AN EVALUATION OF THE MONTHLY VARIATIONS IN YIELDS OF TEA OF TWO ESTATES

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Introduction

The growth of perennial crops of the humid tropics, unlike those of the temperate zones, is not confined to a specific part of the year, though their rate of growth will vary with seasonal variations in environmental conditions. A change in growing conditions and its effect on the crop yield will usually not become apparent at the same time. The time-interval between these two occurrences will for instance depend on the plant part that is harvested (Hasselo, 1961). The shorter this time-interval, the more representative the annual yield level will be of the conditions prevailing during that year.

Since the produce of tea is derived from the vegetative growing-points of the plant, variations in environmental conditions will be reflected in the crop yields with relatively little delay. Therefore, the yield level of tea in a particular year, other conditions being equal, may be taken as an index of the environmental conditions prevailing during that year.

It is the aim of this study to evaluate the effect of variations in annual yield levels, as an index of the effect of annual variations in environmental conditions, on the fluctuations in monthly yields in different years.

Knowledge of such effects might be of great practical importance for the future planning of estate management, particularly with regard to the impact of measures which are aimed at increasing the yields.

Methods

In November 1961 Dr Visser—then Plant Physiologist at the T.R.I. collected estate data for an investigation of the yield pattern during a pruning cycle. From these data, three fields of each of the two estates, which were situated in different districts, will be used for the object of the present study (Table 1).

It will be seen from Table 1 that the three fields of each estate were treated in the same way.

TABLE 1

Estate No.	Field No.	Acreage	Elevation (in feet)	Shade	Date of pruning	Date of 1st pluck	Date of last pluck	Pruning: type & height
A* ...	1	43	4200	Mixed medium	July 57	30–10–57	14– 7–61	Medium—15"
District: ...	2	23	4200	do.	do.	11–11–57	8– 7–61	do.
Dickoya ...	3	36	4200	do.	June 57	28–10–57	21– 6–61	do.
B** ...	1	31	4600–5400	do.	September 56	24– 1–57	15– 7–60	Clean—20"
District: ...	2	43	4500–4800	do.	June 56	24– 9–56	29– 3–61	do.
Pundaluoya ...	3	33	5000–5200	do.	August 56	20–12–56	21– 6–61	Clean—18"

*Manure applied during cycle at average rate of 10 lb N per 100 lb of made tea.
**Manure applied during cycle at average rate of 8.75 lb N per 100 lb of made tea.

TABLE 2.

Yield figures of fields 1, 2 and 3 of Estate A

Year	Field No.	Yield of made tea		Mean monthly yield			Ratio: yield of X highest yielding months / yield of X lowest yielding months				Ratio: yield of Z highest yielding months / mean monthly yield	
		lb/acre p. annum	in %	lb/ acre	standard deviation (lb/acre)	coefficient of variation (%)						
		(y)		(m)	(s)	(cv)	($x_6=6$)	($x_3=3$)	($x_2=2$)	($x_1=1$)	($z_2=2$)	($z_1=1$)
1958	1	1321	127	110.1	± 30.6	27.8	1.61	1.92	2.09	2.29	1.45	1.45
	2	1296	125	108.0	± 28.8	26.7	1.53	1.90	2.07	2.40	1.42	1.51
	3	1604	154	133.7	± 39.9	29.8	1.53	2.04	2.37	2.69	1.54	1.61
1959	1	1304	126	108.7	± 42.1	38.8	1.85	2.70	3.42	3.13	1.61	1.78
	2	1044	100	87.0	± 24.7	28.4	1.57	1.96	2.08	2.32	1.46	1.49
	3	1463	141	121.9	± 26.8	26.8	1.56	1.99	2.25	2.36	1.37	1.39
1960	1	1356	131	113.0	± 32.0	28.4	1.61	2.08	2.32	2.63	1.40	1.49
	2	1039	100	86.6	± 17.5	20.2	1.36	1.62	1.74	1.89	1.35	1.42
	3	1144	110	95.3	± 24.2	25.4	1.55	1.88	2.13	2.43	1.34	1.43
Mean		1286		107	± 29.6	27.6	1.6	2.0	2.3	2.5	1.4	1.5

Correlation coefficient (d.f.=7)

$r_{y.s}=0.7059$*

$r_{y.s}$ (within years) $=0.6320$

$r_{y.cv}=0.3783$

$r_{s.x_6}=0.8254$**

$r_{s.x_3}=0.8265$**

$r_{s.x_2}=0.8201$**

$r_{s.x_1}=0.9103$***

Significance:

*P 0.05=0.6664

**P 0.01=0.7977

***P 0.001=0.8982

Results and discussion

1. *Estate A.*

It will be seen from Table 2 that the yields obtained in the three fields of Estate A fluctuated between 1,039 and 1,604 lb of made tea per acre per annum or to the extent of 54% on the lower yield. Since these fields are part of one estate, it is reasonable to assume that the obtained differences in yield level are largely due to differences in environmental conditions between the different fields and years, and possibly differences arising from the time after pruning.

It appears from Table 2 that in general, the higher the annual yield the larger are the deviations from the mean monthly yield and thus the greater the monthly variations in yield between the different months of a year ($r_{y.s} = 0.7059$). In the period under consideration the mean monthly yield in a year varied between 87 and 134 lb of made tea per acre. The deviations from the mean monthly yield in a year amounted to between 17 and 42 lb of made tea per acre, the coefficients of variation varying between 20% and 39%. The finding that there existed a positive and significant ($P = 0.05$) relationship between the variation in annual yield level and the monthly yield fluctuations for the three fields in different years suggested that this relationship had not been markedly affected by factors such as differential effects arising from differences in soil between the fields, differences in time after pruning and differences in weather conditions in the three different years. The factors which may have affected the relationship can be sub-divided into two groups, *i.e.* those factors which vary from one year to the other ('between years') and those which do not vary with the years ('within years'). It appeared that if the factors 'between years' were eliminated, the extent of the relationship was reduced to a non-significant level, the partial correlation coefficient $r_{y.s}$ (within years) amounting to 0.63 only. This finding showed that the relationship between level of annual yield and monthly yield fluctuations was due to factors which varied from one year to the other (*e.g.* climate, time after pruning) rather than to those 'within years' (soil, topography, *etc.*).

In order to obtain a more detailed picture of the distribution of the extra yield obtained in a high yielding year during the different months of that year, different ratios were worked out (Table 2). Thereto, the total yield produced in the six highest yielding months of each field in a year was compared with that of the six lowest yielding months and expressed in a ratio (x_6). Similarly, the x_3, x_2 and x_1 ratios were computed for the 3, 2 and 1 most favourable and unfavourable months respectively. Correlating these ratios with the standard deviations, it was found that in the case of x_6, x_3 and x_2 approximately 67% ($r^2_{s.x_6}; x_3; x_2 = 0.82^2 = 0.67$) of the variation in monthly yields in a year could be explained by the magnitude of the difference in total yield between the 6, 3 and 2 higher and lower yielding months. In case of x_1 as much as 83% of the standard deviation of the mean monthly yield ($r^2_{s.x_1} = 0.91^2 = 0.83$) could be explained in this way.

These results showed that the larger variations in monthly yields in years with higher annual yields were mainly due to increased differences in yield between the favourable and unfavourable seasons of the year, particularly between the highest and the lowest yielding month of the year under consideration.

2. *Estate B.*

The results obtained from the analysis of the monthly yields of estate B were similar to those of Estate A (Table 3).

TABLE 3.

Yield figures of fields 1, 2 and 3 of Estate B

Year April to April	Field No.	Yield of made tea		Mean monthly yield			Ratio: Yield of X highest yielding months / yield of X lowest yielding months				Ratio: yield of Z highest yielding months / mean monthly yield	
		lb/acre p. annum	in %	lb/acre	standard deviation (lb/acre)	coefficient of variation (%)						
		(y)		(m)	(s)	(cv)	$(x_6=6)$	$(x_3=3)$	$(x_2=2)$	$(x_1=1)$	$(z_2=2)$	$(z_1=1)$
1957/58	1	913	111	76.1	± 14.5	19.1	1.34	1.60	1.76	1.98	1.30	1.33
	2	1108	135	92.3	± 27.8	30.2	1.59	2.10	2.28	2.72	1.44	1.59
	3	820	100	68.3	± 27.6	40.3	2.03	2.57	2.48	2.67	1.62	1.64
1958/59	1	996	109	74.7	± 28.9	38.6	1.64	2.17	2.46	3.25	1.61	2.09
	2	1131	138	94.3	± 26.4	28.0	1.55	1.98	2.24	2.42	1.44	1.54
	3	954	106	79.5	± 27.7	34.9	1.66	2.13	2.37	2.69	1.62	1.82
1959/60	1	1003	122	83.6	± 26.1	31.2	1.53	2.10	2.63	3.24	1.47	1.75
	2	1313	160	109.4	± 43.9	40.1	1.72	1.80	2.98	4.31	1.70	2.01
	3	1017	124	84.8	± 28.9	34.1	1.70	2.35	2.89	3.65	1.53	1.59
1960/61	2	1080	132	90.0	± 33.4	37.2	1.69	2.55	3.13	4.69	1.62	1.82
	3	1124	137	93.7	± 33.9	36.2	1.66	2.30	2.65	3.38	1.63	1.91
Mean		1033		86.1	± 29.0	33.7	1.6	2.2	2.5	3.2	1.5	1.75

Correlation coefficient (d.f.=9)

$r_{y.s}=0.6925^{*}$ $r_{y.cv}=0.1171$

$r_{y.s}$ (within years) $=0.2074$

$r_{s.x_6}=0.5023$

$r_{s.x_3}=0.2577$

$r_{s.x_2}=0.8208^{**}$

$r_{s.x_1}=0.8048^{**}$

Significance:

*P 0.05=0.6021

**P 0.01=0.7348

The major part, *i.e.* 67% ($r^2_{s.x_2}$; $x_1 = 0.82^2 = 0.67$) of the increased variation in monthly yields in a high yielding year on Estate B was due to the increased difference in yield between the one or two most favourable and unfavourable months of that year respectively (*i.e.* x_1 and x_2). The ratios of x_3 and x_6, however, were not significantly correlated with the standard deviations of the mean monthly yields ($r_{s.x_6} = 0.50$; $r_s.x_3 = 0.26$). Thus, when higher annual yields were prioduced in the fields of Estate B, it was reflected by a larger difference in yield between the one (or two) highest and the one (or two) lowest yielding months of the year only, but not, as in the case of Estate A, by that between the 3 or 6 highest and lowest yielding months (*i.e.* x_3 and x_6) of the year. Apparently, an increase in annual yield on Estate B was less uniformly spread over the 12 months of the year than on Estate A.

It will be seen from table 3 that the relationship between annual yield level and fluctuations in monthly yields ($r_{y.s.} = 0.7$) was reduced to a non-significant level of $r_{s.}$ (within years) $= 0.2$, if the effects caused by differences 'between years' were eliminated.

3. *Discussion*

The practical importance of these results is that at higher annual yield levels, the total extra weight of crop obtained in a year is not distributed uniformly over the 12 months of that year, the major amount of it being produced in the most favourable months, particularly in the one (or two) highest yielding months.

Since the same trends were observed on different fields of two differently managed (*see* Table 1) estates with different mean yield levels (*i.e.* 1,033 lb of made tea p.a.p.a. for Estate B—Table 3, against 1,286 lb for Estate A—Table 2), and as these trends did not appear to be masked by the effect of time after pruning or of climatic differences between the three years under consideration, nor by that of possible differences in soil between the different fields, they would seem to be valid whatever the cause(s) of the increased annual yield might have been. This would imply that on estates with rising annual yields the maximum capacity needed per unit time —say per month—to handle and manufacture the extra crop should be based upon the larger extra yields to be obtained in the already highest yielding month. In estate management this is a distinct disadvantage, increasingly so the more the extra crop is produced in a fewer number of months of the year. In other words, on estates with rising yields the labour force, factory capacity, *etc.* will have to be based upon the ever increasing amount of crop of a few high yielding months of the year, rather than on the smaller increase in the average monthly yield, whilst there will be an ever increasing surplus in labour, factory capacity, *etc.* in the lowest yielding months, *i.e.* the major part of the year.

It will be seen from tables 2 and 3, that for Estate A the highest yielding month of the year produced on average 1.5 times as much crop as the average monthly yield for the year and 2.5 times as much as the lowest yielding month of the year. Those figures were 1.75 and 3.2 respectively for Estate B. If Estates A and B were comparable with each other, one would have expected the ratios of 1.5 versus 1.75 (and 2.5 versus 3.2) to have been reversed, the higher figure pertaining to the higher yielding Estate A. That it was not so must have been caused by natural or/and artificial differences between the two estates. If the cause arose from natural differences (climate, soil, topography, *etc.*) between the two estates, then the management of Estate A should be more economical as a smaller labour force and factory capacity would suffice to handle the same annual crop. If, however, the higher annual yield level and the relatively more uniform monthly yield pattern of estate A were not due to differences in natural conditions, then the cause could only be sought in differences in cultivation and/or managerial practices, those on Estate A being the more successful.

Partial correlation studies showed that on both estates the causative agents for the relationship could be assigned to factors arising from differences 'between years' rather than from those 'within years'. As it would seem unreasonable to assume that managerial and cultivation practices varied much from one year to the other on both estates, the more likely cause for the observed differences between Estate A and B would seem to be climatic variations.

Finally, the relationship was worked out between the annual yield levels and the coefficients of variation of the corresponding mean monthly yield levels. If significant, the rate of yield increase in favourable months as compared with unfavourable months would not only be larger but also relatively larger, *i.e.* a larger percentage increase.

It will be seen from tables 2 and 3 that the correlation coefficients for this relationship did not reach significant levels (for Estate A: $r_{y.cv} = 0.38$, for Estate B: $r_{y.cv} = 0.12$). It would appear, therefore, that the fluctuations in monthly yield levels in years with higher yields though larger, were not relatively larger than those in lower yielding years. Thus, when, say 20%, higher annual yield levels are anticipated, the arrangements to cope with this extra crop should be adequate for a 20% increase for the highest-yielding month and not only for a 20% increase in the (lower) mean monthly yield level.

Summary and conclusions

(*a*) The monthly variations in yield of tea were analysed for three fields of each of two estates (A & B) during a period of 3 years after pruning. Estate A is situated in the Dickoya District and Estate B in the Pundaluoya District (Table 1).

(*b*) In the period under consideration annual yields of the three fields fluctuated between 1,044 and 1,604 lb of made tea per acre on Estate A and between 820 and 1,313 lb on Estate B. Monthly yields varied between 40 and 215 lb of made tea per acre on Estate A and between 35 and 220 lb on Estate B (Table 2 and 3).

(*c*) On both estates the fluctuations in monthly yields were generally larger when the annual yields were higher. Determination by means of partial correlation of the effect on this relationship of factors 'within years' (soil, topography, *etc.*) and those 'between years' (climate, time after pruning, *etc.*) showed that factors 'between years' contributed most to the relationship, particularly on Estate B.

(*d*) The major part of the extra amount of crop obtained in years with higher yields was produced in the most favourable months of the year. The results did not, however, indicate that the percentage increase in yield of favourable months in high-yielding years, as compared with low-yielding years, was larger than that of unfavourable months.

(*e*) Knowledge of such trends on estates where higher yields are anticipated is important for the planning of measures to cope with the handling and manufacture of the extra crop. The more pronounced the monthly yield fluctuations, the larger the percentage of the annual harvest which is concentrated in the favourable growing season of the year, and the more extra labour and factory capacity will be needed in those months and the larger the surplus in labour and factory capacity will be in the off-season months.

(*f*) The monthly yield fluctuations were of the same order of magnitude on both estates. Owing to the higher annual yield level of Estate A, the monthly yield fluctuations on Estate A were relatively lower than on Estate B. The causes of this relative difference between the two Estates were discussed in relation to the effect of estate management on the monthly yield fluctuations and, conversely, with regard to the effect of the magnitude of the monthly yield fluctuations on the economy of running an estate.

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Reference

HASSELO, H. N. (1961). The soils of the lower eastern slopes of the Cameroon Mountain and their suitability for various perennial crops. Thesis. Veenman: Wageningen.