

# THE VALIDITY OF ASSESSING TEA YIELDS ON A BASIS OF INTERMITTENT PLUCKING AND TEST PLUCKING

T. Visser

## 1. Introduction

The effect of manuring, cultivation, method of plucking, etc. on the yield of tea often cannot be ascertained by observations over a short period. Consequently, in many instances long term experiments are necessary.

As tea is plucked every 7-9 days, it needs little imagination to realise that the labour involved in plucking and recording the individual yields of the experimental plots is very considerable. This is the more so, when the recorded fresh weights are converted into dry matter, as has been customary at the Tea Research Institute.

In the opinion EDEN (1931), expressing the yields as dry matter is a necessary procedure, because "the incidence of rain during the 24 hours of a day is such that even over a period there can be no balancing out of these effects." According to the same author, experiments might be conducted by means of sample plucking instead of recording every pluck. EDEN compared the total yields (over 42 plucks) with the yields of every *third* round (over 14 plucks) and found a very high and significant correlation between occasional and total pluckings in an uniformity trial. He concluded that the plucking of every third round "gives results which allow valid comparisons without an appreciable loss in accuracy."

The above conclusion was written in 1931, but for unknown reasons this practice was not, or rarely, adopted by the Tea Research Institute. The present author, therefore, has again tested the validity of calculating the total yield of field experiments on intermittent plucking. The validity of basing yields on fresh weight instead of dry weight records was also investigated.

The second part of the paper deals with the question whether for purposes of final selection also the yield of clones can be assessed by intermittent plucking. It was further investigated whether or not "test plucking"—the yield of a number of consecutive plucks over a limited period—could serve for the selection of such clones planted in multiplication plots. The validity of test-plucking has been previously studied *e.g.* by COHEN STUART and WELLENSIEK for large scale mother bush selections. Test plucking has been often used in Indonesia since then for the comparison of yields of mother bushes and in field experiments, and it was also employed at the Tea Research Institute for the initial valuation of the mother bushes in the field. Also EDEN (1941) investigated this method with regard to the number of flush shoot counts required for a reliable estimation of yield of mother bushes.

The usefulness of a quicker and less time-consuming selection is apparent, as so far the selection of clones represented by a limited number of bushes has taken one or more pruning cycles involving the recording of the yields of each clone at each round.

## 2. Intermittent plucking of field experiments

### 2.1. Methods and material

Of each of the field experiments the weighings—or mean of the weighings, in cases where the experiment was replicated—of 90 plucking rounds of the last

completed pruning cycle were taken for calculation. The "actual yield" (total of 90 plucks) was compared with the "calculated yields" based on every 2nd (45 plucks), 3rd (30 plucks), 5th (18 plucks) and 7th (13 plucks) plucks respectively. That is to say, the total calculated yields were obtained by multiplying the individual yields of every 2nd, 3rd, 5th and 7th plucks by 2, 3, 5, and 7 respectively, and adding the figures thus obtained.

The "paired-difference" method was adopted in order to ascertain whether or not the differences occurring between *actual* and *calculated* yields were significant. The same method was applied to demonstrate the significance of differences between yields of *different treatments* when based on intermittent plucks. In certain instances also the Chi-square test was applied in order to ascertain the association between actual and calculated yields.

The data of two treatments each of three long term field experiments—situated in different fields of the estate—were chosen for statistical comparison of actual and calculated yields. The manurial treatments in each of the different experiments were the same, *viz*; manuring with a single dose of nitrogen (S N = 40 lb. N/acre) as compared with a double dose of nitrogen (D N = 80 lb. N/acre). Both treatments received the same basic application of P and K.

## 2.2. Results

As the data regarding the relation between actual and calculated yield were qualitatively the same for all three field experiments, only those for the "cultivation experiment" are given in table 1 (average for 6 replicates each of 1/24th acre). Table 2 presents the Chi-squares for the actual and calculated yields of the same experiment.

Table 1. *The relation between actual and calculated yields based on intermittent plucking.*

1 Yields based on	2 3 4		5 6 7			8 9 10 11				
	Fresh weight lb. per 1/24th acre			Dry weight lb. per 1/24th acre			Correlation with all plucks			
	D N	S N	Difference	D N	S N	Difference	Fresh Weight		Dry Weight	
							D N	S N	D N	S N
All plucks (n = 90)	467	367	100 (27) ***	101	82	19 (23) ***	—	—	—	—
1 in 2 plucks (n = 45)	457	367	90 (25) ***	100	80	20 (25) ***	0.889	0.909	0.912	0.907
1 in 3 plucks (n = 30)	463	362	100 (28) ***	100	82	18 (22) ***	0.865	0.861	0.861	0.983
1 in 5 plucks (n = 18)	450	364	86 (24) ***	98	80	18 (23) ***	0.864	0.924	0.882	0.915
1 in 7 plucks (n = 13)	† 398	† 331	61 (20) **	† 87	† 73	14 (19) ***	0.910	0.912	0.905	0.920

N.B. (a) The figures between brackets in columns 4 and 7 give the mean difference in percentages between plots manured with double nitrogen (= D N); and single nitrogen (= S N);

(b) Differences between *actual yield* (all plucks) and *calculated yield* significant for: † P = 0.05;

(c) Difference between treatments significant for: \*)  $P = 0.05$ ;  
 \*\*)  $P = 0.01$ ; \*\*\*)  $P = 0.001$ ;

(d) All correlations are positive.

Table 2. Association of actual and calculated yields as shown by the Chi-square test.

Yields based on	For fresh weights		For dry weights	
	S N	D N	S N	D N
1 in 2 plucks	12.12:P>0.99	14.03:P>0.99	2.20:P>0.99	2.61:P>0.99
1 in 3 plucks	17.02:P>0.95 <0.99	20.91:P>0.80 <0.90	3.47:P>0.99	3.28:P>0.99
1 in 5 plucks	8.25:P>0.95 <0.99	14.48:P>0.50 <0.70	1.59:P>0.99	2.41:P>0.99
1 in 7 plucks	15.73:P>0.20 <0.50	26.81:P>0.01	3.18:P>0.95	5.39:P>0.80 <0.95

N.B. S N = single dose nitrogen; D N = double dose nitrogen.

The following can be derived from tables 1 and 2:

(a) The correlation coefficients for actual and calculated yields are all high and significant, both for fresh weights (columns 8, 9) and dry weights (columns 10, 11). However, the Chi-squares (table 2) for the yields based on fresh weights are much higher than those for yields based on dry weights, indicating the greater variability of the former yields.

(b) Fresh weight yields (columns 2, 3) and dry weight yields (columns 5, 6) based on 1 in 2, 1 in 3 and 1 in 5 plucks deviate insignificantly from the actual yield, they are also adequately associated with it. Yields calculated from every 7th pluck deviate significantly from the actual yield, and for the fresh weight yield also the association is inadequate.

(c) The differences between treatments (double versus single nitrogen) for actual and calculated yields are significant in all instances, both for fresh and dry weight yields (columns 4,7).

The above observations are qualitatively the same for all three field experiments. It must be added that the significance of the differences becomes less as the number of plucking rounds from which the yield is calculated decreases, slightly more so for fresh weight than for dry weight yields. The margin between significance and non-significance for yields based on 1 in 7 plucks is often narrow, so that it will be safer to base the yields on 1 in 5 plucks, or better still on 1 in 3 plucks.

### 3. Fresh weight as a basis for yield determination

A great deal of time and labour would be saved if yields could not only be based on intermittent pluckings, but also if fresh weights instead of dry weights could be used for an accurate assessment of yield.

EDEN assumed that this cannot be done as moisture adhering to the leaves would increase the variation between individual pluckings to an impermissible extent. However, it seems more likely to the present author that the weighings of different plots of a field experiment over one or more years (40 plucks per year) will contain on average the same amount of moisture. Namely, it may be presumed that over such a period all plucks will be on average an equal number of times dry or wet. Consequently, the differences between treatments will remain approximately the same, irrespective of rain. This supposition is borne out by the fact

that the differences between *treatments*, expressed in percentages, were of the same order in all three field experiments, irrespective of whether dry or fresh weight yields were compared.

The same can be derived from the fact that the average moisture contents—averaged over 100 consecutive plucks—of samples collected from 27 different manual treatments respectively were found to be practically the same.

Table 3. *Correlation between fresh weight and dry weight of actual and calculated yield.*

Treatments	r for actual fresh and dry yields	r for calculated fresh and dry yields			
		1 in 2 plucks	1 in 3 plucks	1 in 5 plucks	1 in 7 plucks
Manurial Single N	0.983	0.987	0.988	0.988	0.857
experiment Double N	0.984	0.986	0.987	0.99	0.984
Plucking Single N	0.965	0.940	0.954	0.981	0.903
experiment Double N	0.962	0.950	0.942	0.978	0.839
Cultivation Single N	0.978	0.901	0.896	0.970	0.993
experiment Double N	0.967	0.987	0.926	0.960	0.982
Average for 3 experiments	0.976	0.957	0.971	0.986	0.956

N.B.—All correlation coefficients are positive.

Further evidence that both actual yields and yields based on intermittent plucking can be determined on a fresh weight basis, is furnished by table 3. This table shows that the correlations between dry and fresh weight yield are high and significant both for actual and calculated yields in all instances.

#### 4. Intermittent plucking and test plucking of clones

##### 4.1. Methods and material

The data below concern clones which were planted in "multiplication" plots in rows of 10-12 bushes per clone. The yields of these clones were recorded on a basis of fresh weights. The validity of yield assessment based on "intermittent" or "test" plucking was ascertained as follows:

(a) Firstly, the actual yield of 90 plucking rounds was compared with calculated yields based on every 2nd, 3rd, 5th or 7th pluck. (See page 21). These calculations were carried out on three clones using the data of the 1st pruning cycle; they belonged to the "main clonal area."

(b) Secondly, it was determined how many consecutive plucks were required, once the clones came into plucking, for a reliable selection of the highest yielders among them. For this purpose 32 clones belonging to the "1947 area" were chosen. Starting with the 6th pluck, the correlation coefficients were calculated for the yield of 1 pluck only (6th pluck), 2 consecutive plucks (6th + 7th pluck) . . . and 11 consecutive plucks (6 + 7 + . . . 16th pluck) respectively with the yield over the 1st year (40 plucks) and over the pruning cycle (120 plucks) respectively.

(c) Thirdly, it was investigated how soon after coming into bearing, the yield based on 10 consecutive plucks could serve to point out the highest yielders among a number of clones. In this case yield data of the first cycle of 22 clones belonging to the "1947 blister resistant area" were used. It was calculated what correlation existed between yields of each series of 10 consecutive plucks (1st-10th, 11th-20th, . . . , 111th-120th respectively) and the total cycle yield (120 plucks).

#### 4.2. Results of intermittent plucking

The data concerning the actual and calculated yield of 3 clones are presented in table 4; those with regard to the Chi-square test on one clone are given in table 5.

Table 4. *Relation between actual yield and calculated yield based on intermittent plucks (in oz. per 11 bushes); observations carried out on clonal tea.*

		CALCULATED YIELD BASED ON				
		All plucks (n = 90)	1 in 2 plucks (n = 45)	1 in 3 plucks (n = 30)	1 in 5 plucks (n = 18)	1 in 7 plucks (n = 13)
Clone 777	(Fresh weight Correlation)	1,167 —	1,187 + 0.938	1,256 + 0.901	1,164 + 0.812	1,050 + 0.773
Clone 1	(Fresh weight Correlation)	1,098 —	1,164 + 0.905	1,059 + 0.922	1,093 + 0.774	1,324 + 0.898
Clone 1294	(Fresh weight Correlation)	540 —	529 + 0.918	557 + 0.904	503 + 0.659	664 + 0.750
Average yield in %		100	102	102	97	111
Difference clone 777-1294		627***	658***	699***	661***	386*
As % of yield of clone 1294		116	125	126	132	58

N.B. For \*, \*\*), \*\*\*see table 1.

Table 5. *Association between actual and calculated fresh weight of clone 1294 as shown by the Chi-square test.*

Chi-square for actual yield with calculated yield	Chi-square	P
1 in 2 plucks	25.14	P > 0.80 < 0.90
1 in 3 plucks	28.73	P > 0.30 < 0.50
1 in 5 plucks	77.11	P < 0.01
1 in 7 plucks	142.4	P < 0.01

It follows from table 4 that the correlations between actual and calculated yield are significant in all instances. However, those between actual yield and the yield based on every 5th or 7th pluck are considerably lower than for the yield calculated from 1 in 2 or 1 in 3 plucks. The variability of yields, based on each 3rd, 5th and 7th pluck, is also demonstrated by the fact that the association with the actual yield is not adequate (Table 5). Nevertheless, none of the differences between actual and calculated yields is significant due to the high standard errors caused by the variability in yield from pluck to pluck.

The difference between the yields of clone 777 and 1294 is great and therefore significant, even if the yields are based on 1 in 7 plucks. However, in the latter case, the calculated difference—reduced to half of the actual difference—is only reliable on the 5 per cent probability level.

It is clear from the Chi-squares given in table 5 that the calculated yields of clones were less representative for the actual yield than was the case in field experiments (table 2) on account of the fact that the former yields were based on 10-12 bushes and the latter on about 700 bushes. The differences between clones also have to be relatively greater as they may display different growth performances from period to period. That is to say, a certain clone may produce a significantly greater yield than another over the first year of the cycle, whereas the roles may be reversed in the following year. Therefore, if fresh yields of clones represented by a limited number of bushes are to be calculated on intermittent plucks, it will be advisable to base the yield on not less than 1 in 2 plucks.

#### 4.3. Results of test plucking

1. The correlation of the yields of consecutive plucks (starting with the 6th pluck after bushes came into bearing) with cycle yield (120 plucks) and the yield over the 1st year (40 plucks) for 32 clones are given in table 6. This table also includes the correlations determined by WELLENSIEK for the yields of an increasing number of consecutive plucks (starting with the 17th pluck) with the yield of 48 plucks for 1555 individual bushes. Also presented are the correlations found by COHEN STUART for the yields of consecutive plucks (starting with the 22nd pluck) with the yield of 42 plucks for about 200 mother bushes.

Table 6. *The correlation of the yields of a limited number of consecutive plucks with the cumulative yield over about one year or longer.*

1	2	3	4
Correlation of yield of 120 plucks with:	Correlation of yield of 40 plucks with:	Correlation of* yield of 48 plucks with:	Correlation of** yield of 42 plucks with:
1 pluck + 0.335	1 pluck + 0.405	1 pluck + 0.396	1 pluck + 0.473
2 plucks + 0.728	2 plucks + 0.783	2 plucks + 0.746	2 plucks + 0.370
3 plucks + 0.658	3 plucks + 0.734	3 plucks + 0.816	3 plucks + 0.688
4 plucks + 0.674	4 plucks + 0.745	4 plucks + 0.898	4 plucks + 0.796
5 plucks + 0.859	5 plucks + 0.923	5 plucks + 0.930	5 plucks + 0.824
6 plucks + 0.891	6 plucks + 0.961	6 plucks + 0.929	6 plucks + 0.858
7 plucks + 0.807	7 plucks + 0.880	7 plucks + 0.926	7 plucks + 0.834
8 plucks + 0.889	8 plucks + 0.973	8 plucks + 0.860	8 plucks + 0.802
9 plucks + 0.866	9 plucks + 0.958	9 plucks + 0.771	
10 plucks + 0.867	10 plucks + 0.954	10 plucks + 0.952	
11 plucks + 0.876	11 plucks + 0.963	11 plucks + 0.949	

\*) Figures from WELLENSIEK \*\*) Figures from COHEN STUART

Table 6 shows that COHEN STUART's, WELLENSIEK's and our figures are very similar. The correlations for the yield of 5 consecutive plucks with the yield of about one year (the first year after the bushes came into bearing for the first time) are already very high and significant (columns 2, 3, 4). It can be observed that a drop in the correlation coefficient occurs for yields based on 7 (column 2), 8 (column 4) or 9 (column 3) consecutive plucks. Correlations for yield based on 1 or 2 plucks more are again higher. Presumably this is not a chance occurrence as such a decline occurs in all three sets of figures. Accordingly, if test plucking is to be carried out, it would seem safer to base it on not less than 10 consecutive plucks.

The correlations of 1, 2 . . . 11 plucks with the cycle yield (column 1) are all lower than the equivalent coefficients with the yield of the first year (column 2). This indicates that test plucking done just after the bushes come into bearing for the first time is not entirely representative for the potential yield of the clones for the whole cycle.

As an illustration of what the correlations would have meant in practice the following can be remarked:

The yield of as few as 5 consecutive plucks would have sufficed to point out the 3 highest yielding clones, viz. respectively 149%, 75% and 75% higher than the average cycle yield for all 32 clones. The next best (77% above average) would have been found on a basis of 10 consecutive plucks. However, not even the cumulative yield of 40 plucks (1st year) would have been sufficient to detect the two subsequent highest yielders (50 and 36% above average). Instead, this yield would have indicated as the next best, two clones which yielded only about 10% above average. In order to detect the former two (50 and 36% above average) either test plucking in the *second* year, or total cycle yields would have been required.

II. In the following table the correlations are given for the yields of each 10 consecutive plucks (1-10th, 11th-20th, etc.) with the cycle yield (for 22 clones), starting from the moment the bushes came into plucking for the first time.

Table 7. *Correlation coefficients for the cumulative yields of each consecutive ten plucks with the cycle yield in relation to the time after the clones came into bearing.*

1st year	1 — 10th	11 — 20th	21 — 30th	31 — 40th
	+ 0.878	+ 0.907	+ 0.927	+ 0.958
2nd year	41 — 50th	51 — 60th	61 — 70th	71 — 80th
	+ 0.949	+ 0.949	+ 0.977	+ 0.963
3rd year	81 — 90th	91 — 100th	101 — 110th	111 — 120th
	+ 0.944	+ 0.941	+ 0.962	+ 0.951

It can be observed from table 7 that all correlations with the cycle yield are high, those for the yields of the first three series of 10 plucks being lower than those for subsequent test plucks. Apparently, test plucks done in the first year are less representative for the yield of the clones than those done in the second year after the bushes came into bearing. The correlations for the third year are somewhat lower than those for the second year.

The practical meaning of the correlation coefficients can be illustrated as follows:—

If on account of the yield for the *first* 10 plucks the four highest yielders had been chosen, one would have found that according to the cycle yield only the best clone (134% above average) was among the four. The other 3 clones would have been comparatively inferior, with cycle yields not much higher than the average cycle yield for all 22 clones. However, among the four highest yielders chosen on a basis of the yields for the *second* series of 10 plucks, one would have found the 3 best clones (134, 92 and 74% above average) and only one relatively low yielding one (28% above average). Only test pluckings in the *second* year after coming into bearing would have ensured that the four highest yielders (134, 92, 74, 68% above

average) chosen on account of the yield of 10 consecutive plucks were also the four best ones on account of their cycle yield.

It appears from the above that in the one area the cumulative yield for the 6th to the 15th pluck in the cycle provided a basis for the selection of the 4 best from among 32 clones. In the other area the yield of the second series of 10 plucks in the cycle sufficed to detect the 3 best clones from a choice of four on a total of 22 clones. Similarly, EDEN (1941) showed that the three outstanding mother bushes, on a selected number of 10, could be found on the basis of the cumulative total of the first 16 consecutive flush counts.

It would seem, therefore, that the yield of the second series of 10 plucks after bushes come into bearing, would provide a good basis for the selection of the best 10 to 15 per cent of clones under trial in multiplication plots. In case one also wants to select the "next best" clones, either test plucking in the second year, or total cycle yields would be needed.

## 5. Summary and conclusions

Calculations were carried out in order to determine whether the work and time involved in assessing the yields of field experiments and clones could not be considerably lessened. To that purpose it was ascertained to what extent yields based on "intermittent plucking"—only every 2nd, 3rd, 5th or 7th pluck recorded—were representative for the absolute yields.

The same method was tested for the assessment of the yield of clones represented by a limited number of bushes. With regard to clones it was also investigated whether "test plucking"—the yield of a consecutive number of plucks—could serve as a reliable basis to estimate the potential yield of a clone early in its cycle.

The following observations and conclusions may be noted.

(1) With regard to field experiments, yields based on 1 in 2, 1 in 3, or 1 in 5 plucks did not significantly deviate from the absolute yields; those based on every 7th pluck often did. These findings are more or less true for yields of clones based on intermittent plucking, but the deviation from the absolute yield might be greater, as yields were based on about 12 bushes only.

(2) Noteworthy differences between yields of different treatments or clones remained significant when yields were based on intermittent plucking. However, the margin between significance and non-significance became narrower as the number of recorded rounds on which yields were calculated became less.

Yields of field experiments based on 1 in 3 plucks and yields of clones based on 1 in 2 plucks (over at least one year) can be expected to give as good a basis for comparison as yields based on all plucks.

(3) Fresh weight yields and dry weight yields were found to be highly correlated. It can be said that intermittent plucking based on fresh weights would provide a reliable basis for long-term yield determination.

(4) With regard to the test plucking of clones it was shown that the yields of 10 consecutive plucks are highly correlated with the cycle yield at each stage of the cycle, but less so during the first year than during the second year of the cycle. The data indicate that the yield for the second series of 10 plucks in the first year after the bushes come into bearing would suffice to choose the *best* clone out of every 10 clones under trial in the multiplication plot. Selection of the next best clones would be possible if the test plucks were carried out during the second year.

## Acknowledgements

My thanks are due to Dr. A. W. R. Joachim, O.B.E., for the kind advice given on statistical matters and to Mr. L. M. de Waas Tillekeratne, B.Sc., for his assistance in the calculating work involved.

### References

- COHEN STUART, C. P.: Research on the leaf-yielding capacity of tea plants (Dutch with English summary) Arch. Theecult. 1, 1929: 275-277.
- EDEN, T.: Studies in the yield of tea I. J. Agric. Sc. 21, 1931: 517-573.
- EDEN, T.: The selection of high yielding tea bushes for vegetative propagation. Tea Quart 14, 1941: 98-102.
- WELLENSIEK, S. J.: Researches on quantitative tea selection IV. (Dutch with English summary) Arch. Theecult. 12, 1938: 42.