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SYMPTOMATOLOGY AND YIELD LOSS DUE TO YELLOWING DISEASE OF COCONUT: A LETHAL MALADY IN SOUTHERN KERALA

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ABSTRACT:

A detailed symptomatological analysis of yellowing disease of coconut and survey on its occurrence and severity were conducted at the Instructional Farm, College of Agriculture, Vellayani. The symptoms were characterized by rapid mid whorl yellowing, abnormal and near total shedding of nuts and flowers, drying of inflorescence and spadix and intense leaf spots and blights, often culminating in the death of the palm within a short period. The survey indicated 1.96% incidence of yellowing disease in the farm and an alarming 60.8% of the infected palms had either total loss of productivity (37.5%) or had less than 10 nuts/ palm/ year (23.3%).

KEY WORD: *Coconut, Disease Severity Index, Symptomatology, Yellowing Disease.*

INTRODUCTION:

Coconut palm (*Cocos nucifera* L.) popularly known as the tree of life or 'Kalpavriksha', is the most useful tropical tree in the world and is cultivated in more than 92 countries and provides subsistence for more than 10 million people globally. It is the principal crop of Kerala and the state ranks top in its area (798160 ha) and production (3990 million nuts) in India (Anonymous, 2015). However the productivity here (4999 nuts ha^{-1}) is far below the national average (7305 nuts ha^{-1}) and that of neighboring states (Tamil Nadu - 10236 nuts ha^{-1} , Karnataka - 8127 nuts ha^{-1} and

Pondicherry - 11887 nuts ha^{-1}). Debilitating non lethal Root (Wilt) Disease (RWD) is the most critical production constraint threatening coconut cultivation in Kerala for more than a century.

Recently, occurrence of Yellowing Disease of coconut, characterized by rapid mid whorl yellowing, abnormal and near total shedding of nuts and flowers, drying of inflorescence and spadix and intense leaf spots and blights is fast spreading in Thiruvananthapuram and nearby districts of Kerala. The affected palms often die within a short period. Deepa *et al.* (2012) conducted a study to elucidate the causative agents associated with these symptoms by nested PCR using the nested primer pairs P1/P7-R16F2n/R16R2; R16mF2/R16mR1-R16F2n/R16R2 and semi nested primer pairs 1F7/7R3-1F7/7R2 and the results indicated that some phytoplasmal groups are associated with these palms, but not 16SrXI RWD phytoplasma. However, no elaborate studies have so far been taken up to elucidate the symptomatology of Yellowing Disease and to compare it with that of RWD.

Measurement of disease intensity in quantitative terms is a critical component to have the realistic information on resultant crop losses. George and Radha (1973) developed a scoring method based on severity of flaccidity, yellowing and marginal necrosis of leaflets of RWD affected palms to quantify its severity which was further simplified by Nambiar and Pillai (1985) by limiting the rating of leaves in any one of the five spirals in the crown of the palm. Unlike RWD affected palms, flaccidity, yellowing and distributed necrosis are equally conspicuous and significant on the leaves of Yellowing Disease affected palms which were first and most conspicuously visible on the mid whorl region of the crown, and later progressed upwards or downwards or both as disease advanced. Such palms also exhibited severe inflorescence drying/ necrosis and abnormal shedding of buttons, immature nuts and mature nuts. This necessitated evolving a modified scale to measure disease severity giving due and equal weightage to the foliar symptoms as well as giving importance to inflorescence necrosis and near total shedding of fruits.

METHODS:

A detailed survey was conducted at the Instructional Farm, College of Agriculture, Vellayani on symptomatological parameters and to estimate the per cent incidence and severity of Yellowing Disease. Symptoms exhibited by the palms were recorded during the survey. The selected palms showing mild, moderate and severe symptoms of Yellowing Disease were regularly monitored for eighteen months to critically evaluate the variations in symptom expression.

In order to fully describe the severity of the disease a new method of estimation was attempted. Since foliar symptoms and inflorescence dieback contribute differently to yield loss different scales were formulated for evaluating foliar symptom severity, severity of inflorescence drying and extent of

button shedding/ nut fall. Severity of foliar symptoms was estimated by providing equal weights to flaccidity, yellowing and necrosis of the leaves showing the symptom in any one of the spirals preferably the third spiral. The grades 0, 1, 3 and 5 each were assigned for describing the severity of flaccidity, yellowing and necrosis.

0 – No symptom

1 – Less than one third leaflets showing mild to moderate symptom

3 – One third to two third leaflets showing moderate to severe symptom

5 – More than two third leaflets exhibiting severe symptom

The index for foliar symptoms (IF) was calculated using the formula,

$$IF = \frac{\text{Sum } (F+Y+N)}{3 \times m \times n} \times 100$$

where 'F', 'Y' and 'N' are the grade points assigned to a leaf for flaccidity, yellowing and necrosis, 'm' represents the maximum score assigned and 'n' is the number of leaves in one spiral.

Severity of inflorescence dieback/ drying was calculated by assessing the extent of drying of six younger most inflorescences of the infected palm. The following were the scores assigned for inflorescence dieback/ drying:

0 - No inflorescence dieback/ drying

1 - Less than one third of inflorescence showing drying/ dieback

3 - One third to two third of inflorescence showing drying/ dieback

5 - More than two third of inflorescence showing drying/ dieback

Index for Inflorescence dieback (IID) was calculated using the formula,

$$IID = \frac{\textit{Sum of scores of inflorescence dieback}}{m \times n} \times 100$$

where 'm' represents maximum score value assigned and 'n' represents number of inflorescences observed.

The severity of nut fall/ button shedding and loss of productivity was evaluated based on the number of buttons or immature nuts and mature nuts still remaining in the palm. The following categorizations were followed for this:-

Mild shedding and loss in productivity - More than 25 nuts remaining on the palm

Moderate shedding and loss in productivity - Between 10 to 25 nuts remaining on the palm

Severe shedding and loss in productivity - Less than 10 nuts remaining on the palm ranging from 1 to 9

Total loss of productivity - All nuts/ immature nuts/ buttons were fallen down and the palm was barren

The index for foliar symptoms of the palms showing mid whorl yellowing varies from zero to 100. If the index for foliar symptoms is less than 20 per cent, the palm is at mild stage of infection, if it is between 20 and 50 per cent the palm is at moderate stage of infection and if it is above 50 per cent the palm is at severe stage of infection. The severity of inflorescence dieback varies from zero to 100 and if this index is less than 25 per cent, the palm is at mild stage of infection, if it is between 25 and 50 per cent, the palm is at moderate stage of infection and if it is above 50 per cent it is at severe stage of infection. If the number of nuts per palm is more than 25 it is considered to be at mild stage of infection, between 10 and 25 nuts, the palm is at moderate stage of infection, if it is below 10 nuts, the palm is at severe stage of infection. If one or more of the above indices falls in the severe category, the palm is categorized as severely infected which needs to be cut and destroyed.

RESULTS AND DISCUSSION:

Detailed symptomatological investigations revealed that Yellowing Disease (mid whorl yellowing) of coconut is characterized by rapid chlorosis or yellowing and/ or bronzing and flaccidity of a few or all the leaves in the middle whorl of the palm crown. Yellowing was initially started on the leaflets at the distal end of leaves which progressed down to the base. In few instances yellowing followed by necrosis and blighting of the leaves were started from the innermost whorl of leaves (Plate 1).

In most cases yellowing/ bronzing and flaccidity were progressed from the middle whorl of leaves upwards and/ or downwards or both as the disease advanced. Rapid drying and necrosis of inflorescence and abnormal shedding of flowers, buttons, immature nuts and mature nuts in succession which occurred either simultaneously or prior to yellowing were always associated with Yellowing disease. Gradually the palms became barren within a short span of four to eight months time. The newly emerging inflorescence with few or no female flowers showed necrosis of spikelets from tip downwards either before or just after opening. On the yellowed/ chlorotic leaves intense brown to black or grey spots of varying sizes and shapes were developed which were further enlarged, coalesced and blighted the leaflets. Necrosis was also started from the tips of yellowed leaflets and progressed inwards. These dried up leaves were shed soon. Sometimes shedding of leaves started from one side of the crown where the first yellowed leaf was observed. The newly

produced leaves were shorter and weaker with chlorosis. The size of the crown was reduced and the growth of the palm was highly retarded. The short leaves in the crown were crowded together resulting in rosette appearance. Inflorescence production was ceased (Plate 2). The spathes if at all produced, were very much reduced in size and turned blackish which failed to open. In adverse cases spindle also got infected, withered and the growing point was rotten leading to death of the palm very rapidly.

Many of the palms affected by Yellowing Disease were also 'super infected' with leaf rot pathogens. Leaf rot initially appeared as minute water soaked lesions having different sizes, shapes and colors on the margins and distal ends of leaflets of the unopened spindle leaf. Further progression of leaf rot disease was similar to that of RWD affected palms.

Most of the symptoms of Yellowing Disease are distinctly different from that of the RWD affected palms. The characteristic intense yellowing/ browning of leaves initially limited to a few leaves in the middle whorl of the crown are typical of Yellowing Disease. The most pronounced symptom was the rapid drying of inflorescence and shedding of buttons, immature nuts and mature nuts in quick succession. Earlier workers (Menon (1937), CPCRI (1985), Koshy (1999), ChandraMohanan (2010)) described variability in RWD symptom, but the rapid decline in the health of the palm, which very often lead to its death, quick spread of the disease to the nearby palms and the unique and characteristic symptomatology which is drastically different from the RWD affected palms clearly suggest that Yellowing Disease of coconut could be different from RWD at least in symptomatology. More elaborate study is required to establish whether Yellowing Disease is a part of RWD, or a totally different disease incited by member of a different phytoplasmal group. It is pertinent to note that some of the symptoms of Yellowing Disease of coconut such as rapid yellowing or browning, rapid and total nut fall in quick succession and occasional death are similar to Lethal Yellowing (Plavsic-Banjac *et al*., 1972; Romney, 1983; Tsai, 1988; Mpunami, 1999; Nipah *et al*., 2007; Harrison *et al*., 2008: Harrison and Elliot, 2008). Sometimes yellowing of single leaf in the middle whorl of the crown followed by its upward progression to other younger leaves was also observed as in the case of Lethal Yellowing (Thomas and Norris, 1980; Tsai, 1988; Harrison and Jones, 2003). In Lethal Yellowing affected palms also sometimes the leaves appeared flaccid (Harrison and Elliott, 2008).

The survey on Yellowing Disease indicated that 120 yielding palms (1.96 %) were infected with the disease out of a total of 6107 palms at the Instructional Farm. The disease intensity with respect to foliar symptoms (IF), inflorescence dieback (IID) and loss of productivity (Number of harvestable

nuts/ palm/ year) were estimated and the data are presented in the Table 1. Index for foliar symptoms (IF) was severe on 21.6 % (26 numbers) of the palms, moderate on 54.2 % (65 numbers) and mild on 24.2 % (29 palms) of the infected palms. Inflorescence drying index (IID) was severe on 55% (66 palms), moderate on 19.2% (23 palms) and mild on 25.8% (31 palms) of the affected palms. With respect to loss of productivity among the 120 infected palms, 60.8 % (73 palms) had less than 10 nuts/ palm/ year out of which 37.5 % (45 palms) had a total loss of productivity (0 nuts/ palm). The results also indicated that 25.8% (31 palms) were at the stage of moderate loss of productivity and 13.3 % (16 palms) had produced above 25 nuts/ palm/ year and are at the stage of mild loss of productivity.

Among the three parameters considered for Yellowing Disease severity, the most conspicuous, distinctive and destructive was the loss of productivity followed by inflorescence dieback. As high as 61.6% of the infected palms (45 numbers) had total loss of productivity out of 60.8% of the palms (73 numbers) in the severe category (less than 10 nuts/ palm/ year) (Table 1 and Table 2). Inflorescence dieback was also equally conspicuous and distinctive and 55 % (66 numbers) of the infected palms were exhibiting severe inflorescence dieback (Table 2).

However with respect to severity of foliar symptoms only 21.6% (26 numbers) of the infected palms exhibited severe category of foliar symptoms whereas 54.2% (65 palms) had shown moderate symptom category (Table 3). It is pertinent to observe here that almost 45.8% (55 numbers) of the infected palms were showing both severe inflorescence dieback and severe loss of productivity (Table 2) while only 17.5 % (21 numbers) of the infected palms exhibited severe foliar symptoms and severe loss of productivity (Table 3). Out of the 73 palms (60.8%) with severe loss of productivity only 19 palms (15.8%) exhibited both severe inflorescence dieback and severe foliar symptoms while 66 palms (55 %) had severe inflorescence dieback and 26 palms (21.6%) had severe foliar symptoms (Table 4). In RWD affected palms the progression of foliar symptoms is rather slow with a still slower productivity decline. Such palms could be supported with good nutrient and health management practices to obtain sustainable yield for long period (KAU, 2007; ChandraMohanan and Peter, 2008; Krishnakumar *et al.*, 2015). However the rapid deterioration of health and decline in productivity of Yellowing affected palms signifies a thorough revision of the current management practices being followed for such palms. It can be inferred from the data that there is more positive correlation between severity of inflorescence dieback and loss of productivity than severity of foliar symptoms and loss of productivity (Table 4 and Table 5).

Except in few cases, in advance of foliar symptom severity the severity of inflorescence dieback and the resultant severe loss of productivity occurred at much severe and faster rate in yellowing disease affected palms. This phenomenon is unlike in RWD wherein the productivity of infected palms could be supported and sustained with good agronomic, management and manurial practices for a considerable period of palm growth. Further evidence to the strong relationship of increase in severity of inflorescence dieback and increasing productivity loss can be obtained from the fact that out of the total 60.8% infected palms showing severe productivity loss *ie*., less than 10 nuts/ palm/ year, as high as 75% of them also exhibited severe inflorescence dieback symptoms while only 29% of these palms had severe foliar symptoms. It clearly indicated that the health and the productivity of the palms deteriorated at much faster rate far ahead of and prior to the slow manifestation of visible symptoms.

Further detailed investigation is required for delineating the etiology and for the development of effective management techniques for the problem.

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Table 1. Disease intensity of Yellowing Disease affected palms

Category of palms	Palms in the mild category (%) (number of palms)	Palms in the moderate category (%) (number of palms)	Palms in the severe category (%) (number of palms)	Palms with total loss of productivity (%) (number of palms)
Foliar symptom severity (IF)	24.2 % (29)	54.2 % (65)	21.6 % (26)	
Inflorescence drying severity (IID)	25.8 % (31)	19.2 % (23)	55 % (66)	
Loss of yield/ shedding of fruits	13.3 % (16)	25.8 % (31)	23.3 % (28)	37.5 % (45)

Table 2. Categorization of Yellowing Disease affected palms based on intensity of inflorescence dieback

Category of palms	Intensity of inflorescence dieback (No. of palms in each category)				Total	Per cent of the total infected palms
	Severe	Moderate	Mild	No symptom		
Palms with total loss of productivity	38	4	2	1	45	37.5 %
Palms with severe loss of productivity	17	8	3	-	28	23.3 %
Palms with moderate loss of productivity	10	11	4	6	31	25.8 %
Palms with mild loss of productivity	1	-	2	13	16	13.3 %
Total	66	23	11	20	120	
Per cent of the total infected palms	55 %	19.2 %	9.2 %	16.6 %		

Table 3. Categorization of Yellowing Disease affected palms based on intensity of foliar symptoms

Category of palms	Intensity of foliar symptoms (No. of palms in each category)			Total	Per cent of the total infected palms
	Severe	Moderate	Mild		
Palms with total loss of productivity	18	24	3	45	37.5 %
Palms with severe loss of productivity	3	17	8	28	23.3 %
Palms with moderate loss of productivity	4	18	9	31	25.8 %
Palms with mild loss of productivity	1	6	9	16	13.3 %
Total	26	65	29	120	
Per cent of the total infected palms	21.6 %	54.2 %	24.2 %		

Table 4. Cumulative effect of foliar symptoms, inflorescence dieback and loss of productivity in the infected palms

	Palms with total loss of productivity	Palms with severe loss of productivity	Palms with moderate loss of productivity	Palms with mild loss of productivity
Palms with severe inflorescence dieback and foliar symptoms	17	2	1	1
Palms with severe inflorescence dieback and moderate foliar symptoms	19	11	7	0
Palms with severe inflorescence dieback and mild foliar symptoms	2	4	2	0
Palms with moderate inflorescence dieback and severe foliar symptoms	0	1	3	0
Palms with moderate inflorescence dieback and foliar symptoms	4	4	3	0
Palms with moderate inflorescence dieback and mild foliar symptoms	0	3	5	0
Palms with mild/ no inflorescence dieback and severe foliar symptoms	1	0	0	0
Palms with mild/ no inflorescence dieback and moderate foliar symptoms	1	2	8	6
Palms with mild/ no inflorescence dieback and foliar symptoms	1	1	2	9
Total	45	28	31	16

Table 5. Correlation matrix for foliar symptoms, inflorescence dieback and yield of the palm

Parameters	Index for foliar symptoms	Index for inflorescence dieback	No. of nuts per palm
Index for foliar symptoms	1.0000		
Index for inflorescence dieback	0.4310**	1.0000	
No. of nuts per palm	-0.3254**	-0.6646**	1.0000

**Values significant at P<0.01

Plate 1. Symptoms of Yellowing Disease in the inner whorl of the affected palm

Plate 2. Symptoms of Yellowing Disease