Research Article

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Role of relative humidity and temperature on the survival of *Phytophthora palmivora*, the incitant of coconut bud rot

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Abstract

A random survey on bud rot disease of coconut, caused by *Phytophthora palmivora*, carried out in Kasaragod, Kannur and Calicut districts of Kerala revealed that, there is correlation between the disease incidence and the location of the palms. The disease incidence was high in the hilly tracts (300-1350 MSL), when compared to that of the plains (150 –300 MSL). Studies on the survival of *P. palmivora* propagules in nature revealed that the pathogen survives in the crown of healthy and diseased palms. However, the percentage of survival was high in the endemic areas (Mandapam, Josegiri and Kuttiadi), both in the case of diseased and healthy palms compared to that of areas with lesser disease incidence. Statistical analysis of moisture content in the debris of crown at different places (CPCRI Kasaragod, Mandapam and Josegiri) during April, July, October and January revealed that differences due to places, season (months) and their interactions are highly significant. Epidemiological observations indicates that macro and micro-temperatures in Mandapam and Josegiri were low, while the micro and macro humidity recorded was high from October–January compared to that of Kasaragod. This shows that the temperature and humidity in the coconut growing tracts of hilly areas of Kasaragod, Kannur and Calicut districts are suitable for the survival of the pathogen in the crown during almost all months, resulting in the high frequency of disease incidence during monsoon season and which is also responsible for the continued infection upto January. Examination of the rain water collected from bud-rot affected coconut gardens also indicated that the pathogen surviving in the crown debris can act as a source of inoculum which spreads to the neighboring palms through rain splashes. Based on the above data, it is possible to predict the bud rot incidence well in advance.

Key words: Coconut, bud rot, *Phytophthora palmivora*, epidemiology, forecasting model

Introduction

Among the diseases, next to stem bleeding and root (wilt), bud rot and immature nut fall caused by *Phytophthora* are the major diseases that affect the coconut in Kerala. Bud rot incidence of 1.2 to 10.9 per cent, and 35 to 40 per cent in gardens having a large number of diseased palms in certain locations of Kerala has been reported (Radha and Joseph,1974). The disease is generally noticed during South -West and North - East monsoon periods when wet weather prevails (Menon and Pandalai, 1958). A combination of temperature of 21-24 ^{0}C and 98 –100 percent RH have been found to be highly congenial for the development of *Phytophthora* incited rots. Joseph and Radha (1975), reported that bud rot had an incubation period of 35 days for the manifestation of visible symptoms. The microclimatic factors prevalent in the axil of leaves were equally important for the development of the disease. It has been reported that higher incidence of *Phytophthora* bud rot was always preceded by heavy rain fall (Quillec *et al*; 1984, Rillo and Paloma, 1989). *Phytophthora* has been reported to survive in the frond bases or basal part of the crown (Radha and Joseph, 1974). From the foregoing account it is clear that not much work has been done regarding environmental factors related to bud rot disease, survival of the pathogen and mode of dispersal of the pathogen. The objectives of the present study were to record the disease incidence in relation to geographic locations, role of environmental factors in disease epidemics in certain areas to find out the perpetuation of the pathogen and its dispersal and to predict the disease incidence .

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Materials and Methods

Survey

A random survey was conducted in different localities of Kasaragod, Kannur, and Calicut, Wayanad, Thrissur, Malappuram, Palakkad of Ernakulam districts of Kerala and Dakshina Kannada district of Karnataka. During the survey, altitude, topography, and the extent of bud rot incidence in each coconut garden were recorded .

Survival of pathogen in diseased gardens

To study the survival of the pathogen in the crown of coconut palms, organic matter (debris) was collected from the axils of diseased and healthy palms. The plots studied were selected in non endemic (CPCRI Kasaragod, CPCRI Kidu farm, Kannur) and endemic areas Mandapam (Kasargod), Josegiri (Kannur), Udayagiri (Kannur) and Kuttiadi (Calicut). 500 cubic centimeters of crown debris measured in 500 ml beaker were moistened with 250 ml sterile distilled water and isolations were made to check the presence of *Phytophthora* by baiting using two month old uninjured Chowghat Orange Dwarf (COD) nuts. The samples were kept for incubation at 24 ± 1 °C for 6 -12 days. After incubation, nuts were observed for lesion development as described by Thevenin *et al.* (1992) and isolations from the nuts were carried out in P_{10}ARP medium (Kannwischer and Mitchell, 1978) and the percent survival was calculated based on the frequency of positive isolations using the formula :

$$\frac{\text{Number of samples with positive isolation}}{\text{Total number of samples observed}} \times 100$$

Seasonal variation in moisture content in the coconut crown debris

Moisture content percentage in the crown debris collected from the 5th and 6th leaf axils during April, July, October and January was calculated on dry weight basis.

Effect of temperature and moisture levels on the survival of *Phytophthora* in crown debris

Crown debris collected from the 5th and 6th leaf axils of coconut palms was air dried at room temperature and autoclaved for one hour at 121 °C for two days. One hundred gm aliquots of debris were taken in bottles and mycelial mats harvested from carrot broth after 15 days of growth were used for inoculation. Mycelial mats were blended in 50 ml of water and mycelial suspension (10 ml) was added to each bottle and mixed well. Moisture levels were adjusted to 20, 40, 60, 80,100 % in the crown debris taken in the bottles on dry weight basis and bottles were covered with polythene bags to check evaporation and were incubated in a incubator at 10, 15, 20, 30 °C. Three replicates were maintained for each treatment. After 30 day intervals, samples were removed and colony forming units were computed by serial dilution method in P_{10}ARP medium.

Trapping of *Phytophthora* propagules from rain water

For collecting rain water, plastic trays were fitted to bamboo poles at 15 and 35 cm above the ground and also at the base of the crown (Thevenin *et al.*, 1992). Rain water samples collected in the trays were applied to wound surface in 2 month old surface sterilized COD nuts. An equal number of sterile distilled water samples served as control and incubated at a temperature of 24±1 °C for 5-6 days and observed for lesion development. The percentage of isolation was calculated using the earlier formula:

$$\frac{\text{Number of samples with positive isolation}}{\text{Total number of samples observed}} \times 100$$

Role of micro and macro climate factors in the incidence of bud rot

The bud rot incidence and environmental factors were recorded for two years in three plots; two in hilly (Josegiri, Mandapam) and one in the plain (Bovikanam) to study the role of environmental factors (both micro and macro) in bud rot incidence.

Results and Discussion

Survey

It was noticed that the number of palms with bud rot incidence was higher in the hilly areas of Kasaragod, Kannur and Calicut districts compared to other districts (Table-1). In certain pockets of hilly regions of Kasaragod, Kannur and Calicut districts, more than 50% of the gardens had heavy losses by bud rot, while few gardens have incidence of more than 60 percent and there was correlation between the location of the palms and the disease incidence compared to that of the plains (Table-2). Dantre *et al.*, (1997) reported that bud rot incidence was high in the plateau region than in the plains of non-traditional coconut growing areas of Eastern Madhya Pradesh. Bud rot of coconut was found to occur during the monsoon season when there is high humidity (90-100%) and optimum temperature in the atmosphere. However, in the hilly areas of Kasaragod, Kannur and Calicut districts it was noted that the disease continued

to occur up to the month of January. In the plains, disease incidence was recorded only up to September. Initial incidence of bud rot disease was always dependent upon the monsoon showers. However, the occurrence of bud rot in subsequent months i.e. from October- January could be attributed to the favorable microclimatic conditions inside the crown with consistent high humidity, low night temperature and the presence of water droplets from dew drops. Bambawale *et al.* (1991) reported the occurrence of late blight of potato, even in the absence of rain, where dew appeared to be the alternative source of moisture.

Table-1. Bud rot incidence in certain districts of Kerala state recorded during the year 1999-2000

Districts	No. of plots surveyed	Total number of palms observed	Number of palms with bud rot	% of disease incidence
Kasaragod	258	10136	438	4.32
Kannur	215	13857	496	3.57
Calicut	160	12125	428	3.52
Waynad	98	1315	115	3.94
Thrissur	138	2158	12	0.55
Malappuram	129	1928	15	0.77
Palakkad	132	2015	8	0.39
Ernakulam	120	1156	6	0.51

$X^2 = 321.12$ with 7df

Table –2. Proportion of diseased palms in different districts

Place	Proportion of diseased palms in the hilly tracts	Proportion of diseased palms in the plains	Z value
Kasaragod	0.0699	0.0060	15.78**
Calicut	0.0644	0.0054	18.23**
Kannur	0.0763	0.0039	22.78**
Pooled data	0.0709	0.0049	33.00**

**Significant at 1%

Survival of pathogen in diseased gardens

Even after prophylactic spray of the palms with 1% Bordeaux mixture high bud rot incidence was noted in Mandapam, Josegiri and Udayagiri. This may be due to improper spraying which has failed in the destruction of the actual source of inoculum. Samples were collected from diseased and healthy palms at CPCRI Kasaragod, CPCRI Kidu farm, Mandapam, Josegiri, Udayagiri and Kuttiadi to study the survival of the pathogen in the crown. Survival of *Phytophthora* propagules was observed in the axils of diseased and healthy palms. In endemic areas like Mandapam, Josegiri, Udayagiri and Kuttiadi where bud rot incidence was found to be increasing year after year, the survival percentage of *Phytophthora* propagules was very high. The wet samples which were collected from the axils of the leaves, readily yielded *Phytophthora* without any additional moistening, thus revealing the survival of the active inoculum in the wet organic matter. The dry samples yielded *Phytophthora* only after moistening with sterile distilled water and incubation at $24\pm1\ ^0C$ for 6–12 days (Table-3).

Table-3. Survival of *Phytophthora* in the crown of coconut palms

Location	Healthy palms		Bud rot affected palms	
	Total number of samples observed	Per cent of isolates obtained	Total number of samples observed	Per cent of isolates obtained
CPCRI Kasaragod	50	18 (9)*	5	40 (2)
CPCRI Seed farm Kidu	50	16 (8)	10	80 (8)
Mandapam	50	42 (21)	20	90 (18)
Josegiri	50	38 (19)	20	95 (19)
Udayagiri	50	30 (15)	20	90 (18)
Kuttiadi	50	24 (12)	20	80 (16)

* Figures in parentheses indicate number of isolations obtained

Present study showed that *Phytophthora* propagules were surviving in the axils of diseased and healthy palms even during the off season. High rate of isolation from leaf axils assumes great significance in the epidemiology of bud rot disease. *Phytophthora* infects the soft spear leaf of coconut and the close proximity of spear leaf with leaf axils gives a strong clue that the presence of inoculum in the leaf axils is a crucial factor in the initiation of infection in spear leaf. This also points towards the importance of crown cleaning for avoiding the disease incidence during monsoon. In endemic areas like Mandapam, Josegiri, Udyagiri and Kuttiadi where bud rot incidence was found to be increasing year after year, the survival percentage of *Phytophthora* propagules in the leaf axils was very high. Thevenin (1992) reported a similar condition in Indonesia. Survival of *P. palmivora* in leaf axils of coconut palms were reported by Menon and Pandalai (1958) and Radha and Joseph (1983). *P. palmivora* is reported to overtide the unfavourable weather conditions in the disease affected crown tissues of the host and begin to multiply at the onset of favourable conditions i.e, during the subsequent monsoon period (Nambiar, 1999).

Seasonal variation in moisture content in the crown debris

To find out the status of moisture content in the crown debris of infected palms in different locations, samples were collected from CPCRI Kasaragod, Mandapam and Josegiri, during April, July, October and January. Statistical analysis carried out for the moisture content % (angular transformation) in the crown debris of different places (CPCRI Kasaragod, Mandapam and

Josegiri) during April, July, October and January revealed that differences due to places, months and their interactions are highly significant. On overall basis it was seen that samples from Mandapam was found to record the highest moisture % closely followed by Josegiri whereas Kasaragod samples recorded the lowest moisture %. As regards months, it was seen that the minimum was recorded in April while July had the highest. (Table-4). Due to cooler temperatures experienced at high altitudes and also dense vegetation, condensation was quite high in the endemic plots situated in hilly areas even during the post monsoon season.

Table- 4. Moisture (%) in the crown debris of coconut palms in different locations

	Moisture (%) in the crown debris of coconut palms in different locations during				
	April	July	October	January	Mean
Kasaragod	19.00 (11.3)*	60.7 (75.6)	40.8 (42.9)	29.9 (24.9)	**37.7**
Mandapam	26.2 (20.0)	62.3 (77.3)	51.0 (60.4)	44.6 (49.3)	**46.0**
Josegiri	27.2 (21.4)	61.6 (76.4)	49.9 (58.5)	43.6 (47.5)	**45.0**
Mean	24.2	61.5	47.2	39.3	

*Figures in parentheses are the actual percentage values

(Transformation used: $\sin^{-1}$ " p where 'p' is the proportion of moisture)

Gen. Mean = 43.1

SE/Plot = 5.1

CV% =11.9

CD (P=0.05) for places = 1.30

CD (P=0.05) for months = 1.50

CD (P=0.05) for places x months =2.60

In vitro experiment to study the relationship between survival of *Phytophthora* in crown debris in relation to moisture % and temperature levels

In vitro study indicated that the levels of temperature and moisture had a profound influence on the rate of survival of *P. palmivora* (Table-5). Colony Forming Units (CFU) were higher at 100 percent moisture level compared to 10 and 35 ^{0}C . Maximum number of CFU were recorded at 30 days after which there has been a significant decline in their population in the successive months. CFU were found to be minimum at temperature levels of 10 and 35 ^{0} C. This may be due to the loss of viability of *Phytophthora* propagules at very high and very low temperatures. Opoku and Wheeler (1998) reported that *P. palmivora* and *P. megakarya* persisted in roots of cacao for at least 6 months, however, the recovery of both fungi from these sources declined with time. Here also the CFU progressively decreased with increasing intervals of time.

Trapping of *Phytophthora* propagules from rain water

Phytophthora propagules were higher in the rain water, which was collected in the trays titled at the base of the crwon than those of fitted to bamboo poles at 15 cm and 35 cm above the ground (Table-6). This shows that the inoculam present in the crown were transported as far as the tray at the base of the crown through rain water. At 35 cm the trapping was minimum . *Phytophthora* propagules were isolated from the trays fitted above 15 cm from the ground. This may be due to the rain water splashing which has projected soil particles, and sometimes soil-borne *Phytophthora* propagules to the tray. It was also possible to trap *Phytophthora* from healthy trees, from the trays fitted to the base of the crown and also 15 cm above the ground. However, the percentage of isolation was high for the trays fitted to diseased palms compared to healthy palms. This indicates that rain water acts as a carrier for the infectious propagules and plays an important role in the spread of the disease (Thevenin,1992; Brahmana *et al.*, 1992).

Table- 5. Variation in colony forming units (CFU) at different moisture and temperature levels

Interaction of moisture x temperature

Moisture level (%)	CFU /g at Temperatures (^{0} C)					
	10	15	20	30	35^0 C	Mean
20	0.39	0.56	0.55	0.22	0.05	0.35
40	0.94	0.94	1.44	0.998	0.553	0.97
60	1.99	1.66	2.21	1.38	0.66	1.58
80	4.52	5.16	5.44	5.71	4.66	5.10
100	6.27	6.94	7.53	7.94	7.16	7.17
Mean	2.82	3.05	3.43	3.25	2.61	

Interaction of moisture x month

Moisture level (%)	CFU /g after month (s)						
	1	2	3	4	5	6	Mean
20	1.3	0.59	0.59	0.39	0.00	0.00	0.35
40	2.26	1.66	1.06	0.66	0.200	0.00	0.97
60	3.12	2.72	1.72	1.06	0.59	0.26	1.58
80	8.26	7.26	5.66	4.32	3.19	1.93	5.10
100	12.39	10.73	7.93	5.39	3.57	2.99	7.17
Mean	5.43	4.59	3.35	2.29	1.51	1.03	

Interaction of temperature x month

Temperature (^{0}C)	CFU /g after month (s)						
	1	2	3		5	6	Mean
10	5.59	4.25	2.66	1.93	1.39	1.13	2.82
15	5.66	4.33	3.53	2.26	1.53	1.00	3.05
20	4.52	5.66	4.19	2.73	2.044	1.466	3.43
30	6.13	4.72	3.59	2.53	1.59	0.93	3.25
35	5.26	3.99	2.79	1.99	0.99	0.66	2.61
Mean	5.43	4.59	3.35	2.29	1.51	1.03	

CD (P = 0.05) for moisture = 0.54

CD (P = 0.05) for temperature = 0.54

CD (P = 0.05) for months = 0.59

CD (P = 0.05) for moisture x month = 1.33

Inter relationship between bud rot incidence and macro and micro climate

Phytophthora infection on coconut occurs when the relative humidity is higher than 94 percent and the temperature lower than 24 ^{0}C. In open spaces it is hard to find humidity higher than 94 percent. Therefore, in the present study macro and micro humidity and temperature of three plots (Mandapam, Josegiri and Bovikanum) were recorded for two years. In all the fields studied, the micro humidity was high and temperature was low when it was compared with that of the ambient (Fig.-1). The mean macro and micro humidity and temperature recorded in the two endemic plots (Mandapam, Josegiri) showed variation compared with that of Bovikanum, with sparse disease incidence.

Table-6-Trapping of *Phytophthora* propagules from rain water

Location	% of trapping of *Phytophthora* propagules from rain water					
	Diseased			Healthy		
Mandapam	15 cm	35 cm	Base of the crown	15 cm	35 cm	Base of the crown
	11.057	3.68	25.104	3.68	0.00	7.37
	(6.00)*	(2.00)	(22.00)	(2.00)	(0.00)	(4.00)
CPCRI	3.686	0.00	5.31	0.00	0.00	3.68
	(2.00)	(0.00)	(4.00)	(0.00)	(0.00)	(2.00)

[(Tansformed values) - Transformation used $\sin^{-1} p$, where 'p' is the proportion trapped]

*Figures in parentheses are actual percentages

Gen. Mean = 5. 29 C.D. (P=0.05) for places = 4.34

SE/Plot= 8.37 C.D. (P=0.05) for disease x health = 4.34

C.V.(%) = 158.01 C.D. (P=0.05) for height = 5.32

Study on the relationship between temperature, macro, micro-humidity and disease incidence in Mandapam, Josegiri and Bovikanam revealed that, there is a high degree of correlation between disease incidence, micro and macro-humidity in Mandapam and Josegiri. However, in the case of Bovikanam the correlation was not significant. Disease incidence was highly correlated with the macro and micro humidity of same month and also that of the previous two months. Table–7 shows the correlation matrices for Mandapam, Josegiri and Bovikanam respectively.

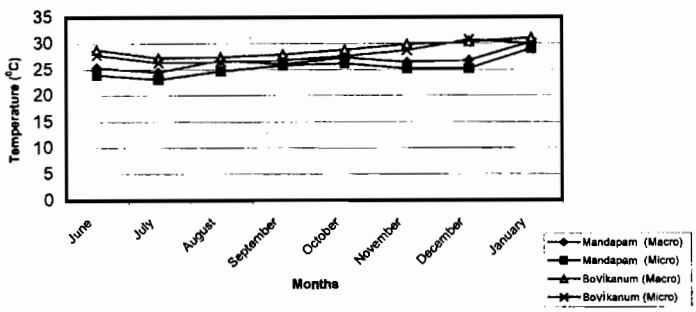
Evolving an equation for forecasting bud rot disease in endemic locations

Regression equation ($y=ae^{bx}$) was fitted for forecasting the number of diseased palms in each location in different months. The compound growth rate showed that, it was higher for the locations 300-1350 M above MSL (Mandapam, Josegiri, Udayagiri, Kuttiadi) when compared to Bovikanam which is 150–300 M above MSL (Table-8).

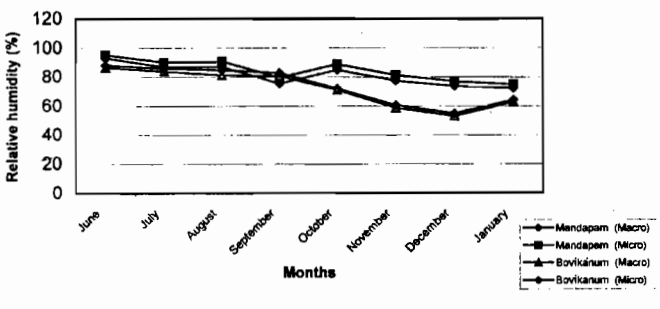
Table-8. Regression equation with CGR in different bud rot affected locations

Location (M above MSL)	a	b	Se (b)	R^2	CGR
Mandapam (300-1350 M)	3.9110	0.0691	0.008428	0.9180	7.15*
Josegiri (300-1350 M)	3.2783	0.0783	0.008475	0.9344	8.15*
Udayagiri (300-1350 M)	3.1693	0.0609	0.006790	0.9306	6.28*
Kuttiadi (300-1350 M)	3.0220	0.0563	0.008685	0.9355	5.80*
Bovikanam (150–300 M)	1.3863	0.0398	0.010288	0.7143	4.07*

*Significant at 5%



a) Temperature



b) Relative humidity

Fig. 1 Macro and micro humidity and temperature recorded in bud rot affected coconut gardens

Table-7 . Relationship between bud rot incidence and macro and micro-climates (Correlation matrices)

Time interval (months)	Temperature						Relative humidity					
	Mandapam		Josegiri		Bovikanam		Mandapam		Josegiri		Bovikanam	
	Macro	Macro	Micro	Macro	Micro	Macro	Micro	Micro	Macro	Micro	Macro	Micro
0	0.320	0.453	0.488	0.23	0.687$	0.683$	-0.802^	-0.780. $	-0.835^	-0.84^	-0.756$	-0.752$
1	0.259	0.375	0.43.	0.149	0.44	0.455	-0.820^	-0.780$	-0.78$	-0.79$	-0.58	-0.57$
2	0.174	0.171	0.24	-0.02	0.069	0.025	-0.707$	-0.642	-0.65	-0.664	-0.355	-0.355
3	0.088	0.048	0.10	-0.18	0.032	-0.61	-0.602	-0.53	-0.46	-0.48	0.00	-0.01
4	0.149	0.0076	0.23	-0.09	0.00	0.00	-0.474	-0.417	-0.47	-0.48	0.00	0.00
5	0.104	-0.076	0.20	-0.129	0.00	0.00	-0.388	-0.32	-0.369	-0.38	0.00	0.00
6	-0.20	-0.28	-0.01	-0.23	0.00	0.00	-0.06	-0.007	-0.150	-0.18	0.00	0.00

$ - significant at 5% level

^ significant at 1% level

Efforts were made to develop an equation to forecast disease incidence in endemic areas (Mandapam and Josegiri) by using relative humidity level of the previous month. Out of the models studied, (same month, after 1, 2, 3, 4, 5 and 6 months) the one using both macro and micro – humidities of previous month and another using the same variable of previous two months, gave the prediction equation with high R^2 at Mandapam.

This suggests that *Phytophthora* inoculum development was intense during the wet period and the incubation period was the time taken for fungus penetration followed by its development inside the coconut crown upto the bud and the appearance of the first external symptom. Rillo and Paloma (1989) found that in the Philippines, higher incidence of *Phytophthora* was always preceded by high rainfall during the previous months.

The forecasting equations for Mandapam plot are

1. $Y = (82.2) - 2.764\ RH_{MACRO} + 2.065\ RH_{MICRO}$

For this the $R^2 = 0.756$

Where 'Y' is the disease incidence (%) of particular month

RH_{MACRO} is the average relative macro-humidity of the previous month

RH_{MICRO} is the average relative micro-humidity of the previous month

2. $Y = (72.455) - 4.315RH_{MACRO} + 3.699RH_{MICRO}$

For this the $(R^2 = 0.759)$

Where 'Y' is the disease incidence (%) of a particular month

RH_{MACRO} is the average relative macro-humidity of the previous 2 months

RH_{MICRO} is the average relative micro-humidity of the previous 2 months

The forecasting equations for Josegiri plot are :

3. $Y = (36.5) - RH_{MACRO} + 0.2578\ RH_{MICRO}$

For this the $(R^2 = 0.623)$

Where 'Y' is the disease incidence (%) of particular month

RH_{MACRO} is the average relative macro-humidity of the previous month

RH_{MICRO} is the average relative micro-humidity of the previous month

4. $Y = (37.9) - 0.2629RH_{MACRO} + 3.699RH_{MICRO}$

For this the $(R^2 = 0.634)$'

Where 'Y' is the disease incidence (%) of a particular month

RH_{MACRO} is the average relative macro-humidity of the previous 2 months

RH_{MICRO} is the average relative micro-humidity of the previous 2 months

The number of palms with bud rot incidence in different months was estimated using regression equation $Y = ae^{bx}$ (Table-9). From the foregoing discussion, it is clear that micro climate is directly influenced by macro climate. Forecasting disease incidence is very important for the management of the disease. Out of the models studied, (same month, previous 1, 2, 3, 4, 5 and 6 months) the one using both macro and micro – humidities of previous month and another using the same variable of previous two months gave the prediction equation with high R^2 at Mandapam and Josegiri. From Table – 9 it is very clear that the difference between the predicted and actual disease incidence has been insignificant. This is the first time a forecasting equation was developed for predicting bud rot disease in Kerala. This would help the farmers to take up prophylactic measures before the disease outbreak and there by save the palms from the lethal disease. Forecasting systems based on weather parameters well in advance can result in reducing crop loss, and adopting control measures at a reasonable time to avoid the recurrence of disease epidemics.

Table-9. Estimated value for bud rot incidence in different locations by regression equation $Y = ae^{bx}$

Location (in M above MSL)	Estimated value for bud rot disease in 1999						
	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
Mandapam (300-1350 M)	57.35 (55.00)*	65.45 (58.00)	65.85 (62)	70.56 (68.00)	75.61 (73.00)	81.02 (79.00)	86.81 (84.00)
Josegiri (300-1350 M)	31.02 (26.00)	33.55 (28.00)	36.288 (35.00)	39.244 (38.00)	42.44 (39.00)	45.89 (42.00)	49.63 (46.00)
Udayagiri (300-1350 M)	26.87 (23.00)	28.55 (25.00)	30.35 (28.00)	32.25 (31.00)	34.28 (34.00)	36.437 (35.00)	38.72 (36.00)
Kuttiadi (300-1350 M)	22.97 (22.00)	24.31 (22.00)	25.718 (23.00)	27.2 (26.00)	28.78 (27.00)	30.45 (30.00)	32.21 (31.00)
Bovikanam (150-300 M)	4.33 (4.00)	4.50 (5.00)	4.69 (6.00)	4.88 (6.00)	5.07 (6.00)	5.28 (6.00)	5.49 (6.00)

* Figures in parentheses are observed values

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