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EXTENT OF BUSH DAMAGE AND RESULTANT YIELD LOSSES OF A TEA CLONE, SUSCEPTIBLE TO STEM BLIGHT, CAUSED BY *Nemania Diffusa*

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Hypoxylon stem blight, caused by fungus *Nemania diffusa* is capable of inflicting heavy losses in certain clones grown in tea gardens located above 1500 m elevation. At the age of around 25 years, a susceptible clone, under natural field conditions could reach a disease intensity of >60% in more than 50% of its stand. Disease intensities from 60-90% and >90%, could inflict significant yield reductions amounting to 24% and 34% respectively.

Key words: Tea (*Camellia sinensis*); Stem blight; *Nemania diffusa*; *Hypoxylon vestitum*; yield

INTRODUCTION

Hypoxylon stem blight, has emerged as a disease in Sri Lanka somewhat recently (Arulpragasam and Balasuriya, 1991). It was found to occur quite extensively, in the Nuwara Eliya and Dimbula Districts, confined to a few tea clones. It is now confirmed that this disease is caused by *Nemania diffusa* (Sawerby) Y.-M. Ju & J.D.Rogers, (Syn. *Hypoxln vestitum*) (Ju, 1997). Petch (1924) described *H. vestitum*, for the first time in Sri Lanka, having obtained it from a tea branch from Diyanillakelle Estate.

Several species of *Hypoxylon* have been reported either as associated organisms or as those inflicting heavy casualties in other tea growing regions. The earliest reports of such associations were from Sri Lanka (then Ceylon) (Petch, 1906; 1924). India identified such associations to be diseases in certain tea districts as early as 1935 (Anon., 1935). Subsequently to this, several workers studied these associations in more detail (Sarmah, 1960; Venkata Ram, 1962; Agnihothrudu, 1965). It was much later, that Kenya reported a similar disease situation (Laycock, 1978; Onsando, 1985). Malawi and Zimbabwe too identified this as a disease in 1988 (Rattan, 1988). Ju and Rogers (1996), who did an exhaustive coverage of all the

Hypoxylon spp., described a range of them having the ability to occupy the positions of weak to damaging pathogens.

Venkata Ram (1962), has estimated a yield reduction in the range of 20-32%, as a result of infections by *H. serpens* in tea in India. According to the estimates of Anderson (1964), *H. mammatum* caused about 1 to 2% death of standing aspen (*P. tremuloides*) annually. Marty (1972) described *H. mammatum* as an important pathogen, which is typically, associated with dead branch stubs of aspen, causing annual losses worth several million dollars in the United States.

MATERIALS AND METHODS

A naturally infected field in Diyagama West Estate, planted in 1970, consisting of 5 ha, of the clone K145 (highly susceptible to *Hypoxylon* stem blight) in one contiguous block was selected for this study. The bushes were approximately 26 years old, after five pruning cycles and in the fourth year of the current cycle. The elevation of the field was 1524 m. The general infection level at this stage was almost 85%.

Sixty individual bushes were selected at random. In each bush, the disease intensity was visually scored on a scale of 0-8. A rating of 0 was given for unaffected bushes and a score of 8 represented very heavy infection. This method was selected because of its wide acceptance (James, 1974). The following key gives a description and the associated damage as a percentile in respect of each rating.

1.	0	-	Apparently healthy, no visual infection
2.	<10	-	Very light infections on one or two main branches
3.	10 - 30	-	Light infections on two or three main branches
4.	30 - 50	-	Heavy infections on two or three main branches
5.	50 - 70	-	as above plus part of the collar
6.	70 - 80	-	as (5) above plus one or two broken snags
7.	80 - 90	-	as (5) above plus two or three broken snags
8.	90 - 100	-	infection in the entire collar plus few broken snags

The examination of individual sixty bushes was done very carefully at close range with a repeat performance in order to establish the disease intensities clearly. The task was performed by three individuals separately, using above scale. The vigour of bushes was thus determined based on occurrence of healthy, infected and dead primary branches due to disease. Individual bushes were numbered and flagged. They were then harvested separately, at weekly intervals over a period of eight weeks, in order to include all probable growing points in a given bush (Das, 1981; Smith *et al.*, 1990). At the time of harvest, two persons stood by each bush, isolating it from the rest, while the plucker harvested all the standard shoots (bud and two or three leaves). The shoots of individual bushes were counted separately, oven dried overnight, at 85°C and dry weights recorded.

The first computation of data followed the initial eight classes of the disease. The total shoot counts and shoot dry weights of individual bushes cumulated over 6, 7 and 8 weeks were averaged into each class of the disease. In the middle range of intensities of the disease, a broader percentage was allowed due to two reasons. Firstly, a narrow group would have included fewer numbers of affected bushes and secondly, it was often difficult to distinguish with certainty, between two adjacent disease classes. In the second computation, the range of disease intensity classes, were made wider, thus narrowing down the number only to five which was used in assessing the overall vigour of bushes. However, in the computation of total yields, since there was an apparent increase from 0 to the first disease level (<30%), it was decided to pool them together thus ending up having only four disease classes, i.e. 0-30, 30-60, 60-90 and >90%.

RESULTS

Disease intensity and bush vigour

The healthy bush (apparently) category had only 9 bushes, compared to slightly higher numbers in the other classes (12-15). However, this recorded a very good relationship on the number of live (healthy) main-frame-branches and the disease level. Healthy bushes accounted for the highest number of total branches at 7, which gradually decreased, to reach a minimum of 3, at >90%, disease intensity. Similarly, the highest number of diseased and dead branches (shown as snags) were found to be 5 at the highest level of the disease (Table 1).

Table 1: Number of healthy and dead main-frame-branches, for a given bush in a range of disease intensities

Disease level (%)	No. of Bushes	Live branches/ bush	Dead branches/ bush
Healthy	9	7	0
<30	12	6	1
30-60	12	5	2
60-90	15	4	3
>90	12	3	5

Disease intensity and bush yield

Apparently healthy bushes did not average the highest shoot count or shoot dry weight at any of the intervals considered. They were trailing marginally behind the next class of the disease (<10%). A disease intensity of <10%, always recorded the highest values for both these parameters. But as the disease intensity was progressively increasing the yield parameters started to decline steadily. The lowest values were associated with the highest intensity of disease (Table 2).

Table 2: Cumulated yield data of individual bushes at 6,7 and 8 weeks, as affected by the disease at a range of different intensities

	At 6 weeks		At 7 weeks		At 8 weeks	
Disease level (%)	No. of shoots	Shoot wt. (g)	No. of shoots	Shoot wt. (g)	No. of shoots	Shoot wt. (g)
Healthy	196	29.4	216	31.4	256	35.1
<10	206	32.2	224	33.9	260	36.9
10-30	195	27.4	221	30.2	266	34.1
30-50	190	26.8	217	29.9	253	33.2
50-70	192	26.1	214	28.6	248	31.6
70-80	189	24.6	222	27.9	264	31.3
80-90	165	23.1	186	25.3	216	28.1
90<	150	21.1	171	23.6	202	26.3

When the initial eight intensity classes were merged into four broader ones, a definite trend emerged. In the new grouping, the lowest intensity class (<30%) giving the highest yield and the highest intensity class of disease yielding the lowest. Even the intermediate classes followed a steady drop, step-wise (Table 3). In the least affected category, during a period of six weeks, a bush was putting out 200 shoots at 30.1 g (dry wt.) per bush, which gradually decreased with increasing disease intensity, to end up yielding 150 shoots at 21.1 g per bush at >90%. Corresponding values at the end of seven weeks were 220 shoots at 32.1 g and 171 shoots at 23.6 g and at the end of eight weeks 260 shoots at 35.6 g and 202 shoots at 26.3 g per bush respectively.

Table 3: Cumulated yield data of individual bushes at 6,7 and 8 weeks, at disease intensities, rearranged into four discrete categories

	At 6 weeks		At 7 weeks		At 8 weeks	
Disease level (%)	No. of shoots	Shoot wt. (g)	No. of shoots	shoot wt. (g)	No. of shoots	Shoot wt. (g)
<30	200±28.5	30.06±5.3	220±29.0	32.13±5.1	260±31.0	35.56±5.1
30-60	191±23.6	27.30±4.0	216±23.9	29.92±3.9	251±24.2	33.23±3.8
60-90	181±13.3	24.09±1.7	209±14.3	27.03±1.7	246±17.0	31.28±1.9
>90	150±24.3	21.12±3.4	171±24.4	23.63±3.3	202±25.0	26.28±3.3

A linear regression analysis of data in Table 3, gave very high correlation coefficients between disease levels and the average yield of the bushes. This was true for both parameters at all three intervals (Table 4). However, the coefficients for shoot dry weights were always superior. This analysis using cumulative yields at 6 weeks, produced the best values, with shoot dry weight showing a correlation coefficient of 0.996, which was significant at <1% probability (Figure 1). Even by the end of seven and eight weeks these coefficients were still significant at P<5%. But there was a gradual decline in the level of significance and the 'r' values, after each additional week up to eight. Based on this, for the best estimate of yields it was decided to use the cumulative shoot dry weight at six weeks as the best guide, which apparently represents one shoot replacement cycle (SRC) in this particular situation.

Table 4: Regression analysis of the disease severity class on shoot number/bush and the cumulative shoot weight/bush respectively

	At 6 weeks		At 7 weeks		At 8 weeks	
	No. of shoots	Shoot wt. (g)	No. of shoots	Shoot wt. (g)	No. of shoots	Shoot wt. (g)
r^2 =	0.835	0.992	0.696	0.966	0.716	0.958
P =	<10%	<1%	<20%	<5%	<20%	<5%

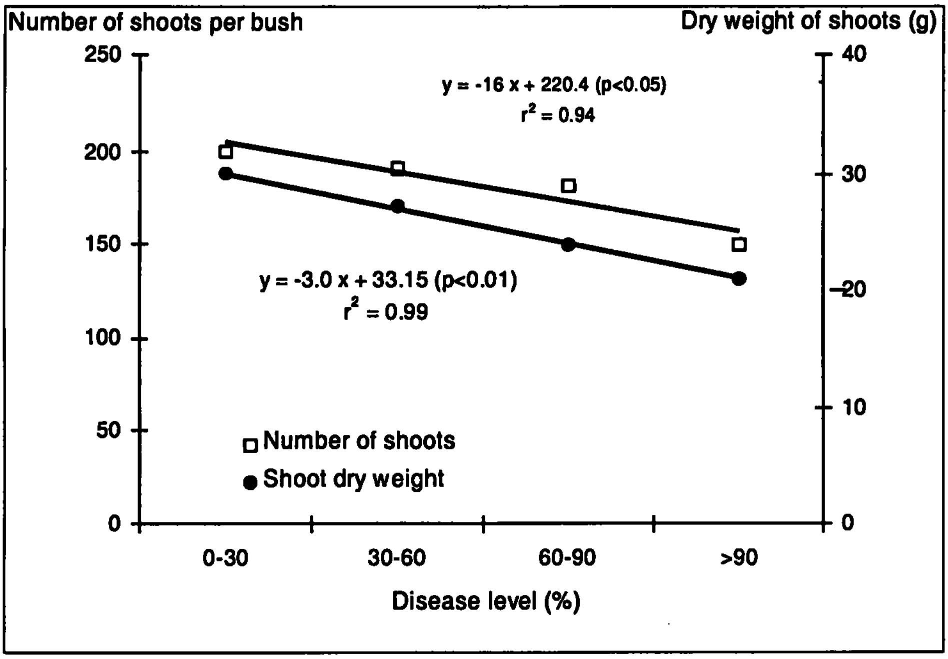

Figure 1. *Regression of the disease intensity on the number of shoots and their dry-weights, harvested from a single bush.*

Crop loss estimates

Individually recorded bush yields, cumulated over six weeks were averaged under each broad category (four) of disease. The annual yields were estimated for each intensity class of the disease as follows;

$$Y = X \times 12500 \times \frac{52}{6} \times \frac{1}{1000}$$

where; Y = yield of made tea kg ha^{-1} yr^{-1}
X = cumulative shoot dry weight for 6 weeks (g)
12500 = number of bushes per hectare at a spacing of 120 x 60 cm
52 = weeks for the year

Accordingly, when the disease level was <30% it was capable of yielding 3,261 kg of made tea ha^{-1} yr^{-1}. This could come down to 2,288 kg of made tea ha^{-1} yr^{-1} when the disease was >90%. Therefore, the weighted annual average yield of made tea from the same field, worked out to be 2,837 kg. From the estate records, three-year-average (1994 - 1996) of the actual yield for this field was found to be a very close, 2,839 kg (Table 5).

Table 5: Yield estimates of the susceptible clone K145, under four major categories of disease

Disease level (%)	As a proportion of the total	Cumulative shoot weight at 6 weeks (g)	Estimated yield ha^{-1} yr^{-1} (kg made tea)
<30	35%	30.1	3261
30-60	20%	27.0	2925
60-90	25%	24.1	2611
90<	20%	21.1	2288
Weighted average yield of the field (estimated)			**2837**
Actual average yield of same field .... (estate records, averaged over 1994, '95 and '96)			**2839**

Estimated yields at each level of the disease were compared, to establish the potential yield reduction with the progress of the disease to the next category above (Table 6). For this comparison, the least category of the disease was taken as the base, as this entire field was infected. This led to a 10% reduction in yield with the progress of the disease to the next category. The highest category yielded significantly lower than the least affected one.

Table 6: Estimated yield reductions in clone K145 in the field, due to infection by *N. diffusa*, at different intensities, as compared with the least affected category (<30%)

Disease level (%)	Estimated yield (kg ha^{-1} yr^{-1})	Yield as a % of least affected	Probability P=*
<30	3261	100%	-
30-60	2925	90%	ns
60-90	2611	80%	ns
>90	2288	70%	5%

*Using, Behrens-Fisher Distribution

From the regression equation above (Figure 1) a similar bush, totally free of the disease could be expected to produce about 213 plucking points at 32 g (dry wt.) of yield. Using this formula, an estimated yield of 3453 kg could be obtained for a similar field, when it is completely free of the disease. Using this as the base, respective yields under different disease categories were compared to work out the maximum possible yield reductions due to the disease (Table 7).

Table 7: Estimated yield reductions in clone K145 in the field, due to infection by *N. diffusa* at different intensities, as compared with zero disease situation

Disease level (%)	Estimated yield (kg ha^{-1} yr^{-1})	Yield as % of unaffected	Probability P=*
Healthy	3453	100	-
<30	3261	94	ns
30-60	2925	85	ns
60-90	2611	76	5%
>90	2288	66	5%

* Using, Behrens-Fisher Distribution

In this analysis, there appeared to be a drop in yield of 6% when the totally healthy bushes reach the infection up to the first level (<30%). The next two, intensity classes recorded additional 9% drop in yield with the disease progressing into the next higher category. And the highest (last) intensity class (90%<) indicated a further loss in yield by another 10%. Both intensity classes of the disease at 60-90% and >90% were capable of inflicting significant (P<5%) yield reductions of the magnitude of 24% and 34% respectively (Table 7).

DISCUSSION

Disease intensity and bush vigour

One way of assessing bush vigour is looking at its intact main-frame-branches, which are healthy. The justification for the isolation of a healthy (apparently, because there are no external symptoms) category from the least affected class (<30%) is because, there is an assurance that any possible, yet unseen infections could not have any effect on the number of main frame branches. Accordingly, this provides evidence that in a healthy bush of tea clone K145, around 26 years, there could be 7-8 main-frame-branches, when it is free from *Hypoxylon* stem blightdisease. At >90% disease intensity it could have up to five infected and/ or dead branches per bush. These numbers in return will have a direct bearing on the final yield of an affected bush.

Disease intensity and bush yield

In the first categorisation (Table 2), taking into consideration the relative slow pathogenicity performance of the disease and the narrow ranges employed, it is not surprising that the yields (both shoot count and shoot dry weight) did not always follow disease intensity classes exactly. A rare possibility is that certain diseases, as described by Gäumann (1950), have the ability to stimulate increased dry matter production in response to a fresh attack of a disease. Nevertheless, a general declining trend in the yield parameters was seen immediately after this disease intensity class with a steady progression.

The second categorisation (Table 3), which combined adjacent disease classes, helped establishing distinct relationships between the intensity of disease and yield. This relationship was at its maximum at 6 weeks (Table 4) for both yield parameters. Das (1981), working with 15, Tocklai VP clones demonstrated that the duration of flushing among the clones ranged from 23-37 days and a complete growth cycle lasted 44-66 days. Similarly, Smith *et al.* (1990), working on seven Malawian clones established that the shoot elongation reached a maximum at 42 days, whereas the point of inflexion for dry weight of shoots was between 56-70 days. Therefore, with the kind of correlation coefficient ($r=0.964$) and at the level of significance ($P<0.1\%$), it will be reasonable to assume that the tea clone, K145 completes one growing cycle (SRC) in about 6 weeks. In view of this it was decided to use the cumulative yield data obtained at 6 weeks, as the basis for crop loss estimates due to this disease in this clone.

Crop loss estimates

Considering the present disease situation of the field, a significant reduction in yield of the magnitude of 34%, could be expected only when it reaches >90% intensity. Apparently, this is only when the grower sees the real physical damage with main branches collapsing in the field at regular intervals. Therefore, from the productivity point of view of a given field, it would be safer to propose replanting them with a resistant clone when more than 50% of the population is infected at >90%.

However, if these losses are compared with a no-disease situation, the threshold disease intensity at which a significant loss could be expected is in the range of 60-90%. Then, one should think of replanting such fields with a resistant clone, when more than 50% of the population has reached 60-90% intensity (with 3 or more, dead main frame branches). Venkata Ram (1974; 1976) reported crop losses due to *H. serpens* in South India to range from 20-32%. Therefore, this enables reviving this crop loss range due to *Hypoxylon* stem blight, to be in the order of 24 to 34%. Once the infection has taken place in a favourable location and when it is left unattended, it is bound to increase steadily, with time. This process may appear to be slow. Unless very stringent and timely measures are taken, this disease will certainly reach a stage where it can cause significant reductions in yield quite prematurely. When the magnitude of yield losses are assessable this way, the application of appropriate remedial measures could be justified for higher profitability and better hygiene of tea fields in the up country tea districts.

CONCLUSIONS

At about 25 years of age, a fair percentage (20%) of a susceptible clone (K 145) of tea clone could reach a disease intensity in excess of 90%, while another 20-25% of the stand could reach an intensity of 60-90%, due to *N.diffusa*.

Around this time, a totally healthy bush of this susceptible clone (K145) would have 7-8 intact, main-frame branches. When the disease reaches an intensity of 60-90%, this will be reduced to 4-5 and upon reaching an intensity of >90%, this will be further reduced to 2-3 main-frame branches.

With the reducing number of main-frame-branches, at 60-90% disease intensity, a susceptible clone will have lost 24% of its potential yield. Upon reaching >90% disease severity, this potential will be lowered by further 10% to reach a total loss of 34% in yield.

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