RESEARCH ARTICLE

Level of technology adoption and factors associated with tea bush debilitation in smallholdings in three selected ranges in Matara district

K.J.G.P. Mahindapala[1*], C.E. Munasinghe[2], S.P.A.P.K. Jayaratna[1], H.B. Tharangika[2], B.G.A.R.L. Batheegama[1]

[1] *Tea Research Institute, Advisory and Extension Division, 70 000, Ratnapura, Sri Lanka*
[2] *Tea Research Institute, Regional Centre, 81 500, Deniyaya, Sri Lanka*

Submitted: September 30, 2019; Revised: December 8, 2019; Accepted: December 18, 2019
*Correspondence: prasanjithjm@gmail.com

ABSTRACT

Tea smallholding sector plays a significant role in the tea industry of Sri Lanka. Tea bush debilitation in tea smallholding sector has been reported as a critical problem in Matara district. This study attempted to examine the bush debilitation status, in the smallholding sector in the region and to identify the attributes. The primary data were collected using a structured questionnaire through face to face interviews, and field inspections and non-parametric statistical methods were adopted to analyse the data. Results showed that stress symptoms appeared in 82% of the holdings and caused a significant yield loss to the affected holdings. Results revealed that the adoption level of some of the critical Good Agricultural Practices (GAPs) was not at a satisfactory level and certain pest incidents were significantly (P<0.05) high in the affected bushes. Some land characteristics, inadequate crop management interventions together with some pest and diseases, are found to be collectively contributed to the problem.

Keywords: *Tea, bush debilitation, technology adoption, smallholding, Matara*

1. INTRODUCTION

Tea (*Camellia sinensis* (L.) kuntze) has been playing a significant role in the economy of Sri Lanka since the early 20th century to date. At present, the tea sector contributes to the 0.7% of the Gross Domestic Product (GDP) and 15% of the foreign exchange earnings of the country (Anon, 2017a). Tea industry mainly consists of three sectors, namely the corporate estate, medium scale estates and smallholdings occupying nearly 204,024 ha in the country (Anon, 2016). Tea lands below 4 ha in extent are defined as smallholding tea lands. The tea smallholding sector is considered as the most dynamic segment of the tea sector as it contributes over 60% of the national production and 59% of total tea extent of Sri Lanka (Anon, 2017a and 2017b). As per the statistics, nearly 400,000 tea smallholdings are found in Sri Lanka distributed mainly in 8 administrative districts (Anon, 2005). At present, tea productivity of smallholdings sector remains ~1995 kg ha^{-1} (Anon, 2017) which is considered as a low level of productivity when compared with some countries. Such low productivity of smallholdings sector possibly may be due to many factors such as land degradation, ageing of tea bushes, pest and disease damages and poor adoption of recommended agricultural measures (Mahaliyanarachchi and Sivayoganathan, 1996; Rajasinghe, 1999; Anon, 2008; Anon, 2008, Jayarathna, 2012).

Tea smallholdings profile of Matara district

Matara is considered as one of the major tea growing districts in the low country region of Sri Lanka. According to the statistic, nearly 69,000 tea smallholders are found in Matara district, which represent approximately 17% of the total smallholder population of the country (Anon, 2005). Matara district has been divided into 03 sub-regions by the Tea Small Holding Authority (TSHDA) namely Akuressa, Kotapola and Pasgoda, each of which is re-divided into several Tea Inspector Ranges (TIR). Accordingly, there are 20 TIR in the Matara district, and each range is monitored by a tea inspector.

Adoption of recommended agricultural practices by the tea smallholders

Agricultural recommendations and innovations have great potential to make an impact on production. However, the uptake of such technologies by smallholders seems to be relatively weak. Mahaliyanarachchi and Sivayoganathan (1996) found out that only 32.5% of Low Country tea smallholders had a satisfactory knowledge on fertilizer usage and only 13.25% had a fair knowledge on pest management. Surveying tea smallholders in Matara district, Samaraweera *et al.* (2013) found that only 20% had good knowledge about overall tea cultivation. Moreover, Ratnayaka *et al.* (2013) identified that the implementing of improper agronomic practices as a major cause for tea bush debilitation problem prevailing in Deniyaya region. Several studies have been carried out to find out the factors that affect the level of adoption of smallholding farmers. Adoption of agricultural innovations by smallholding farmers largely depends on their intrinsic factors such as knowledge, perceptions and attitudes (Meijer *et al.*, 2015) as well as community and social factors (Hornik, 1988).

Tea bush debilitation problem in the tea smallholdings sector

Plant debilitation is a situation that deteriorates the usual health condition of the plant and fallen into a state where it cannot perform potentially. Considering the crop biology of tea, Sivapalan (1972) and Mohotti (2005) have identified few major above ground (i.e. stem and foliage) and below ground (i.e. root system) symptoms of a debilitated tea bush. Accordingly, formation of *bangi* buds, die-back, dwindling of new shoot development, loss of maintenance foliage and unusual production of flower buds could be identified as above-ground symptoms while loss of feeder roots is considered as major below ground symptom that can be occurred in a debilitated tea bush. According to the records, the history of bush debilitation in Deniyaya region was first reported in year 2000 (Anon, 2000). Since then, bush debilitation has been a crucial factor that affects the productivity of smallholdings in the region. Ratnayaka *et al.* (2013) have estimated that bush debilitation problem accounts for nearly 12% yield drop of smallholding tea lands in Deniyaya region.

In response to this problem, a few case studies have been conducted in some of the selected tea growing areas from time to time and have come up with some progressive outcomes (Mohotti, 2005; Ratnayaka *et al.*, 2013). However, after 2014, such kind of debilitation has been reported mainly in the TIR of Deniyaya, Kolawenigama and Beralapanathara, and therefore, need was arisen to conduct a unique systematic and more focused study covering whole the area being affected to identify the responsible causes with a view to manage the problem through the appropriate extension approaches. This study was therefore aimed at evaluating the level of technology adoption among tea smallholders and to examine the possible attributes of bush debilitation.

Objectives of the present study were to assess the level of technology adoption of tea smallholders in the selected regions and to identify the possible factors that contribute to the tea bush debilitation in the study area.

METHODOLOGY

Study area and sampling frame

Since the problem mainly reported from Deniyaya, Kolawenigama and Beralapanathara TIR, the same TIRs were purposely selected as the study areas. According to the TSHDA statistics, there are nearly 10,000 tea smallholdings in this region (Anon, 2005). Smallholdings, which are in the age range of 4 – 30 yr in this area, was considered as study population, and the list of tea smallholdings prepared for the distribution of fertiliser subsidy by the TSHDA, Matara, in the aforesaid TI ranges was selected as the sampling frame.

Sampling technique exclusion criteria and ethical considerations

Using the smallholding list of each range, a sample of 130 tea smallholders was selected based on the stratified and random sampling method allocating approximately 43 for each selected range. The sampling population comprised nearly 1.25% of the smallholder population in the range.

Initially, randomly selected 250 smallholders were interviewed over the phone to collect the basic data in order to see whether these respondents meet the pre-requisites for the study. These pre-requisites including the age of tea (4 – 30 yr old), accessibility, single-owner operated and non-abandoned. Finally, 170 tea smallholders who met all the pre-requisites mentioned in the above were selected from 4 – 9 and 10 – 30 age categories (fair proportion from each category) for data collection. Simultaneously, the smallholders below 18 yr and over 80 yr of age were excluded from the sample, assuming that they were not incapable of understanding the objectives of the study and properly responding to the questionnaires. In consideration of survey ethics, the people who were not in consent either to provide information or be interviewed were excluded from the sample. Following this process, 106 smallholders were finally selected for the study excluding 25 who failed to meet the basic criteria. Moreover, all the respondents willing to provide information and be interviewed were clearly made aware of the objectives of the study, before data collection.

Data collection instruments

A structured questionnaire was prepared as the data collection instrument, and both interview and field observation methods were employed to collect data in the study. The questionnaire was formulated based on the objectives of the study by the authors and perfected with the inputs given by research and extension staff of Tea Research Institute of Sri Lanka (TRI). The questionnaire mainly consisted of following components.

(a) Basic information about tea smallholders and their tea cultivation.
(b) Level of adopting GAPs by the smallholders.
(c) Problems encountered in tea bushes, particularly the symptoms of debilitation and visible damages to the bushes.

Agronomic practices and pest and disease severity were evaluated based on the guidelines stated in the TRI advisory circulars and observations were ranked using a Likert scale ranging from 0 – 5 i.e. 0 for no; 1 for very low; 2 for low; 3 for moderate; 4 for high and 5 for very high (Likert, 1932).

Data collection

A field survey was conducted in the selected tea inspector ranges from November to December 2018 (2 months period) to collect data. Each respondent was separately interviewed for about 30 – 45 min time period to collect the basic information (component i). After the interview, the tea land of each respondent was inspected in order to collect data on level of GAP adoption (component ii), and the problems appear in the bushes (component iii).

Data processing and analysis

Questionnaires were re-evaluated and the data were tabulated in Excel Worksheet and analysed using descriptive statistics, chi-square, correlation Mann-Whitney test and pooled t-test using SPSS and Minitab statistical analysis software.

RESULTS AND DISCUSSION

Soil and land conditions

As per the recommendations of TRI, soil physical properties such as soil depth, gravel content, slope and rockiness were estimated. Accordingly, 58.5% of lands were observed with less than 5% of rockiness, 27.4% lands had moderate rockiness (5 – 10%) and the rest 14% were found with high rockiness (over 10%). When considering the gravel content of the soil, nearly 81% of lands were observed as less or no gravels in the soil (i.e. 0 – 10% in top 50 cm) which is the most favourable condition for tea. Another 14% had a moderate level of gravels (10 – 50%) while the rest 5% was with higher gravel content (>50%) in soil. The ideal soil depth for tea (>90 cm depth) was found out in 85% of tea lands while it was observed moderate and unsatisfactory in 7 and 8% of holdings, respectively. When considering the slope, 24% of lands were found to be less than 25% of the slope while 67% of lands are within the moderate or acceptable range (25 – 70%) and rest (7% of lands) are having severe slop (>70%). Based on these data, the association between the soil condition of lands and the level of symptoms in tea bushes was evaluated using the Chi-square test. However, results show that the variability observed in the above soil physical properties have no significant impact on the debilitation symptoms except rockiness, where the positive association was detected with those two variables (Table 1).

Table 1: Association between soil conditions and intensity level of symptoms.

Soil condition	Chi-square value	p-value
Rockiness	4.965	0.084**
Gravel percentage	4.026	0.402
Steepness	5.643	0.343
Soil depth	0.525	0.769

** Significant at 90% level

Level of technology adoption

Adoption of GAPs by the respondents were also evaluated and illustrated in Table 2. Accordingly, Table 2 indicates that the technology adoption levels of farmers with respect to few GAPs are at a satisfactory level. Use of recommended cultivars (90.5%), use of a correct type of fertiliser (80%) and removal of mossing and ferns at pruning (89.5%) were satisfactorily adopted by the smallholders. Simultaneously, some other GAPs such as correct fertiliser dosage (52.4%) and sanitary pruning (56.2%) were observed to be moderately adopted. However, the adoption level of the majority of the GAPs was poor. These poorly adopted GAPs include basic practices such as soil rehabilitation (41%), deep forking (27%), testing of pH (30%) and advanced practices (20%) recommended in the post prune period.

Table 2: Level of technology adoption by the respondents.

GAP Item	Number Adopted (N=105)	Percentage (%)
Basic GAPs		
Deep forking during land preparation	28	26.7
Rehabilitation prior to replant	43	40.9
Use of at least moderate quality nursery	52	49.5
Use of recommended cultivars	95	90.5
Use of correct fertilizer mixture	84	80.0
Use of correct fertilizer dosage	55	52.4
Testing of soil for pH	31	29.5
Correct use of Dolomite	46	43.8
Mossing and removal of ferns	94	89.5
Proper harvesting interval	50	47.6
Advanced GAPs		
Correct period of resting	21	20.0
Burial pruning	08	7.6
Wound dressing on pruned cuts	01	0.9
Sanitary pruning	59	56.2

Presence of stress symptoms

The symptoms of bush debilitation clearly appeared in 86 smallholdings out of 106, which is nearly 82% of the sample and of which majority (45.3%) were at moderate severity (Table 3). When the distribution of symptoms within the land is concerned, 41% of smallholdings was observed with debilitation symptoms in 30 – 40% of the total land extent. Higher distribution (over 50%) of stress symptoms was observed only in 30% of the smallholdings. Rest of 29% of smallholdings was found with low spreading (10 – 30%) of stress symptoms within the land extent (Table 04). Major symptoms observed in tea bushes were flowering and setting of fruits, die-back, poor shoot generation, yellowing of leaves and formation of inactive buds (*Banjis*). Out of these symptoms, poor shoot generation, flowering, fruiting and die-back were the most prominent symptoms.

Table 3: Severity of bush debilitation symptoms appeared.

Category	Frequency (N= 86)	Percentage (%)
Very Low	02	2.3
Low	20	23.2
Moderate	39	45.3
High	23	26.7
Very High	02	2.3

Table 4: Distribution of bush debilitation symptoms.

Distribution	Frequency (N= 86)	Percentage (%)
< 10% of extent	07	8.1
10 – 30% of extent	18	20.9
30 – 40% of extent	35	40.7
50 – 70% of extent	21	24.4
> 70% of extent	5	5.8

Impact of intensity level of symptoms on yield of tea lands

The mean tea yields of affected (appearing of stress symptoms) and non-affected (not appearing of stress symptoms) tea holdings were compared using pooled t-test and test statics are shown in Table 5.

Table 5: Yield comparison of affected and non-affected tea.

	N	Mean yield (kg/acre/month)	Mean standard error	t	P value
Affected tea	20	251.8	19.5	2.384	0.024
Non affected tea	80	353.0	37.7		

This shows that the stress symptoms have impact on tea yield and tea yield has decreased by 28%. This estimation doubles the estimation made by Rathnayaka *et al.* (2013) and would have been due to the advancement of the problem over the five years.

Further, the average yield (green leaf/month/acre) of tea lands were categorised based on the intensity level of symptoms (Figure 1). As indicated in Figure 1, average yield was decreased with the progression of the severity the symptoms. The Spearman Correlation test was carried out to see the impact of intensity level of symptoms on average yield, and it was revealed that the correlation is significant at 0.001 level (correlation coefficient -0.344, p=0.001). It can therefore be concluded that the yield level has a negative correlation with the intensity of symptoms.

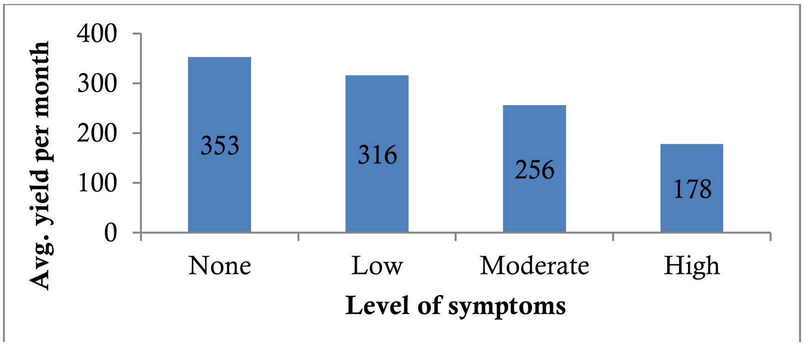

Figure 01: Change of average yield with the intensity level of symptoms.

The outcome of the above two test confirms that debilitation has a significant impact on tea yield.

Pest and disease status of tea bushes

Table 6 shows information related to pest and diseases in tea bushes.

Table 6: Presence of pest and diseases in tea bushes.

Pest/Disease	Presence in the bushes (N=86)	
	% in Healthy-looking bushes	% in Unhealthy bushes
SHB (Primary)	87.2	94.2
SHB (Secondary)	89.5	94.2
SHB (main)	46.5	76.7
LCLWT	15.1	22.1
ST	50.0	84.8
CC	66.3	82.5
BB	67.4	67.4
SBC	82.5	95.3
WR	53.5	94.2
HHB	32.5	33.7

Major pest and disease problems that usually prevalent in the low and mid elevations such as Shot Hole Borer (SHB), Low Country Live Wood Termite (LCLWT), Scavenging Termites (ST), Collar Canker (CC), Blister Blight (BB), Stem and Branch Canker (SBC), Wood Rot (WR) and Horse Hair Blight (HHB) were observed separately in healthy-looking tea bushes and debilitated tea bushes of the affected holdings and are illustrated in the Table 06.

Table 6 indicates that SHB, ST, CC, SBC and WR are the major pest and diseases in the particular smallholdings and their incident levels reported in unhealthy tea bushes (debilitated) were relatively higher than that of healthy tea bushes.

Impact of major pest and disease on bush debilitation

The severity level of the above pest and diseases (based on the measured Likert scale value), was statistically compared with the randomly selected healthy and unhealthy tea bushes using Mann-Whitney test to see their impact on bush debilitation and results were given in Table 7.

Table 7: Analysis of major pest and diseases on bush debilitation.

Pest/Disease damage	W	Median value		Mann-Whitney test significance level
		Healthy	Unhealthy	
SHB damage in primary branches	6090	2	3	0.000*
SHB damage in secondary branches	6113	2	3	0.000*
SHB damage in main stem	6055	1	3	0.000*
LCLWT damage	7249	1	1	0.1830
Scavenging termite damage	6346	1	3	0.000*
Stem & Branch canker damage	5998	2	3	0.000*
Wood rot damage	5753	1	3	0.000*

* - Significant at 0.05 confident interval

According to the results, SHB, SBC, ST and WR are significantly ($P<0.05$) affected on the formation of stress symptoms in tea bushes. Therefore, it is cleared that managing the above pests and diseases in smallholdings is essential to control the bush debilitation.

Impact of parasitic nematode on bush debilitation

Further, soils and roots samples obtained in the field have been tested in the laboratory for nematode, and plant-parasitic nematodes were detected in 19% of the samples and of which 85% was a very light level of infestation. However, the Chi-square test confirmed that there is no association between nematode incidents and presence of symptoms (Chi-square value 2.203, P =0.138). Even those holdings which have highly debilitated did not show a direct association with nematode incidence (Chi-square value 6.093, P=0.297). This situation is different from the results observed in the study conducted in Balangoda region (Rajasingh *et al.,* 2015) and Mathugama region (Mahindapala *et al*., 2019), and it would have been due to very light nematode counts. However, some studies revealed that even such, level of incident would also sufficient to make a serious consequence under the poor crop management scenario (Mohotti *et al*., 2017).

Association between adoption of gaps and debilitation symptoms

A chi-square test was performed to identify the possible associations between the adoption of GAPs and the incidents and intensity level of bush debilitation symptoms in tea lands. Results of this statistical analysis are given in Table 8 and 9.

Table 8: Association between GAPs and appearing of symptoms.

Association	Chi-square P value
Burying of pruning and the presence of symptoms	0.365
Removal of mosses and presence of symptoms	0.418
Wound dressing and presence of symptoms	0.888
Resting prior to prune and the presence of symptoms	0.084**
Fertilizer mixture and presence of symptoms	0.767
Planted cultivar and presence of symptoms	0.540
Quality of plants and presence of symptoms	0.637
Rehabilitation and presence of symptoms	0.446
Forking and presence of symptoms	0.591

** - Significant at 10% confident interval

Table 9: Relationship between GAPs and intensity of symptoms.

Association	Chi-square P value
Sanitary pruning and intensity level	0.07**
Burying of pruning and intensity level	0.425
Removal of mosses and intensity level	0.864
Wound dressing and intensity level	0.429
Use of Dolomite and intensity level	0.852
Fertiliser dosage and intensity level	0.504
Fertiliser mixture and intensity level	0.816
Planted cultivar and intensity level	0.353
Quality of plants and intensity level	0.564
Rehabilitation and intensity level	0.614
Forking and intensity level	0.717

* - Significant at 10% level

As per the results, it was revealed that resting prior to pruning has a significant association with the occurrence of bush debilitation symptoms. Resting helps plant to build up an adequate starch level in the roots, which assure the proper recovery after pruning. Moreover, the quality level of sanitary pruning too has a significant association with the intensity level of bush debilitation symptoms and which means that higher the quality of sanitary measures, less likely to occur the stress symptoms.

CONCLUSIONS AND RECOMMENDATIONS

Tea smallholdings in the studied area of Matara district experience bush debilitation problem causing a considerable impact on the productivity of tea lands. The poor adoption of some crucial GAPs was found, and some of them have an association with debilitation condition. Pests and diseases such as SHB, Canker, Wood-rot, and Scavenging termite play a crucial role in appearing the stress symptoms. Nematode infestation has not shown a direct relationship with the present debilitation.

The extension agencies should pay attention to improve the adoption of GAPs among the smallholders. Periodic monitoring of nematode levels are also encouraged.

ACKNOWLEDGEMENT

Authors wish to acknowledge the Director, TRI, Dr. K.M. Mohotti and Dr. M.A. Wijerathna for providing logistics support and guidance, nematology staff for analysing the samples and NDT Trainees at TRI during 2017/2018 and Ms. Mahshika, Ms. Wathsala for data tabulation.

REFERENCES

Anon (2000). Annual report, Tea Research Institute of Sri Lanka, Talawakelle, pp 33–34.

Anon (2005). Census of smallholding in Sri Lanka, Department of Census and Statistics and Tea Small Holding Development Authority, Colombo.

Anon (2008). A sample survey conducted by Tea Small Holding Development Authority.

Anon (2016). Statistical information on plantation crops, Ministry of Plantation Industries. Colombo. pp 4–6.

Anon (2017a). Annual Report 2017. Central Bank of Sri Lanka. Colombo 01.

Anon (2017b). Annual Report 2017, Tea Small Holding Development Authority, Pelawatta, Battaramulla.

Hornik, R. (1988). The knowledge-behavior gap in public information campaigns: A development communication view, working paper (No. 110) International Centre for Health and Development Communication, Annaberg School for Communication, University of Pennsylvania.

Jayamanne, V.S., Wijeratne, M.A. and Wijayaratna, C.M. (2002). Adoptability of new technology in the small-holdings tea sector in the low country of Sri Lanka. J. Agric. Rural Dev. Tro. Subtr., 103 (2), 125–131.

Likert, R. (1932). A technique for the measurement of attitudes. Arch. Psych., 140, 44–53.

Mahaliyanaarachchi, R.P. and Sivayoganathan, C. (1996). Factors affecting technical knowledge of tea small holders in Sri Lanka. Trop. Agric. Res., 8, 38–46.

Mahindapala, K.J.G.P., Jayarathna, S.P.A.P.K., Dayananda, H.N., Jayaweera H. and Nishanthi, M.A.H. (2019). Investigation of debilitation of tea and technology adoption in smallholders in Mathugama division in Kalutara district in Sri Lanka. pp 332, Proceedings of 12th International Research Conference, General Sir John Kotelawala Defence University, At Ratmalana.

Mohotti K.M, Premathunga, A.K, Amarasena, P.G.D.S, Navarathna, N. and Herath, U.B. (2017). Attributes of nematode infestation to bush debilitation, unusual yield decline and death of tea in low grown areas. Proceedings of 234th E & E forum, Tea Research Institute of Sri Lanka, pp. 45-56, 12th International Research Conference, General Sir Johan Kotalewala, Defence University Ratmalana.

Meijer, S., Catacutan, D., Ajayia, O.C., Sileshi, G.W. and Nieuwenhuis, M., (2015). The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa. Inter. J. Agric. Sust., 15 (13), 40–54.

Rajasinghe, J.C.K. (1999). Is this the tip of an iceberg – A cautionary note for low-country tea growers. In TRI Updates, Vol. 04. Tea Research Institute of Sri Lanka, Talawakelle.

Janaka, R., Mahindapala, J., Dayananda H. and Sajeevika, I.D.C. (2015). Die back of tea in Balangoda, Kalawana and Galllella areas in Ratnapura district – Results of case studies, Tea Bulletin Vol 24 (2), Tea Research Institute of Sri Lanka, pp.1–6

Ratnayaka, S.P. and Munasinghe, C.E. (2013). Possible causes affecting tea bush debilitation in Deniyaya region: A sample survey. Tea Bulletin, Vol. 23 (1). Tea Research Institute of Sri Lanka. pp. 1–11.

Samaraweera. G.C., Ping, Q. and Yanjun, L. (2013). Promoting tea business in the tea smallholding sector in developing countries through efficient technology transfer system: Special reference to Sri Lanka. (Online), at http://www.academicjournals.org/AJBM.

Shikuku, K.M., Winowiecki, L., Twyman, J., Eitzinger, A., Perez, J.G., Mwongera, C. and Läderach, P. (2017). Smallholding farmer attitudes and determinants of adaptation to climate risks in East Africa. Climate Risk Management. Vol. 16, Pages 234 – 245. (Online). www.sciencedirect.com,

Sivapalan, P. (1972). Nematode pest of tea. In: Webster, J.M. (Ed.). Economic Nematology, Academic Press, New York, pp. 285–310