Sri Lanka J. Tea Science Vol.85, Part 1&2; 45-57
DOI: https://doi.org/10.4038/sljts.v85i1-2.15

(Reproduced from the proceedings of the seventh symposium on plantations crop research published in November, 2019)

Factors Associated with Declining Yield in Corporate Sector Tea Plantations in Ratnapura and Kegalle Districts

K G J P Mahindapala[*1], J C K Rajasinghe[2], S P A P K Jayarathna[1], B A D Samansiri[3] and H N Dayananda[1]

[1]*Advisory and Extension Division, Low Country Research, Advisory and Extension Centre, Tea Research Institute of Sri Lanka, Ratnapura, Sri Lanka*
[2]*Advisory and Extension Division, Mid Country Research, Advisory and Extension Centre, Tea Research Institute of Sri Lanka, Hantan, Sri Lanka*
[3]*Tea Research Institute of Sri Lanka, Talawakelle, Sri Lanka*

Corresponding author: prasanjithjm@gmail.com

ABSTRACT

The contribution to the Sri Lankan tea industry from the low grown tea is substantial. However, a recent study revealed that the corporate sector tea plantations of Ratnapura and Kegalle districts were experiencing a yield decline at a rate of 3.6% and 2.4%, respectively per year. This study attempted to find out the possible reasons for such yield decline.Primary data collection was done mainly by reviewing the estate records and through field observations in tea plantations owned by Regional Plantation Companies (RPCs) of the respective regions while the secondary data were collected from the "Diagnostic Survey" conducted in 2010. Data were analysed using statistical tools such as correlations, descriptive methods, log-linear and chi-square techniques. Results showed no direct relationship of rainfall and ambient temperature with present yield decline. However, the senility of tea and low rate of replanting were found to be core contributory factors for the yield decline. The labour scarcity too, has contributed by disrupting the planned capital work, harvesting and executing the good agricultural practices. Debilitation of tea bushes resulting from the damage caused by Wood-rot, Shot-hole borer and Canker seem to have contributed to the yield decline. The poor adoption of post pruned sanitary measures and poor shade management practices were also contributed to the yield reduction. This study has also elucidated the relationship between low levels of soil organic carbon and low productivity of young tea. Hence, it could be concluded that the yield reduction in Ratnapura and Kegalle districts can be attributed to multiple reasons.

Keywords: Adoption, GAPs, labour scarcity, RPC, senility, replanting, yield decline

INTRODUCTION

Tea growing area of Sri Lanka can be divided into three categories based on elevation, namely; Low-country, Mid-country and Up-country. The tea growing areas below 600 m and within 600-1200 m amsl are considered as Low- country and Mid-country, respectively. Contribution of low grown tea to the tea industry of Sri Lanka is significant in terms of tea production, productivity, area under tea and livelihood of the people. About 63% of the total tea production of Sri Lanka comes from low-country tea lands (Anon., 2016a, 2016b). The low-country is the largest tea growing area, where majority (80%) of the studied tea plantations in Ratnapura and Kegalle districts are located. Three main sub-sectors can be identified in these districts in terms of the size of the holding. The 'Smallholders' are tea growers who own less than 10 acres of land, and medium-scale estates are the land categories between 10 - 50 acres. The balance is corporate sector estates, with the extents over 50 acres, which are owned by the government and managed by Regional Plantation companies (RPC's). The corporate sector tea estates in Ratnapura and Kegalle districts are spread out in five Agro-ecological regions (AER) namely; WL1a, WL2a, WM1a, WM1b, IM1a (Punyawardhana *et al.,* 2003).

The environmental factors such as rainfall, temperature, sunshine hours, wind velocity and humidity are generally favourable in low-country for growing tea and therefore, tea productivity is much higher in smallholding sector in this area than elsewhere (Anon., 2005). However, the several studies have revealed that average tea yields of most of the low-country RPC estates are comparatively less than that of the estates in up-country (Anon, 2003; Samansiri *et al*., 2011). Furthermore, a study conducted in the low-country region revealed a declining trend of tea yield in several districts (Mahindapala *et al*., 2017). The total tea production and average tea productivity in the corporate sector in Ratnapura district, have been decreased by 36% and15% over the last 10-year period since 2007 (Mahindapala *et al*., 2017). The similar trend existed in Tea plantations in Kegalle district as well. Accordingly, the tea production in corporate sector in Kegalle district has come down by 24 % during the last ten-year period. The recent national level tea production statistics also show a stagnation and gradual decline of the contribution made by low country tea estates to national tea production (Anon., 2010-2017). Hence it is essential to identify the attributes of this scenario.

Previous studies have quantified the magnitude of yield decline in Ratnapura and Kegalle districts, and the objective of the present study is to find out the factors contributed for yield decline of RPC tea plantations in the same districts.

MATERIALS AND METHODS

The data were collected from all RPC tea estates in Ratnapura and Kegalle districts coming under WL1a, WL2a, WM1a WM1b, and IM1a AERs. The data with respect to revenue extent and replanted tea extent were extracted from the office records over the ten years from 2007 to 2016. The data on labour availability and the number of plucking rounds were also obtained from the estate check roll books.

In addition to the above data, set of secondary data which had been collected from a national level survey in 2010 (referred to as "Diagnostic Survey") were also used. The data on incidence level of some of the key pest and diseases such as Shot-hole borer, Canker and Wood-rot with respect to high and low yielding VP tea fields in the age range of 12 - 15 years were analysed using log-likelihood technique to establish the log-linear relationships. Further, field observations on incidence level of pest and

diseases from randomly selected two fields (that are in same age range) were recorded in each estate in Ratnapura and Kegalle districts in order to further validate the relationships established using secondary data. They were analysed using descriptive techniques.

As mentioned in the above, the secondary data on pest, diseases and yields were categorized into two categories, and an attempt was made to fit the following log-linear model using CATMOD statistical technique using SAS software.

Log Mijkl = X+ X1 + X2 +X 3 + X4 + X5+
X1*2+X1*3 ….+ X4*5

where X_1 - X_5 are main effects:

X_1- Infestation level of Shot-hole-borer (SHB)

X_2- Infestation level of Low-country live wood termite (LCLWT)

X_3- Infestation level of Canker disease

X_4- Infestation level of Wood-rot disease

X_5- Yield level

X_{1*2} ---- X_{4*5} – Different combinations of interaction effects

The chi-square analysis was done to analyse the secondary data on levels of adoption of some of the critical cultural practices such as bush sanitation at the time of pruning, soil conservation and shade management in order to see the association with yield level. The data collected on worker availability were also analysed using descriptive techniques. Rainfall and ambient temperature data were collected in two locations, and trend analysis was done.

The past analytical reports on soil organic carbon (SOC) available in plantations and the corresponding average cycle yield were also reviewed and analysed using the chi-square test to see the possible relationship with the yield level.

RESULTS AND DISCUSSION

Several likely factors were considered using different analytical tools to identify attributes for the declining trends in tea production.

Rainfall and ambient temperature

The rainfall pattern and number of wet days in Ratnapura were given in Figure 1.

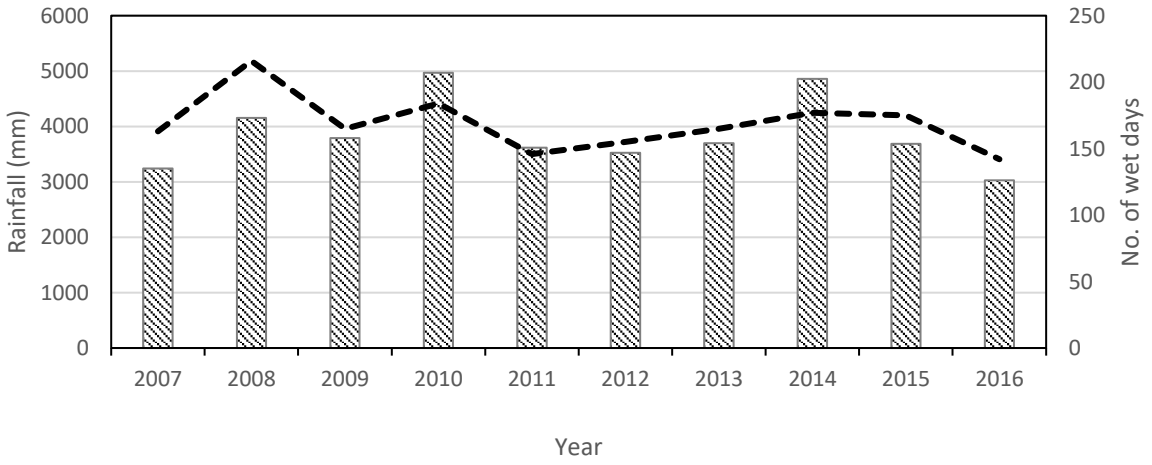

Figure 1. Total annual rainfall and number of wet days in Ratnapura

Although the rainfall was erratic with extreme events, no declining pattern of total rainfall was observed. Similarly, in the case of annual maximum ambient temperature (Figure 2), no significant correlation between present yield declining and mean maximum annual temperature over the last 10-year period (Pearson correlation coefficient (-0.264 at p=0.4618) was found, although, there was a slight increment of temperature experienced in latter part of the period. Furthermore, even in Kegalle district no declining trend in rainfall was observed (Figure 3). Hence, neither rainfall nor temperature was responsible for the declining of tea yield in the period under reference.

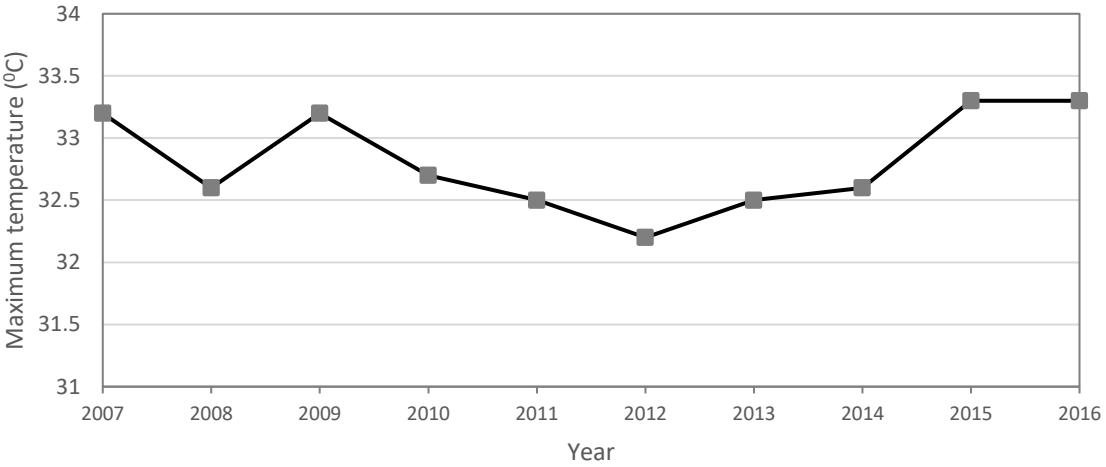

Figure 2. Mean maximum monthly ambient temperature in Ratnapura

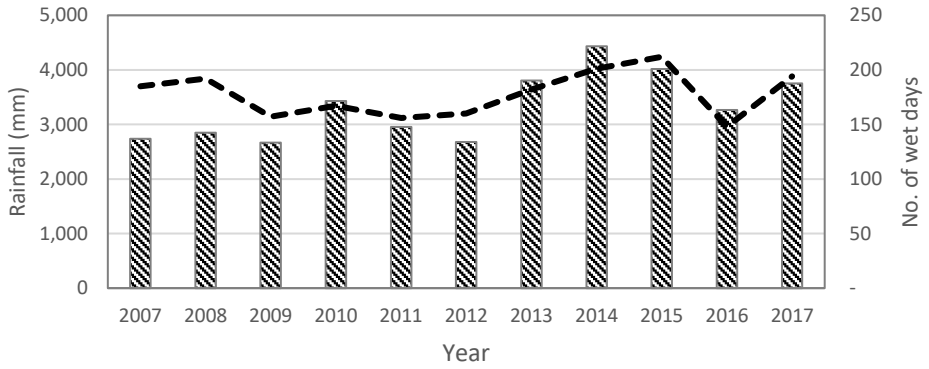

Figure 3**.** Total annual rainfall and number of wet days in Deraniyagla of Kegalle districts

Senility

Figures 4, 5, and 6 are derived from the secondary data on age of VP tea collected from the diagnostic survey carried out in the corporate sector estates in 2010. When analysing the data it was clear that on estates coming under the largest RPC in Ratnapura district more than 50% of the tea extent is older than 30 years and 70% is older than 20 years as depicted in Figure 4.

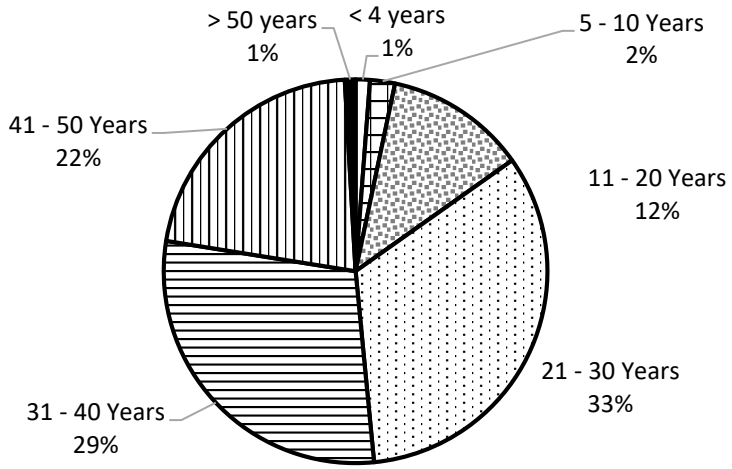

Figure 4. Age profile of tea in Regional Plantation Company (BPL) of Ratnapura district

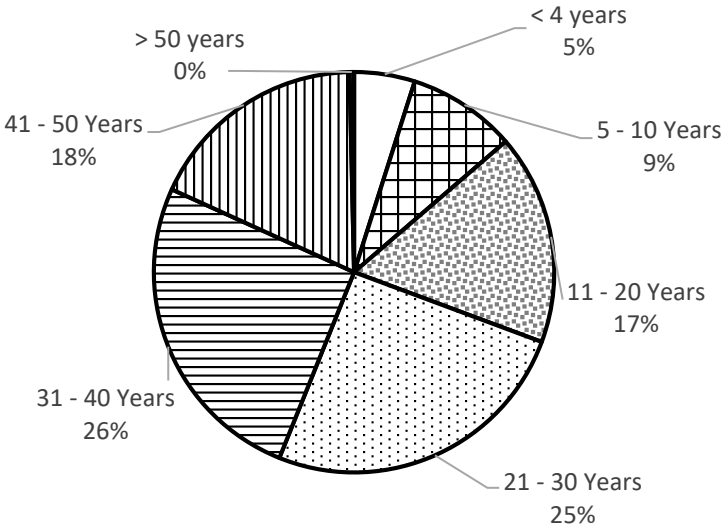

Figure 5. Age status of tea in a Regional Plantation Company in Ratnapura district

Figure 5 presents the general situation in the age profile of the estates in Regional Plantation Company (RPC) sector operated in Ratnapura district while Figure 6 depicts the same trend in Kegalle district. It was revealed that a substantial portion of tea extents under the purview of RPCs in both Ratnapura and Kegalle districts have become senile. Moreover, this results substantiated the earlier findings on economic lifespan of VP tea in low country as 25-30 years (Jayakody, 1999) which confirmed by Samansiri *et al.,* (2010). Therefore, it is clear that a considerable proportion of low country tea extent is in low productive phase. Out of the two districts studied, highest proportion of older tea was in RPCs of Ratnapura district (44%) than estates in Kegalle district (30%), which justify the highest yield reduction rates (3.6% per year) in Ratnapura as against the Kegalle (2.4% per year).

The current level of tea replanting rates, both national as well as in the corporate sector, is less than 0.4% (Samansiri *et al.,* 2011, Anon., 2015a). Therefore, issue of senility could be much serious today than in 2010, which likely to cause a greater yield reduction in the region.

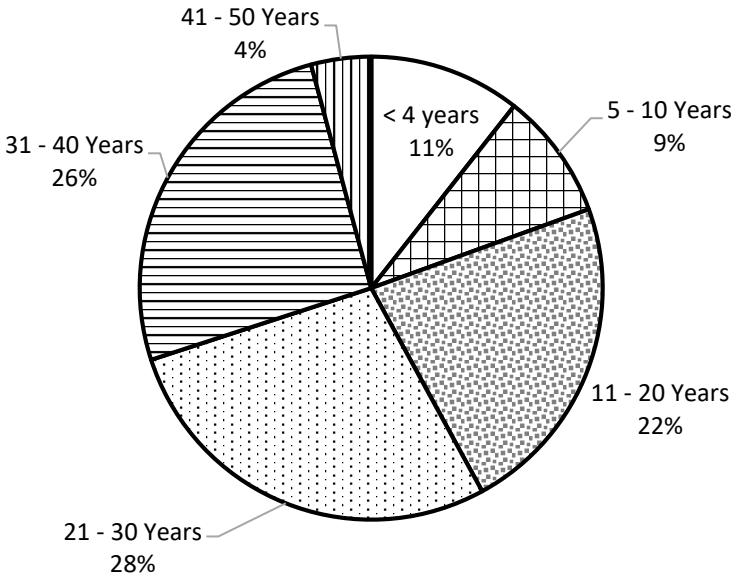

Figure 6. Age status of tea in a Regional Plantation Company in Kegalle District

Replanting of tea is a process of upgrading tea fields, by replacing the old unproductive teas that are in revenue, with a new set of plants, which is a primarily important factor that ensures the sustainability of tea plantations. Although recent studies suggested a 4% rate of replanting (Samansiri *et al.*, 2010), that rate was never achieved. The finding of this study revealed that the estates which undertook replanting programs in an adequate manner have not experienced the yield reduction (Figure 7 and Table 1).

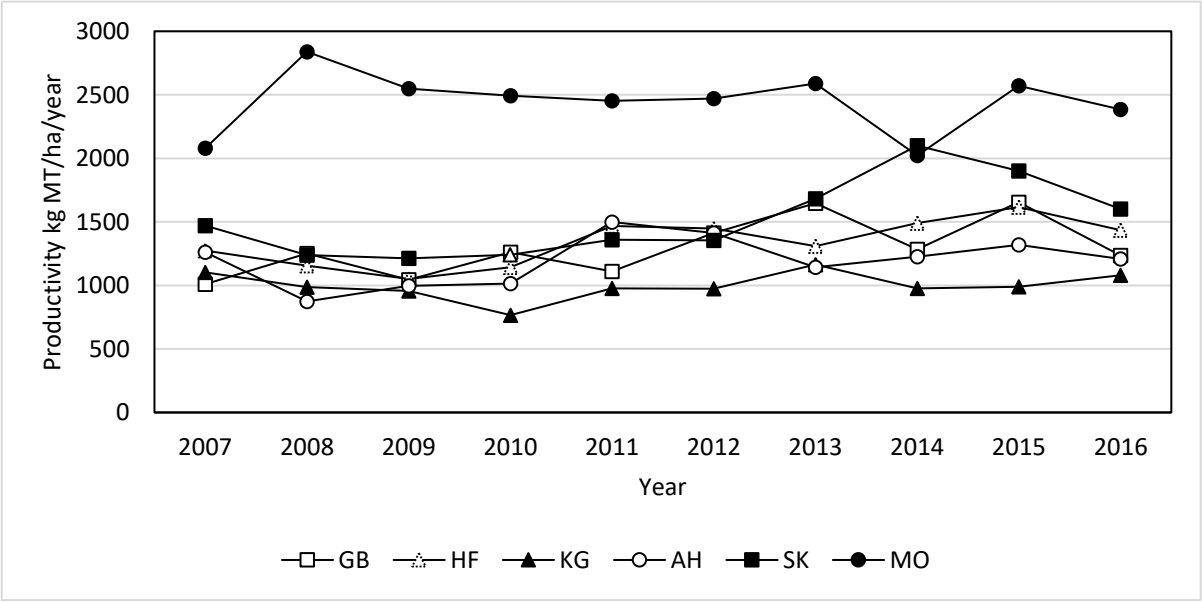

Figure 7. Yield trend of the estates that followed better replanting rate over 3%

Table 1. Replanted volume, average revenue extent and rate of replanting estates, which showed increasing yield trends

Estate	District	Average replanted Area (ha/year)	Average revenue extent (ha)	Replanting rate (%)
GB	Ratnapura	4.99	75.15	6.47
KG	Ratnapura	3.56	79.42	4.49
HF	Ratnapura	2.48	68.75	3.60
SK	Kegalle	2.19	53.66	4.10
AH	Kegalle	0.45	14.05	3.27
MO	Kegalle	0.93	10.28	13.7

Further, Pearson correlation test was performed to test the correlation between the percentage of yield reduction over the last 10-year period and the average rate of replanting in the same period using the data obtained from 53 estates in Ratnapura and Kegalle districts. The results revealed that there is a negative relationship between Replanting Rate and the decrease in production ($r=-0.536$, $p<0.001$). These results highlight the importance of replanting in order to maintain tea yields in productive level and level of contribution of senility towards the yield reduction.

Worker availability

Data on worker availability in 40 RPC estates in Ratnapura and Kegalle districts are given in summary form in the Figure 8.

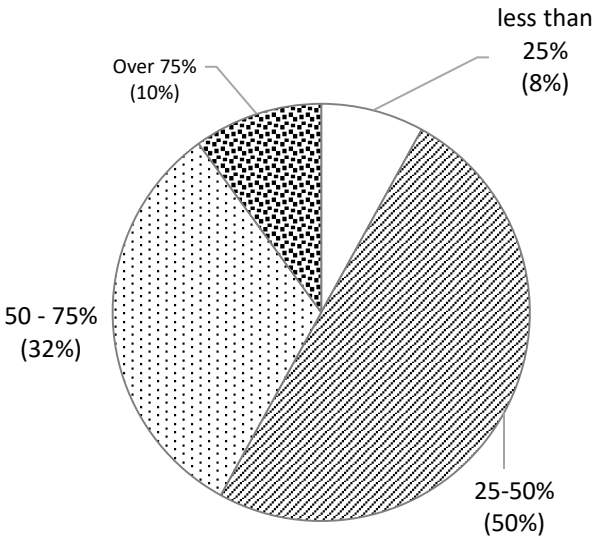

Figure 8. Labour availability as a percentage (%) of required labour in RPC estates in Ratnapura and Kegalle Districts.

It is revealed that more than 90% of the estates have less than 75% of the required labour force (Figure 8), indicating the gravity of the situation. It is, therefore, possible that the scarcity of labour would have contributed to the low rate of replanting throughout the estates in these districts. Further, worker shortage had an impact not only on capital work such as replanting, block infilling and adoption of good agricultural practices (GAPs), but also affected harvesting process specifically maintaining of appropriate plucking rounds which determined the sustainability. The number of plucking rounds adopted in some of the "A" category fields (high yielding fields) in six sampled estates in WL1a AER under favourable weather (April to June and September- November) in 2015 is summarized in the Table 2. Accordingly, all these estates, that was sampled, maintained less number of plucking rounds (longer plucking interval) as against the ideal number of rounds (16 - 18).

Table 2. Number of plucking rounds adopted in high yielding fields (category A) of sampled tea fields of the estates in WL1a AER in Ratnapura district

Estate	Field No.	Category	No. of plucking rounds undertaken		Ideal no. of rounds
			April to June	September to November	
HG	14	A	12	12	
WP	34	A	13	10	
HF	9	A	15	12	16-18
PG	3A	A	14	13	
KG	2	A	14	13	
DW	15	A	13	10	

This condition is due to the dearth of labours, as no estates curtail or delay the plucking in high yielding fields. Longer plucking rounds resulted in poor yield (Wijeratne, 2001) and hence, scarcity of labour contributed towards yield decline in many ways.

Debilitation of tea bushes due to pest and disease

The log-linear analysis (G^2 analysis) was performed using the data collected on level of infestation of some of the key pest and diseases [Shot-hole borer (SHB), Canker and wood-rot] in the diagnostic survey to explore possible associations existed with level of pest and disease incidence with yield level. This technique is a stepwise procedure, and G^2 and P values with respect to first, second and third steps are given in Tables 3, 4 and 5, respectively.

Table 3. Step No. 1 of Log-likelihood analysis

Uniform Order	**G^2**	**d.f.**	**P**
Model containing no interaction term - C1 C2 C3 C4 C5	151.8	11	<0.0001
A model containing all two-way interaction terms and lower order terms	0.4	1	0.5062

Table 4. Step No. 2 of Log-likelihood analysis

No	The model with 1 two-way Interaction	G^2	df	P	ΔG^2
1	X1*X2	147.23	10	<0.0001	4.61
2	X1*X3	124.51	10	<0.0001	27.33
3	X1*X4	86.54	10	<0.0001	65.30
4	X1*X5	88.93	10	<0.0001	62.91
5	X2*X3	136.85	10	<0.0001	14.99
6	X2*X4	134.26	10	<0.0001	17.58
7	X2*X5	138.41	10	<0.0001	13.43
8	**X3*X4**	**69.27**	**10**	**<0.0001**	**82.57**
9	X3*X5	127.68	10	<0.0001	24.16
10	X4*X5	90.51	10	<0.0001	61.33

Finally, the analysis proceeded up to the 5th step, and four interactions terms were fitted to the model. The outcome of the log-linear analysis suggested the following model as the best fitting;

viz.

Log Mijkl = Main Effects + (X3*X4) +

(X1*X5) +(X4*X5) + (X1*X4)

(Lowest G^2=19.15, at P<0.0141)

This analysis revealed that there were associations between Canker disease with Wood-rot, tea yield with Shot hole-borer infestation, tea yield with the incidence of Wood rot, and SHB with Wood-rot. There was an indirect association between canker and tea yield too. This can be further explained using the original data which were given in Tables 6, 7 and 8. Accordingly, 87% of fields which had been highly infested with wood-rot had given low yields and 95% of the fields which had mild wood-rot infestation given high yields.

Table 5. Step No. 3 of Log-likelihood analysis

No	The model with 2 two-way Interaction	G^2	df	P	ΔG^2
11	X3*X4 + X1*X2	44.38	9	<0.0001	24.89
12	X3*X4 + X1*X3	47.10	9	<0.0001	22.17
13	X3*X4 + X1*X4	39.92	9	<0.0001	29.35
14	**X3*X4 + X1*X5**	**30.58**	**9**	**<0.0001**	**38.69**
15	X3*X4 + X2*X3	58.9	9	<0.0001	10.37
16	X3*X4 + X2*X4	61.85	9	<0.0001	7.42
17	X3*X4 + X2*X5	64.65	9	<0.0001	4.62
18	X3*X4 + X3*X5	68.99	9	<0.0001	0.28
19	X3*X4 + X4*X5	59.41	9	<0.0001	9.86

Table 6. Association between Wood-rot and yield

Disease		Yield	
		High	Low
Wood rot	High	9 (13%)	64 (87%)
	Low	59 (95%)	3 (5%)

Table 7. Association between Shot-hole-borer damage and yield

Pest		Yield	
		High	Low
SHB	High	6 (12%)	46 (88%)
	Low	62 (75%)	20 (25%)

Also, 88% of fields which had been highly infested with SHB had given low yield and 75% of the fields which had mild SHB infestation given high yields.

Table 8. Association between Canker and Wood-rot

Disease		Wood rot	
		High	Low
Canker	High	55 (93%)	4 (7%)
	Low	18 (24%)	58 (76%)

Further, 93 % of fields which had been highly infested with canker produced high wood-rot and, thereby caused low yield. Seventy-six per cent (76%) of the fields which had mild canker infestation produced low wood rot resulted in achieving high yields.

Therefore, finally, it can be concluded that the majority of low yielding fields associated with a high level of infestation of SHB, Canker and Wood-rot while majority of high yielding fields associated with low infestation levels of the above pests and diseases.

Moreover, the above hypothesis was validated by a field assessment survey conducted in 53 RPC estates in Ratnapura and Kegalle. The data collected in that survey on different pest and disease incidents in VP tea fields, in the age group of 15 - 25 years are given in the Figure 9.

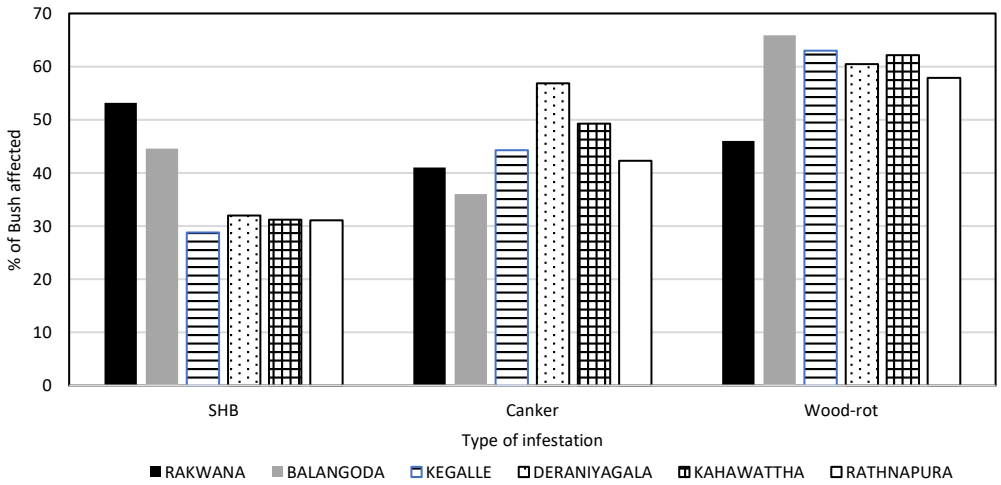

Figure 9. Different pest and disease infestation levels in RPC estates in different planting regions in Ratnapura and Kegalle Districts.

It was observed that a considerable amount of tea bushes were affected with SHB, canker and wood-rot. The SHB infestation level was more than 30% in the RPC estates in Ratnapura and Kegalle district, while the highest infestation reported was found in the estates located in Rakwana and Balangoda planting districts. Similarly, average canker infestation was 40% (highest in Deraniyagala and Kahawatta sub planting districts) while average wood-rot infestation was more than 50%. Therefore, these field observations can be used to validate the outcome of the diagnostic survey and thereby, the yield reduction could be attributed to shot hole borer, canker and wood-rot. Adoption of the GAPs.

Furthermore, data with respect to the level of adoption of some of the important cultural practices which had also been collected in the diagnostic survey were given in Tables 9 and 10. Data were analysed using the chi-square test in order to see the relationships with yield.

Table 9. Variation in yield with the level of sanitary measures adopted at the time of pruning

Sanitary measures adopted	**Yield level**		
	High	**Low**	**Total**
Satisfactory	36 (72%)	14 (28%)	50
Not Satisfactory	32 (38%)	53 (62%)	85
Total	68	67	135

Table 10. Variation in yield with the level of shade management adopted

Shade management adopted	**Yield level**		
	High	**Low**	**Total**
Satisfactory	30 (79%)	8 (21%)	38
Not Satisfactory	38 (39%)	59 (61%)	97
Total	68	67	135

Chi-square analysis revealed that there were associations among the productivity and the degree of sanitary measures adopted during the pruning and level of shade management (Chi-square value = 15.897 and 17.277, respectively at $P<0.0001$). The lack of sanitary measures (possibly as a result of worker shortage) adopted at the pruning could have led to accumulation of wood-rot on the frames over the consecutive pruning cycles (this was evident in Figure 9, where high amount of wood-rot was observed throughout both districts) which would have had some impact on the observed yield reduction.

Soil carbon content

Many studies have emphasised the role or effect of Soil Organic Matter (SOM) or Soil Organic Carbon (SOC) on tea yield and soil fertility (Sivapalan, 1993, Zoysa, 2008, Shan-Lian Qiu, 2014, Nath 2014).

Thus, TRI has recommended desirable SOC levels to be maintained in tea growing soil, based on the elevation category. It is generally considered desirable if the SOC level is maintained above 2% in Low and mid-elevations for its sustainability (Sivapalan, 1993, and personal communication with Head, Soils and Plants Nutrients Division, TRI). Several studies have proved that the highest productivity of tea in low country corporate sector is achieved when tea is in 9-15 years of age (Jayakody, 1999, Amarathunga *et al.,* 2000, Samansiri *et al.*, 2010). In view of all the above factors, soil analytical reports available on estates were examined during the study and found that 61 tea fields of 16 estates in the above age group had been subjected to SOC analysis during the period under reviewed. The yields of the respective cycles have also been considered, and both values were categorised as given in Table 11.

Table 11. Cross-tabulation of soil carbon content (SOC) level and yield level

		[2]Yield level		
		High	**Low**	**Total**
[1]SOC Level	High	10	4	14
	Low	9	38	47
Total		19	42	61

[1]SOC level >2% - High, <2% – Low

[2]Yield > 1800 kg MT/ha/year - High, and < 1800 Low-based on national average)

Chi-square test was done to test the degree of association between SOC levels and Yield levels. It was found that there is an association between SOC level and Yield Level (Chi-Square value 13.747; P<0.0001), which revealed the SOC as an attribute for productivity decline in young tea.

CONCLUSION

Yield reduction of tea in corporate sector in Ratnapura and Kegalle districts over the last 10-year period since 2007 can be attributed to multiple reasons- namely the senility of tea plants due to low rate of replanting, the scarcity of labour, debilitation of tea as a results of incidence of canker, wood-rot and shot-hole-borer infestation and poor adoption of sanitary measures during the pruning and unsatisfactory level of shade management. Moreover, the climatic factors have played less role in yield reduction during the same period.

This study also found the evidence to prove the low level of association between soil organic carbon content and productivity decline in young tea.

ACKNOWLEDGEMENTS

Authors wish to acknowledge, managers, assistant managers, office and field staff of the estates in Ratnapura and Kegalle districts for the cooperation extended for this study and Miss Gayani and Achalanka, NDT students for supporting the data collection.

REFERENCES

Amarathunga, M.K.S.L.D. and Wijeratne, M.A. (2000). Study on variation of the productivity of the tea lands in different agro-ecological regions in Sri Lanka, (In) Proceedings of Annual Session, Sri Lanka Association for the advancement of Science. Section B 56(1), December 2000, Colombo, Sri Lanka

Anon. (2003). Agriculture profile of the corporate sector tea, Tea Research Institute of Sri Lanka, Talawakelle.

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

Anon. (2010 to 2017). Annual Reports, Sri Lanka Tea Board, Colombo.

Anon. (2016 b). Annual Report 2016, Central Bank of Sri Lanka, Colombo.

Jayakody, J.A.A.M. (1999). Economic feasibility of tea replanting as a strategy to improve productivity in tea lands, (In) Proceedings of the 198th Experiment and Extension Forum, Tea Research Institute of Sri Lanka, Talawakelle.

Mahindapala, K.G.J.P., Samansiri B.A.D., Jayarathna S.P.A.R.K., Dayananda H.N., Rajasinghe J.C K., Ratnayake S.P., Mahinda T.G.N., De Alwis P.D.D. and Jayaweera H. (2017). Yield declining and bush debilitation in low- country tea plantations. (In) 234th Experiments and Extension Forum, Tea Research Institute of Sri Lanka, Talawakelle.

Nath, T.N. (2014). Soil texture and total organic matter content and its influences on soil water holding capacity of some selected tea growing soils in Sivasagar District of Assam, India International Journal of Chemistry Science 12(4), pp.1419-1429.

Punyawardhana B.V.R, BandaraT.M.J, Munasinghe, M.A.K, Bandara N.J. (2003). The Map on Agro-Ecological Regions of Sri Lanka, Department of Agriculture, Sri Lanka.

Samansiri, B.A.D., Rajasinghe J.C.K. and Hiromi Nishanthi, M.A. (2010). Forecasting productivity of VP tea under varying rates of replanting in the corporate sector of Sri Lanka, S.L.J Tea Sci. 75 (2), 30-45.

Samansiri, B.A.D., J.C.K. Rajasinghe, and K.G.J.P. Mahindapala, (2011). Agronomic profile of corporate Sector Tea Plantation in Sri Lanka, Tea Research Institute of Sri Lanka, Talawakelle.

Shan-Lian Qiu, Li-Min Wang, Dong-Feng Huang, and Xin-Jian Lin. (2014), Effects of fertilisation regimes on tea yields, soil fertility, and soil microbial diversity, Chil. J. Agric. Res. 74(3) pp.333-339.

Sivapalan, P. (1993). Shade and green manure trees in tea – A holistic appraisal, Sri Lanka, S.L.J Tea Sci. 62 (2), 41-46.

Wijeratne, M.A. (2001). Shoot growth and harvesting of tea, Tea Research Institute of Sri Lanka, Talawakelle.

Zoysa A.K.N, Ananthacoomarswamy and De Silva M.S.D. (2008). Management of soil fertility in tea lands, pp. 16-33, *Handbook on tea* (Eds.) Zoysa .K.N., Tea Research Institute of Sri Lanka