Duration of the Stages of Cadang-Cadang Disease of Coconut Palm

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ABSTRACT

ZELAZNY, B., and B. S. NIVEN. 1980. Duration of the stages of cadang-cadang disease of coconut palm. Plant Disease 64:841-842.

The time between the first appearance of the symptoms of cadang-cadang disease and the death of a palm was indirectly estimated by recording changes in the disease status of 8,786 palms at 6-mo intervals for 3 yr and by assuming a constant rate of infection. The disease was estimated to last 7.5 yr in 22-yr-old palms and 15.9 yr in 44-yr-old palms. However, changes in the infection rate apparently affected the accuracy of estimates.

Cadang-cadang is a destructive disease of coconut palm in some parts of the Philippines. The percentage of palms showing symptoms has been recorded periodically to assess the economic impact of the disease (2,5). However, the incidence does not immediately provide the number of palms that become infected or die in 1 yr, unless the average time between the appearance of the first symptoms and the death of the palm is known. This time is unknown, although casual observations indicate that it is more than 5 yr (Price [4] stated that many palms live 5–15 yr after symptoms appear).

Because measuring the duration of the disease directly in a number of palms would take many years, we made indirect estimates. We distinguished between the early, medium, and late stages of cadang-cadang disease, estimated the duration of stages separately, and combined them to estimate the total duration of the disease.

METHODS

Field observations. Between January 1976 and January 1979, 8,786 marked coconut palms in a plantation near Ligao, Albay Province, were observed every 6 mo for symptoms of cadang-cadang disease. From the heights of the palms and information from the plantation owner, we estimated that 8,218 palms were planted in 1950 or later (young palms), the majority between 1950 and 1955, and the other 568 palms (old palms) before 1950. Each infected palm was carefully studied for symptoms, and the early, medium, or late stage of the disease was determined (1,3,6). The classification was always made by the same persons.

During the observations, 11 palms were classified as being in the early stage of disease but were recorded as being healthy at later readings. These palms were not used for estimating the duration of the stages, nor were four young and 53 old infected palms that were felled by the plantation owner during the observation period. Readings on 385 young palms and 73 old palms that showed symptoms of cadang-cadang infection during the observation period were used for the estimates. In January 1976 the average ages of the young and old infected palms were estimated to be 22 and 44 yr, respectively. It was not always possible to distinguish clearly between the early and medium stages and between the medium and late stages of the disease. For instance, during six consecutive readings, the disease stage of a palm might be recorded as early, early, medium, early, medium, medium. For estimating the duration of the stages, such a sequence was then altered into early, early, early, medium, medium, medium.

This research was performed while the senior author was employed as entomologist in the UNDP/FAO Coconut Research and Development Project in the Philippines.

0191-2917/80/09084102/$03.00/0

Estimating the duration of stages. In the following, only the method for estimating the duration of the early stage of disease is described. The methods for estimating the duration of the medium and late stages are very similar, with minor changes in the terminology.

The average duration of the early stage was divided into n 6-mo intervals; that is, on average a palm goes through n 6-mo intervals before it starts showing symptoms of the medium stage. If the rate of infection is constant, then the same number of palms would enter the early stage every 6 mo, and each 6-mo interval of the early stage would be represented by the same number of palms.

At time 0 the number of palms that are in the first 6-mo interval is called E_{10}, the number of palms in the second 6-mo interval E_{20}, etc, and the number of palms in the nth 6-mo interval E_{n0}. Six months later, at time 1, the numbers of palms in the different 6-mo intervals are called E_{11}, E_{21}, . . . E_{n1}. The total number of palms in the early stage at time 0 is called E_0, at time 1 E_1, and so on.

At time 1, two of the E_{ij} can be observed: E_{11}, the number of palms that did not show any symptoms of the disease at time 0 but showed symptoms of the early stage at time 1 (eg, first figure of first line in Table 1), and E_{n0}, the number of palms that showed symptoms of the early stage at time 0 but symptoms of the medium stage at time 1 (eg, first figure of third line in Table 1). By observing a group of palms initially and 6 mo later, the total number of palms in the early stage can be estimated by:

$$\hat{A}_1 = (\hat{E}_0 + \hat{E}_1)/2.$$

For example, in the first column of Table 1, $\hat{E}_0 = 145 + 27 = 172$ and $\hat{E}_1 = 29 + 145 = 174$; therefore $\hat{A}_1 = 173$. The number of palms in one 6-mo interval can be estimated by:

$$\hat{B}_1 = (\hat{E}_{11} + \hat{E}_{n0})/2.$$

In the first column of Table 1, $\hat{E}_{11} = 29$ and $\hat{E}_{n0} = 27$; therefore $\hat{B}_1 = 28$. Because $A_1 = nB_1$, an estimate of n can now be obtained, assuming that the number of palms in each 6-mo interval is constant:

$$\hat{n}_1 = \hat{A}_1/\hat{B}_1.$$

Because n_1 is given in 6-mo intervals, we have to divide by 2 to obtain an estimate of the early stage in years. For example, in the first column in Table 1, $\hat{n}_1 = 173/28 = 6.18$; that is, the early stage is estimated to last 3.09 yr (see first figure of first line in Table 2).

For more accurate estimates of n, we used seven consecutive readings at 6-mo intervals from time 0 to time 6. The estimate of n, which is called $\hat{n}_6$, proceeded similarly, and the following expressions were obtained:

$$\hat{n}_6 = \hat{A}_6/\hat{B}_6,$$

$$\hat{A}_6 = (\hat{E}_0 + \hat{E}_1 + \ldots + \hat{E}_6)/7,$$

$$\hat{B}_6 = (\hat{E}_{11} + \hat{E}_{12} + \ldots + \hat{E}_{16} + \hat{E}_{n0} + \hat{E}_{n1} + \ldots + \hat{E}_{n5})/12.$$

Using the data from the first three lines of Table 1, the calculation of $\hat{n}_6$ proceeds as follows:

$$\hat{A}_6 = [(145 + 27) + (149 + 25) + (130 + 44) + (105 + 39) + (93 + 23) + (88 + 28) + (7 + 88)]/7 = 141.57,$$

Table 1. Changes in the status of cadang-cadang disease in 458 palms[a]

Change in disease stage	Between Jan. and July 1976	July 1976 and Jan. 1977	Jan. and July 1977	July 1977 and Jan. 1978	Jan. and July 1978	July 1978 and Jan. 1979	Average
From healthy to early	29 (3)	25 (1)	14 (0)	11 (0)	23 (0)	7 (0)	18.2 (0.7)
Remained in early	145 (17)	149 (20)	130 (18)	105 (15)	93 (7)	88 (4)	118.3 (13.5)
From early to medium	27 (3)	25 (0)	44 (3)	39 (3)	23 (8)	28 (3)	31.0 (3.3)
Remained in medium	57 (7)	55 (5)	65 (3)	82 (3)	89 (4)	87 (10)	72.5 (5.3)
From medium to late	10 (4)	29 (5)	15 (2)	27 (3)	32 (2)	25 (2)	23.0 (3.0)
Remained in late	36 (37)	41 (40)	65 (43)	69 (44)	90 (46)	108 (47)	68.2 (42.8)
From late stage to dead	1 (1)	5 (1)	5 (2)	11 (1)	6 (1)	14 (1)	7.0 (1.2)

[a] In each set of numbers, the first number represents changes in status among palms planted in 1950 or later; the number in parentheses represents changes among palms planted before 1950.

Table 2. Estimates of the duration of the stages of cadang-cadang disease in palms (yr)

Observation period	Stage Early	Medium	Late	Total duration
Jan.–July 1976	3.09	2.04	3.77	8.90
July 1976–Jan. 1977	3.48	1.52	1.71	6.71
Jan.–July 1977	2.74	1.60	3.75	8.09
July 1977–Jan. 1978	2.60	1.74	2.32	6.66
Jan.–July 1978	2.52	2.12	2.87	7.51
July 1978–Jan. 1979	3.01	2.14	3.27	8.42
Jan. 1976–Jan. 1979 (palms planted in 1950 and later)	2.88	1.82	2.78	7.48
Jan. 1976–Jan. 1979 (palms planted before 1950)	3.75	1.42	10.73	15.90

$\hat{B}_6 = (29 + 25 + 14 + 11 + 23 + 7 + 27 + 25 + 44 + 39 + 23 + 28)/12 = 24.58$,

$\hat{n}_6 = 5.76$, and $\hat{n}_6/2 = 2.88$ yr (see first figure of second to last line in Table 2).

RESULTS

Table 1 gives changes in the disease status of the palms of the Ligao plantation during the observation period. With these data, the durations of the early, medium, and late stages were estimated using either two consecutive readings (of the young palms) or all seven consecutive readings (Table 2). The data were considered insufficient to estimate the durations in the old palms with two consecutive readings only.

Twenty-seven young palms were in the early stage of the disease in January 1976 but in the medium stage in July 1976 (Table 1). All but five of these changed to the late stage before July 1979. By assuming that these palms would also change to the late stage before July 1980, it was possible to obtain a direct estimate of the average duration of the medium stage, which was 1.89 ± 1.33 (SD, N = 27) yr.

Only one palm (planted about 1969) went through all disease stages during the observation period. It was recorded as healthy in January 1976; showed symptoms of the early stage of cadang-cadang disease in July 1976, the medium stage in January 1977, and the late stage in July 1977; and died in March 1979. The total duration of the disease was about 3 yr.

DISCUSSION

Our studies and casual observations suggest that the duration of the cadang-cadang disease can vary considerably among palms, and some palms seem to die much more slowly than the average. If the duration of the disease is estimated with the described method, these slowly dying palms would influence the estimates only a little, but they would make considerable difference if averages of direct measurements were available. The estimates of the duration of cadang-cadang disease given in Table 2 may therefore be conservative.

The accuracy of the estimates further depends on whether the rate of new infections was constant. With a constant rate of infection, a similar number of palms would be expected to change from one disease status to another in each 6-mo period. However, Table 1 shows that many more young palms changed from the early to the medium stage (an average of 31 every 6 mo) than from the late stage to dead (an average of 7 every 6 mo). The numbers of palms changing from healthy to the early stage and from the medium to the late stage were intermediate. Apparently the rate of new infections was very low in the beginning, then increased, and later decreased again.

These changes also resulted in a decrease in the number of early stages during the observation period and an increase in the number of medium and late stages. These variations made it impracticable to estimate the total duration of the disease with the described method. The total number of diseased palms would have been too large in comparison to the number of palms changing from healthy to the early stage or from the late stage to dead. On the other hand, separate estimates for the durations of the early, medium, and late stages can be considered more accurate because the changes in the infection rate seem to be rather slow, spreading over several years. For instance, a good estimate was obtained for the duration of the medium stage (1.82 yr), which is very close to the directly measured duration (1.89 yr). The sum of the durations of the early, medium, and late stages (7.5 yr) is therefore considered to be the best estimate for the total duration of the disease in the young palms.

The accuracy of the estimates of the duration of the disease in older palms was similarly affected by changes in the infection rate. The accuracy was further reduced by the low number of palms available and by the fact that no new infections were recorded after January 1977.

ACKNOWLEDGMENTS

We wish to thank W. S. Imperial, F. Otilano, and D. Quinalayo for their assistance.

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