected with development and growth of normal tissues.

Viruses are also known to cause damage to the phloem tissue (Cook, 1931; Esau, 1938; 1941; Swingle, 1938). In the American elm trees, infected with necrosis virus, degeneration of sieve tubes and adjoining cells following their maturation, hypertrophy of nuclei in these cells, necrosis of protophloem etc. in the roots have been observed (McClean, 1944). A deep browning of the root tissue following infection has also been observed. In the case of root (wilt) diseased palms also a deep browning of the roots as compared to the healthy root system has been noted (Michael, loc cit.). Bawden (1950) has stated that damage to the phloem could lead to starvation of roots by way of inadequate transport of food. In the case of root (wilt) disease, preliminary studies have indicated that the carbohydrate content of diseased roots is lower than that in healthy roots (unpublished data).

The possibility of virus infection of the root causing disfunction to the mechanism of absorption in the roots of coconut palm can very well be envisaged. In a number of flowering plants in which plant viruses

produce necrotic localised lesion on the leaf, investigations have indicated that general metabolic disturbance is induced almost within hours of virus entry, long before necrosis of tissue becomes visible to the naked eye (Weintraub et.al. 1960; Ramadasan, 1962). In a variety of tabasco pepper, in which tobacco etch virus (TEV) produce wilt, marked changes in permeability in the root cells of virus inoculated seedlings have been observed to occur 24-36 hours before the plants started to wilt; while such permeability changes were never found to occur in another variety of the same plant in which TEV does not produce wilt. Further, stained sections prepared from the roots of inoculated seedlings of the former variety showed no phloem or cambium necrosis at the time of induction of permeability changes (Ghabrial and Pirone, 1964). These findings are of the utmost importance with reference to the present problem. In this connection the presence of virus in the soil, reported in the case of root (wilt) disease, attains special significance (Menon and Shanta, loc cit).

NUTRITION OF DISEASED COCONUT PALMS :

Nutrition of diseased coconut palm has been the subject of detailed investigations at the Central Coconut Research Station, Kayangulam. Regular manuring with NPK fertilizers has been found to improve the yield of healthy and diseased palms; however, no ameliorative effect on the disease syndrome has been observed. A sand culture experiment on dwarf seedlings to study the deficiency symptoms of N, P and K nutrients and their probable relationship to wilt disease revealed that although nitrogen and potassium deficiency could produce yellowing of foliage, no other foliage character comparable to the disease syndrome of wilt diseased palm was noticed (Mathew and Ramadasan, 1964).

A detailed study on the effect of micronutrients on the wilt disease has been in progress since 1953. A total of 384 palms in a diseased sandy tract consisting of trees in the different stages of wilt disease has been receiving all micronutrients and magnesium, singly as well as in all possible combinations. Preliminary analysis of data collected so far revealed that yield of these experimental palms has generally increased irrespective of their diseased condition. However, not only have these treatments failed to improve the diseased condition of the palms but also more than 50% of healthy palms receiving these treatments became diseased during the course of this experiment.

A manurial experiment (started in 1956) consisting of organic manures, such as 2.27 Kg. of groundnut cake, 22.7 Kg. of ash, 45.4 Kg. of cowdung, 2.27 Kg. lime and 4.54 Kg. of common salt per tree per year, on 30 palms in the different stages of disease revealed that 28 of these have deteriorated further since then while 2 have already been cut.

Similar results have been obtained for "cadang-cadang" disease

also. Soil amendments or foliar application of various mineral nutrients such as magnesium sulphate, potassium phosphate, copper sulphate, ferrous sulphate, sodium molybdate and sodium borate to diseased palms only helped to deteriorate the condition of the trees (Subido, 1957 ; Price, 1958). The experimental observations detailed above indicate strongly that these diseases cannot be combated by any of these conventional nutritional treatments alone.

In view of the parasitic nature of many of these diseases an important problem involved is the possibility of the nutrients applied to the diseased palm being ultimately harnessed by the parasite, leaving the host cells 'starved', as has been observed by Sempio (1959). In the case of root (wilt) disease of South India, although some of the treatments have produced some beneficial effects on the disease by way of improvement in yield, it seems to be better to be cautious to conclude on the effect of these specific nutrients on the wilt disease, in view of the fact that a virus has been found to be associated with this disease.

Soil conditions influencing the nutrition of plants have been shown to have a definite relation to virus infection. The subject of mineral nutrition of virus infected plants with reference to all major and micro-nutrients has been reviewed in detail recently by Sadasivan (1963). Disucssing this aspect, Bawden (1950) has stated that the more favourable the soil conditions are for the growth of the host, the more definite will be the reaction of the infected plants. Besides, the more vigorously the plant is growing at the time of infection, the more pronounced will be its effect on a systemic host. In the case of wilt disease of South India it has been shown that palms at the bearing or prebearing stage viz., 6-10 years old are more susceptible to disease than the middle aged adult palms (Shanta et al, loc cit). Progress and severity of disease also have been found to be more in young palms of this age group than in adult palms (Ramadasan et al, 1964).

CONCLUSION :

In the foregoing, an attempt has been made to elucidate the physiology of wilt disease in coconut palm with special reference to pathogenesis and related nutritional problems. In doing so the available pertinent data have been utilised to the maximum to draw logical lines of conclusions. The increasing evidence for the infectious nature of root (wilt), and "lethal yellowing" of coconut palm suggests that wilt in these cases is pathological as distinct from the wilt diseases of known aetiology viz., bronze wilt and tapering stem wilt. Drawing concurrent evidences from the investigation on pathological wilt diseases of other flowering plants, it seems probable that phyto-toxicity at the leaf level caused by toxins, metabolites or serious ionic disturbances initiated by pathogen would have resulted in serious derangements in all

the physiological processes related to growth and development. It is quite probable that any such serious disturbances in the osmoregulatory functions of leaf cells would lead to increased water loss resulting in internal water deficit. However, it must be remembered that there are too many gaps in the investigations on the physiology of wilt diseases of coconut palm, as it applies to specific cases, and such fundamental aspects as absorption, translocation and metabolism of diseased palms at subcellular level are yet to be investigated thoroughly to draw definite conclusions on the physiological nature of wilt. In this connection, the employment of special research methods might be necessary in view of the unique features of the coconut palm and the use of radio-isotopes in such investigations might go a long way in giving us a better insight into these problems.

Menon and Pandalai (1958) observed that "the main task of the research worker in this connection involves the consideration of different problems designed for improving the productivity of palms, as well as dealing effectively in the prevention of loss of yield by malnutrition and pathogenic agencies". It may be legitimately hoped that the zeal of coconut research workers, coupled with effective co-ordination among them, can give us answers to these problems in the near future.

Table 1

Diseases of Coconut Palm

Serial number	Name	Distribution	Reference
1	Tapering stem wilt	Burma, Ceylon, Trinidad, Jamaica.	Furtado (1923); Bryce (1921); Briton Jones (1928;1940).
2	Bronze leaf wilt	Jamaica, British Guiana; St. Lucia, Tobago, Trinidad, Ceylon.	Briton Jones (1928); Park (1932).
3.	Maturation wilt	New Guinea.	Dwyer (1937).
* 4.	Cadang-cadang	Philippines.	Calica and Bigornia (1953).
5.	Lethal yellowing or unknown disease	Jamaica.	Ashby (1915).
6.	Root (wilt) disease	India.	Menon and Nair (1949).
7.	Other wilt diseases	West Indies, Jamaica, Ceylon, New South Wales, Mauritius, India.	Stockdale(1907); Anon (1908); Petch (1910); Small(1927); Park(1928); Shepherd (1927).

* Wilting reported as a symptom in the later stages.

Table 2

Characters of the boles and roots of healthy and diseased palms.

Serial No.	Condition of the tree	Circumference of the bole	Main Roots		
			Total No.	Maximum horizontal spread	Maximum depth
		Meters		Meters	Meters
1	Healthy	1.18	1256	6.7	4.3
2.	"	1.10	1024	8.8	3.2
3.	"	1.0	860	10.7	3.9
4.	"	0.95	700	7.6	5.7
5.	"	0.81	440	7.8	2.3
6.	Diseased	0.88	624	10.7	4.8
7.	"	0.84	612	7.6	4.0
8.	"	0.75	515	7.9	4.2
9.	"	0.76	481	7.2	2.0
10.	"	0.66	404	9.5	3.8

(After Michael, K. J. 1964).

Table 3

Micronutrient contents in the leaves of healthy and root (wilt) diseased palms

Micronutrients	Condition of trees	Mean PPM.	Standard deviation	Statistical significance. P : 0.05
Manganese	Healthy	68.44	21.20	
	Diseased	155.87	19.60	Significant.
Copper	Healthy	21.72	9.27	
	Diseased	38.76	11.53	Significant.
Iron	Healthy	270.31	71.47	
	Diseased	256.41	73.14	Not Significant. ✓
Boron	Healthy	7.04	2.31	
	Diseased	15.38	3.28	Significant.
Molybdenum	Healthy	0.26	0.13	
	Diseased	0.36	0.25	Not Significant. ✓
Zinc	Healthy	24.78	10.44	
	Diseased	51.57	12.46	Significant.

(After Pillai, 1959).

Table 4

Silica content in the leaf tissue of healthy and root (wilt) diseased palms growing in different types of soils

Type of Soil	Healthy	Diseased	% Increase in the diseased
I. Sandy Soil (Average of 10 palms)	2.67	5.22	95.5
II. Loamy Soil (Average of 5 palms)	1.94	4.51	132.5
III. Clayey Soil (Average of 10 palms)	3.20	3.78	18.1
IV. Laterite Soil (Average of 10 palms)	3.44	5.46	58.7

(Annual report of Central Coconut Research Station, Kayangulam for 1958-1959).

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