*RESISTANCE OF TEA CLONES TO THE ROOT-LESION EELWORM, *PRATYLENCHUS LOOSI*

A. Kerr & M. K. Vythilingam

Sixty-eight clones have been tested for resistance to the root lesion eelworm, *Pratylenchus loosi*, and have been classified as susceptible, slightly resistant, moderately resistant or highly resistant. From field observations, other clones have been *tentatively* classified similarly. Growth of a clone in eelworm infested soil is dependent on the innate vigour of the clone, its resistance to eelworm and on the soil conditions in which it is growing. Tolerance of infection does not appear to be an important factor.

Introduction

The root lesion eelworm was first described in 1939 (Gadd 1939) when damage was confined to mature tea and to relatively few estates. With the start of the replanting scheme, in which unproductive tea was uprooted and the area replanted with potentially high-yielding clonal tea, the problem of eelworm damage became more serious and widespread on up-country estates, particularly in Dimbula, Dickoya and Hewaheta. There are three main reasons for this : first, young plants are much more liable to damage by *Pratylenchus loosi* than are mature bushes ; secondly, the most widely planted clone in these areas is TRI 2024, a clone now known to be very susceptible to *P.loosi* and finally the transporting of rooted cuttings from one estate to another, a practice still common although prohibited by law, has spread the pathogen to previously uninfested areas. Numerous failures of new clearings due to *P.loosi* infestation have been reported.

Since 1939, clones have been selected and tested for resistance to eelworm by the TRI and progress was briefly reported by Hutchinson (1964). This paper gives a more detailed account of work since 1962.

Methods of testing

Before 1962, clones were tested either by growing them in an infested field or in infested soil in pots in the nursery. Neither of these methods was entirely satisfactory : in the field, considerable soil variation occurs from place to place and unless tests are statistically designed with adequate replication, it is impossible to draw valid conclusions. There is also the possibility that virulence of eelworms may vary from estate to estate, and it may be dangerous to conclude that results from one estate can be applied to another. Pot experiments also have several disadvantages ; although soil variation can be virtually eliminated, uniform drainage in all pots is sometimes difficult to achieve ; plant roots may become pot-bound, soil temperature variation is much greater than in field soil and in general, growing conditions are unnatural. Most of these disadvantages were obviated in the nursery tests designed by Hutchinson (1962a) and described below.

Four rectangular blocks, 35 ft by 5 ft were marked out and surrounded by concrete bricks to restrict movement of eelworms between the blocks and the surrounding soil. Infested soil from 25 estates was brought to the TRI, thoroughly mixed and added to the four blocks which were then divided in half by asbestos sheets, four feet deep. Half of each block was fumigated with DD at the rate of

* Advance information on research projects

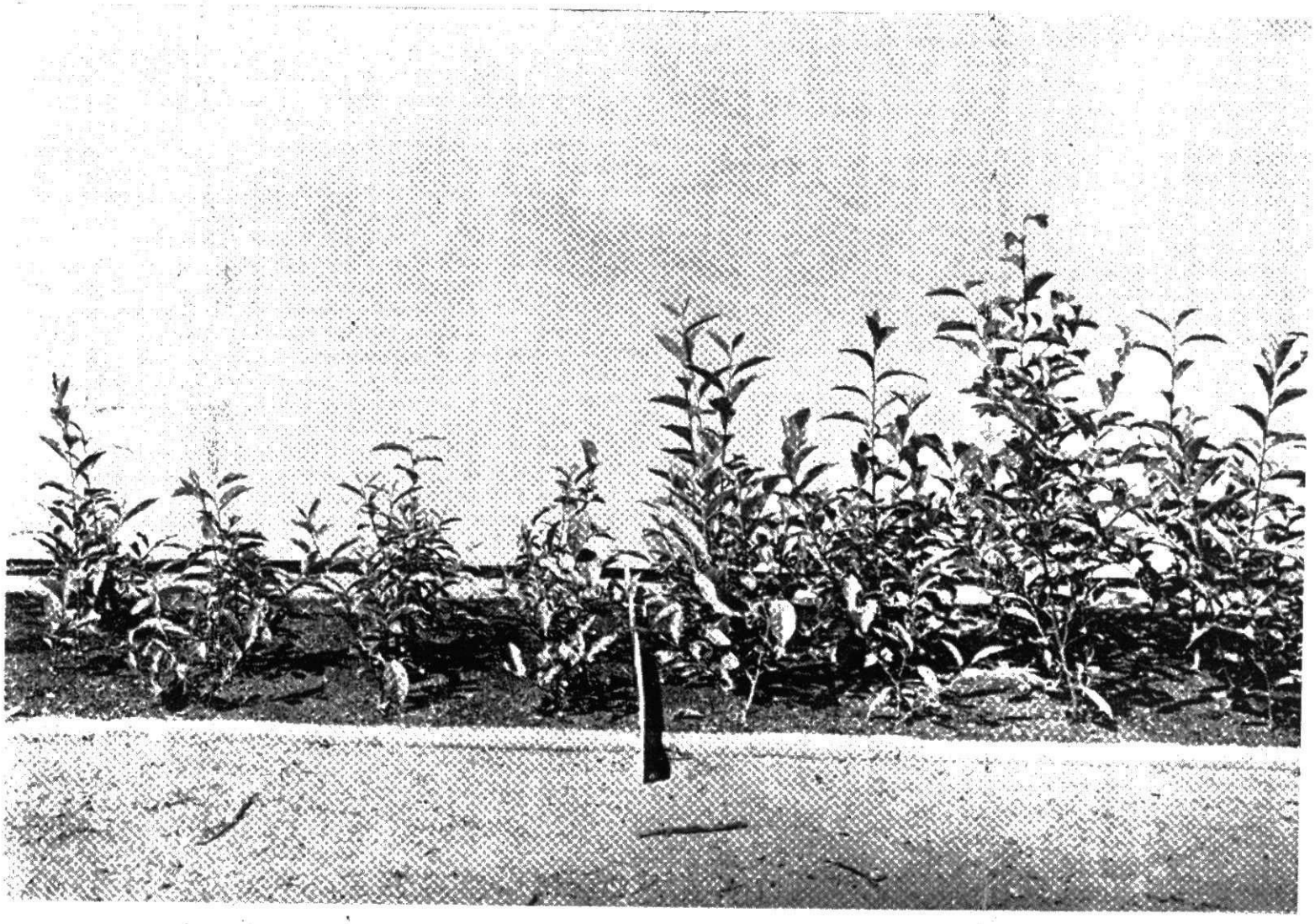

FIGURE 1 — *Tea clones growing in infested (left) and fumigated (right) soil*

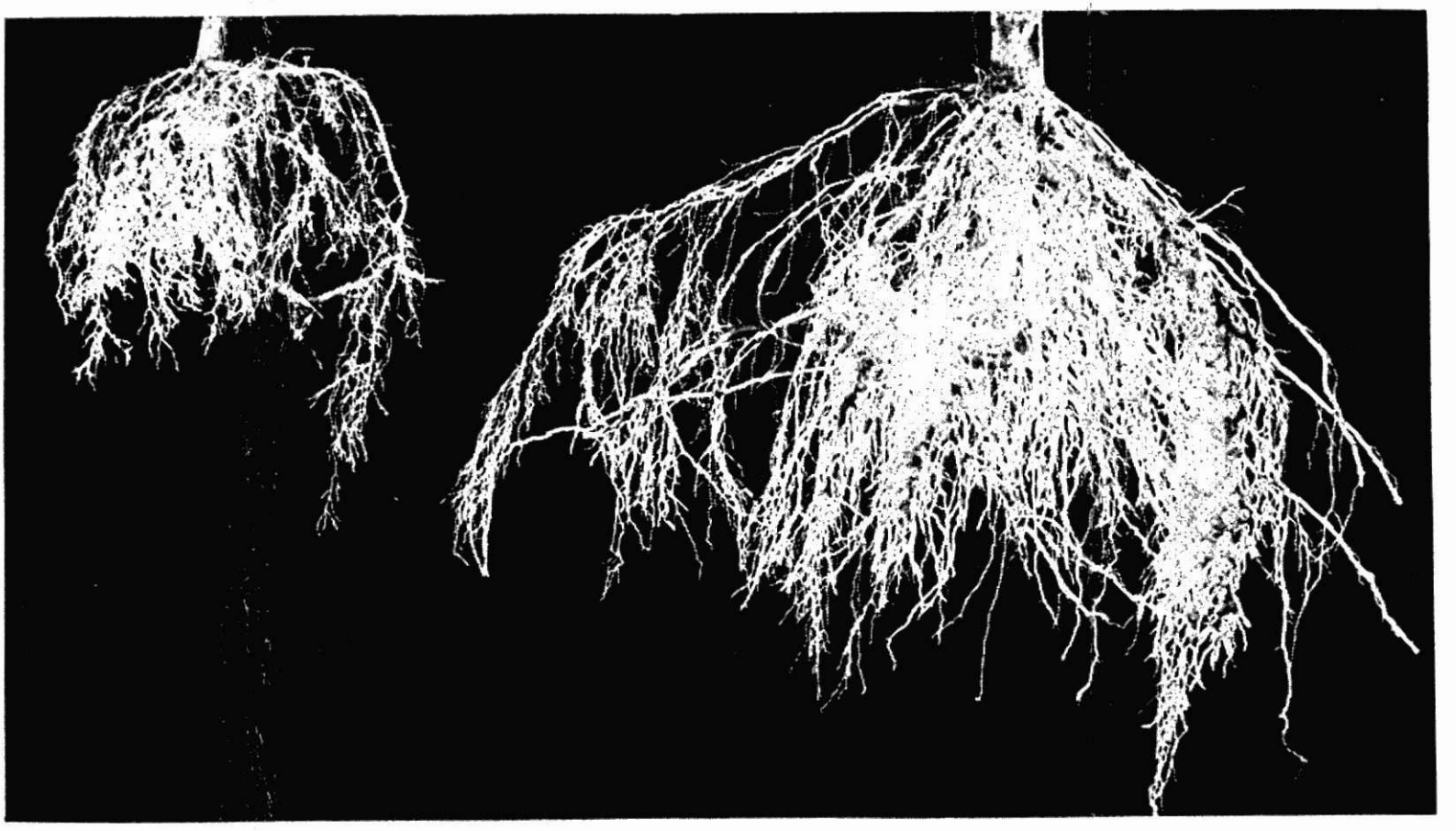

FIGURE 2 — *Roots of clone MO 20 from infested (left) and fumigated (right) soil*

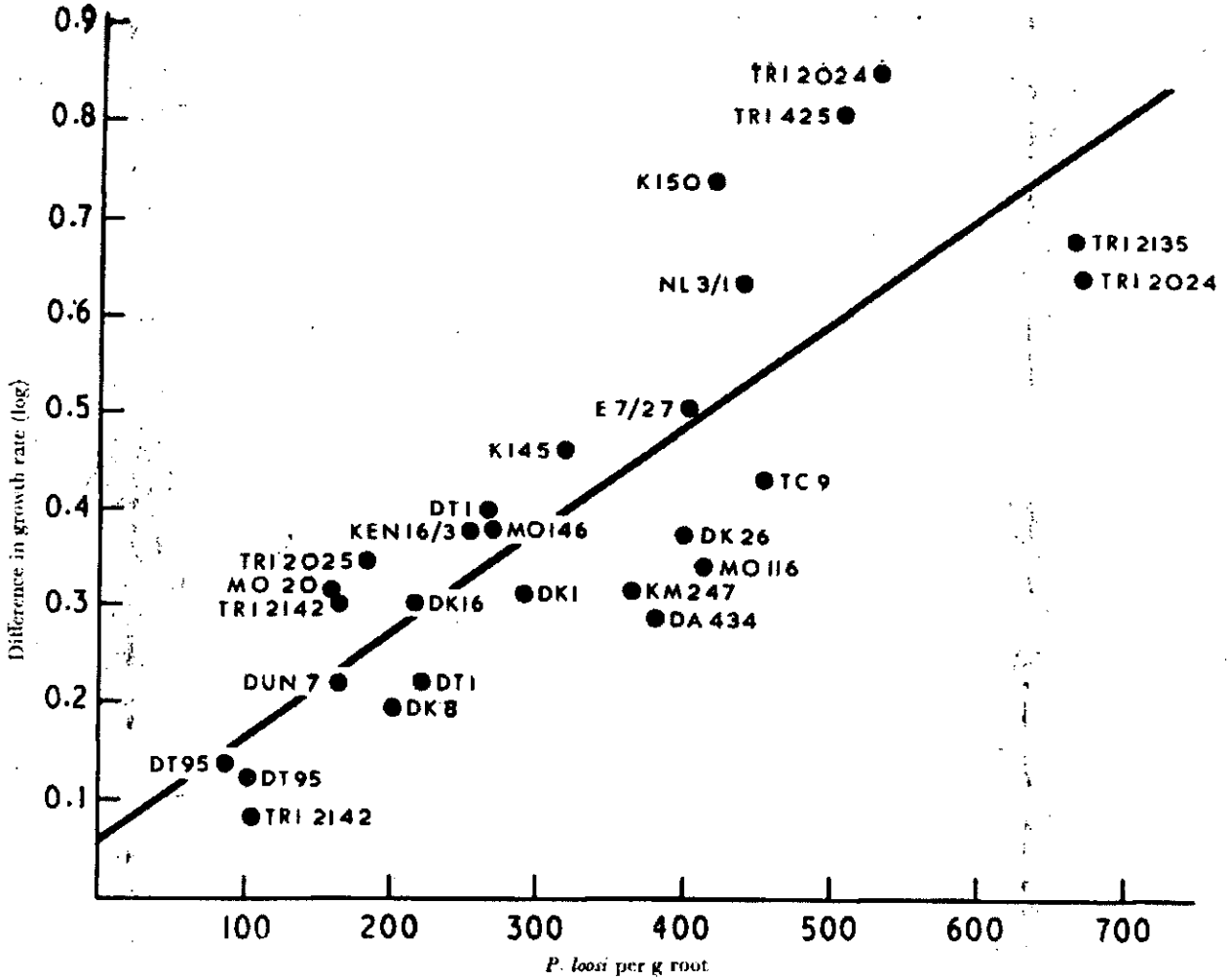

FIGURE 3—*Relationship between difference in growth rate of clones in fumigated and in infested soil, and level of infection*

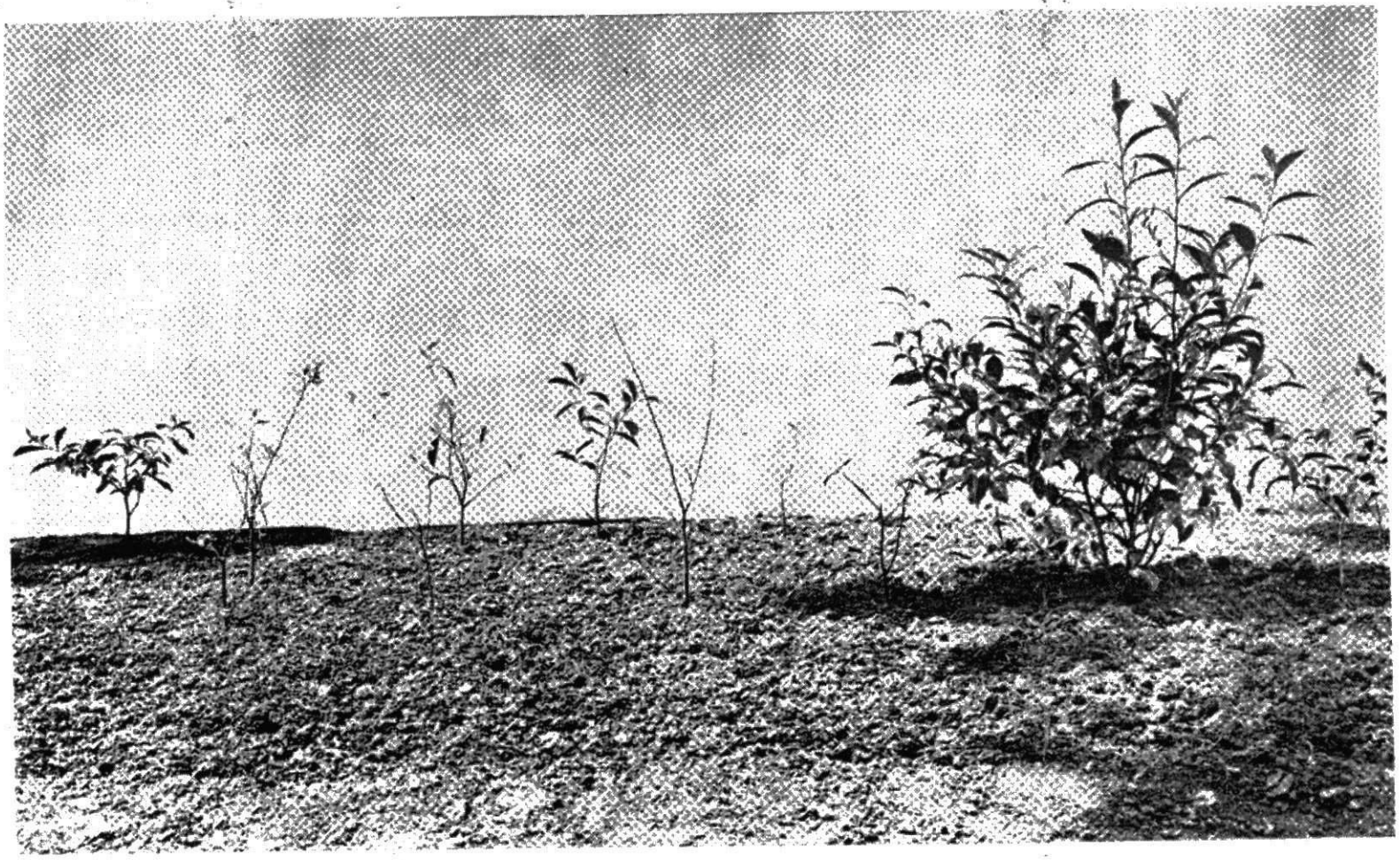

FIGURE 4—*Seedlings of TRI 2024, two years after inoculation with* P.loosi—*One plant apparently resistant*

48 Imperial gallons per acre. Twelve clones, including two standard clones, DT 95 (resistant) and TRI 2024 (susceptible), were planted approximately 4 weeks later in both fumigated and infested soil. In each block there were three replicates of every clone growing in infested soil and three in fumigated soil. The planting distance was 15 in by 12 in and a row of guard plants surrounded the test clones. In 1963 the size of blocks was increased to 50 ft by 6 ft and this enabled 16 clones, replicated four times in each half block, to be tested. In 1965, it was decided that a comparison of the growth of clones in infested and fumigated soil was not necessary (see page) ; the soil fumigated in the previous years, was removed and replaced with infested soil from several estates. This enabled two concurrent trials to be run, with 16 clones tested in each experiment.

All experiments continued for approximately 12 months, when fresh weight of roots and shoots was measured, and the level of infection in the roots determined by the method described by Hutchinson (1962b). Growth of clones in infested and fumigated soils is illustrated in Figure 1 and the corresponding root growth in Figure 2.

Classification of clones for resistance and susceptibility

Results of all tests are given in the Annual Reports of the TRI (Hutchinson 1963 ; Kerr 1965 ; 1966 ; Shanmuganathan 1967) but the data presented there may be difficult to translate directly into terms of practical planting. For this reason, we have classified the tested clones into four categories, *viz* susceptible, slightly resistant, moderately resistant and highly resistant (Tables 1-4). In the last two categories we have listed the clones in approximate order of resistance and also presented information on other clonal characteristics such as quality and yield potential.

TABLE 1—*Clones susceptible to* P.loosi—*These clones should not be planted in infested fields*

Origin	Clone No.	Origin	Clone No.
Carolina	CAR 2/18	Neluwa	NL 3/1
Carolina	CAR 7/10	Neluwa	NL 4/2
Chapelton	C 33	Neluwa	NL 8/3
Chapelton	C 38	Ouvakelle	OK 4
Craigie Lea	GL 6	Ouvakelle	VK 1
Coombewood	CW 21	St Coombs	TRI 425
Diyanilakelle	DK 14	St Coombs	TRI 777*
Diyanilakelle	DK 19	St Coombs	TRI 1446
Diyanilakelle	DK 26	St Coombs	TRI 2023*
Derryclare	DR 12	St Coombs	TRI 2024
Eskdale	ESK 95*	St Coombs	TRI 2026*
Gonamotawa	GMT 9	St Coombs	TRI 2027
Great Western	GW 19	St Coombs	TRI 2116
Harrow	H 5/1	St Coombs	TRI 2135
Kirkoswald	K 150	St Coombs	TRI 2151
Kotiyagalla	K 65*	St Leonards	SL 3/112*
Liddesdale	LD 502*	Tangakelle	WY*
Liddesdale	LD 999*	Waltrim	WT 26*
Mooloya	MO 57		

* Field observations only

TABLE 2—*Clones slightly resistant to* P.loosi—*These clones should only be planted in infested fields following rehabilitation, when soil conditions are ideal*

Origin	Clone No.	Origin	Clone No.
Dambatenne	DA 434	Mooloya	MO 114
Diyanilakelle	DK 16	Mooloya	MO 208
Diyanilakelle	DK 17	Mooloya	MO 209
Diyanilakelle	DK 48	Mooloya	MO 241
Diyanilakelle	DK 69	Tangakelle	E 7/27
Eildon Hall	EH 8/15	Tillicoultry	TC 9
Fernlands	F 4	Tillicoultry	TC 15/9
Kenilworth	KEN 15/7	Wootton	W 3
Kirimetiya	KM 247	Wootton	W 14
Mooloya	MO 20	St Coombs	TRI 2117
Mooloya	MO 110	St Coombs	TRI 2145

TABLE 3—*Clones moderately resistant to* P.loosi—*The clones are listed in approximate order of resistance, DUN 7 being the most resistant—(These clones are recommended for replanting infested fields following rehabilitation, and for supplying following soil fumigation)*

Origin	Clone No.	Quality	Field potential	Rooting ability	Blister Blight Resistance
Dunsinane	DUN 7	A 1/2‡	B	A	–
Nayabedde	NAY 3	A 2‡	A	A	A
Tangakelle	CY 9	C‡	B	A	B
Drayton	DT 1	A 1	B	A	C
Mooloya	MO 146	B‡	B	A	–
St Coombs	TRI 2025	B	A	A	B
Kirkoswald	K 145	C‡	B	A	B
Mooloya	MO 116	A 2‡	–	A	–
Diyagama West	N	B	B	A	C
Diyanilakelle	DK 1	B	B	A	C
Mooloya	MO 21	B	–	B	–
Kirkoswald	K 136	A 2‡	C	B	A
Kenilworth	KEN 16/3	A 2	A	A	A
Diyanilakelle	DK 8	A 2	B	A	–
Dambatenne	DA 1408	–	B	B	A
Uda Radella	UR 12	A 2‡	B	B	A

‡ = Provisional rating
A = Above average ;
B = Average ;
C = Below average ;
– = Not tested

TABLE 4—*Clones highly resistant to* P.loosi—*These clones are recommended for supplying infested fields and for replanting following rehabilitation*

Origin	Clone No.	Quality	Yield	Rooting	Blister Blight Resistance
Drayton	DT 95	A 2	B	A	–
St Coombs	TRI 2142	A 1	B	C	A
Norwood	N 2	A 1‡	B	A	–

‡ = Provisional rating
A = Above average
B = Average
C = Below average
– = Not tested

The allocation of clones to the four categories is somewhat subjective. Clones tested in more than one year did not necessarily perform in exactly the same way in different tests. For example, clones TRI 2142 and TRI 2025 performed much better in the 1962 test than in 1964 and even clone DT 95, the most resistant clone tested, did not grow well in one of the 1965 tests. Also, we considered it more helpful to Superintendents, if the categories indicated the likely performance of clones in infested soil, rather than the actual numbers of *P.loosi* within the roots. Using the latter criterion, we would have placed a clone like UR 12 in a much higher position, because it had a relatively low level in infection ; but it also grew relatively poorly in infested soil and we have placed it at the bottom of the moderately resistant clones. Our judgement has also been influenced by field observations on different estates.

Resistance or tolerance

Every year since 1962, some clones have performed significantly better than others in infested soil. This difference between clones could be due either to resistance or to tolerance. *Resistance* means that there is some factor or factors within the plants which restricts root infection, or the growth and development of *P.loosi* within the root. Resistance is not an absolute term, but a relative one. Thus we can have highly resistant, moderately resistant or slightly resistant clones, depending on how much infection or development of *P.loosi* is restricted. *Tolerance*, on the other hand, means that there is no factor restricting root infection or subsequent development of *P.loosi*, but that the resultant damage is relatively slight.

The data obtained from the first three experiments on resistance can be used to examine the relative importance of resistance and tolerance. In these tests, we obtained three sets of measurements : growth of each clone in fumigated soil (G_f), growth of each clone in infested soil (G_i) and the number of *P.loosi* in the roots of plants growing in infested soil (I). At the start of each test, plants in fumigated and infested soil were of the same size, but after 12 months, plants in infested soil were always smaller than those in fumigated soil. In other words, growth rate was reduced by the presence of *P.loosi*. The difference in growth rate of any clone in fumigated and in infested soil can be measured by $\log G_f - \log G_i$. If resistance is an important factor, we would expect the difference in growth rate to be closely correlated with the number of *P.loosi* per unit weight of roots (I). The calculated correlation coefficient is $r = 0.83$ and is very highly significant ($P < 0.001$). The reationship between difference in growth rate and level of infection is illustrated in Figure 3. A regression line has been drawn and it may be argued that clones placed below the regression line are tolerant, because the difference in growth rate is less than would be expected from the level of infection. This seems unlikely, however, because a clone tested twice, may appear below the regression line in one test, and above it in the other, *eg* clones DT 1, TRI 2142, and TRI 2024. In our opinion, tolerance is not a very important factor.

The slope of the regression line was calculated to be 0.001. So the relationship between reduction in growth rate and number of eelworms in the roots can be represented by the equation,

$$\log G_f - \log G_i = 0.001 \quad I \qquad (1)$$

It can be seen from this equation, that if we can measure two of the three variable factors, we can calculate the value of the third factor. For example, if we know the growth of a clone in infested soil (Gi) and the level of infection in infected soil (I), we can calculate the growth of the same clone in fumigated soil (Gf). So growing

plants in fumigated soil does not seem absolutely necessary and was dispensed with in 1965, allowing two trials to be run concurrently and enabling us to test twice the number of clones.

Growth in infested soil

The primary concern of a Superintendent is to know how well a particular clone will grow in a particular infested field. We can change Equation (1) to read

$$\log G_i = \log G_f - 0.001 \quad I. \qquad (2)$$

It is clear that to obtain a high value for G_i, the value of G_f should be high and the value of I, low. In non-technical terms, this means that growth of a clone in infested soil will be good, if it grows well in eelworm-free soil and if it is resistant to eelworm. Growth of a clone in eelworm-free soil will be dependent on the innate vigour of the clone and on the soil conditions in which it grows. **We can confidently say that good growth in infested new clearings will be obtained by planting a vigorous, resistant clone in fertile soil, although eventually yields will be less than those that would have been obtained if soil was nematode free.** Soil conditions are extremely important. If plants are grown in gravelly or poorly drained soil or nor given adequate fertilizer, the damage caused by eelworms may be much more serious. **We believe that Ceylon tea Estates have impoverished soils as a result of excessive weeding on steep slopes, leading to soil erosion, and we have wondered if perhaps the weed scraper is not a more serious pest than** *P.loosi*.

Discussion

It has already been shown (Kerr & Vythilingam 1966) that during the rehabilitation of eelworm infested land, numbers of *P.loosi* fall to a low level, but we know of no case where *P.loosi* has been eradicated from soil as a result of rehabilitation. We must assume that after replanting, numbers increase. Form this reason it is essential that only eelworm resistant clones are planted in infested soil, even after two years rehabilitation. Specific directions are given in Tables 1-4 on what clones to plant. If soil conditions are excellent, clones that are only slightly resistant can be grown successfully, but under normal or poor soil conditions, only those clones listed in Tables 3 and 4 should be considered. At present, there are 19 clones that have either moderate or high resistance and many of them have other desirable qualities such as good rooting, high yield and high quality. Each year, new clones will be tested, and in the not too distant future, there should be a very wide selection of resistant clones available to Superintendents for replanting or supplying eelworm infested areas.

Acknowledgements

We wish to thank Dr D. Kirtisinghe and Mr A. V. Richards for details of clonal quality, yield potential, *etc* presented in Tables 3 and 4. The work described in this paper could not have been performed without the full co-operation of all members of the Nematology Division, of the Tea Research Institute of Ceylon.

The research work was financed in part by USDA Grant FG-Ce-100.

References

GADD, C. H. (1939). A destructive root disease of tea caused by the nematode, *Anguillulina pratensis*. *Tea Quart.* **12** : 131-139.

HUTCHINSON, M. T. (1962a). Report of the Nematologist for 1961. *Rep. Tea Res. Inst. Ceylon* : 84-92.

HUTCHINSON, M. T. (1962b). Rehabilitating tea soils : I. Susceptibility of plants now in use to the root lesion nematode, *Pratylenchus loosi*. *Tea Quart.* **33** : 138-140.

HUTCHINSON, M. T. (1964). Further developments in the control of meadow nematode. *Tea Quart.* **35** : 90-95.

KERR, A. (1965). Report of the Adviser in Nematology for 1964. *Rep. Tea Res. Inst. Ceylon* **2** : 67-72.

KERR, A. (1966). Report of the Nematology Division. *Rep. Tea Res. Inst. Ceylon* 1965 **2** : 62-67.

KERR, A. & VYTHILINGAM, M. K. (1966). Replanting eelworm infested areas *Tea Quart.* **37** : 67-72.

SHANMUGANATHAN, N. (1967). Report of the Plant Pathology and Nematology Division. *Rep. Tea Res. Inst. Ceylon* 1966 **2** : To be published.

(*Accepted for publication—20th November 1966*)