THE OUTTURN OF MADE TEA TO GREEN LEAF (THEORETICAL AND PRACTICAL CONSIDERATIONS)

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In recent years the percentage outturn of made tea to green leaf* has been of considerable general interest and occupies a place in tea culture only a little way behind manufacture. One difficulty of the tea planter is to know whether the outturn he gets is satisfactory or not. Numerous current theories exist, adding confusion and giving rise to superficial conclusions, from which tangle has grown suspicion of the accuracy of figures recorded in a factory.

To most planters percentage outturn appears to be a figure which fluctuates chiefly with rainfall and age from pruning. This view is justifiable but incomplete. Few realize how wide is the scope of this subject. Several considerations have to be borne in mind and these are the subject of the present article, the purpose of which is to draw attention to the more important factors which affect outturn and the general principles underlying it.

In the first place it may be as well to explain that it is the dry matter in the leaf which constitutes the made tea. The percentage outturn of made tea to green leaf is therefore the ratio of the amount of dry matter to the fresh weight. Accordingly, the more moisture leaf contains, whether internally, or externally as surface moisture, the less the dry matter, or to put it simply, the lower the outturn. That is to say, if leaf contains 75 per cent. moisture the outturn is 25 per cent., if 80 per cent., the outturn is 20 per cent. and so on. Strictly speaking, however, the two figures do not add up to 100 because a certain amount of dry matter is lost in the withering process and possibly in the other processes as well. But as this loss is to some extent offset by the moisture in the made tea, the figure for percentage dry matter may for comparative purposes be taken to represent the percentage outturn of made tea to green leaf.

The moisture content of a plucked tea shoot varies considerably. Not only is there a difference between the fresh leaves and stalk, but some leaves contain more moisture than others, some stalks are more succulent than others, and the proportion of stalk to leaf also varies. To these causes must be added the external wetness of the leaf, which varies not only according to the degree of wetting but also to the size of the leaf. The internal moisture of the leaf itself is influenced by its morphological properties, age from pruning, and climatic and weather conditions. Hence it is quite impossible to decide whether the variation in the moisture content of flush is due to any particular cause. For example, the percentage moisture of surface dry flush may be as low as 68 per cent. or as high as 78 per cent. In wet weather it may still be 78 per cent. or reach the abnormally high figure of 85 per cent. A 78 per cent. moisture content may be associated with 'dry' leaf or wet leaf, or again it is quite possible for flush with a high proportion of stalk to have a moisture content

* "Leaf" is used in a general sense in this article, meaning the leaves and stalk from a freshly plucked shoot, unless a clear distinction is drawn between the two terms.

higher than 78 per cent. even though it may be perfectly dry on the outside. It is quite fallacious to assume that green leaf free from surface moisture should yield a constant outturn.

The factors that exercise the greatest influence on the moisture content of a plucked shoot are therefore:

(1) its composition,
(2) the weather,
(3) age from pruning.

These may or may not be interrelated, but an examination of each in turn will be helpful in throwing some light on a complex and controversial question.

Composition of the Plucked Shoot.—This is closely related to type of leaf and rate of growth, the latter being governed by environment and age of the bush from pruning. The cumulative effect of all these factors is to alter the proportion by weight of stalk and also its moisture content.

It is a current impression that flush from 'young' fields generally contains a higher proportion of stalk than that from 'old' fields but in the case of bushes of poor growth the plucked shoot may actually resemble one from a bush due to be pruned. Table 1 shows the variation and also the respective moisture contents obtained from the more stalky and less stalky flush gathered at the same plucking from a field with mixed 'jats'.

Table 1. *Relative proportions and moisture contents of stalk and leaves in flush from a 'young' field.*

Age from pruning	Sample	Proportion by fresh weight		Moisture content		
		Stalk	Leaves	Stalk	Leaves	Whole shoot
5 months	(*a*) more stalky shoots	28%	72%	85%	76%	78½%
"	(*b*) less stalky shoots	14%	86%	83%	76%	77%

From observations made on the distribution of moisture in a shoot, it has been established beyond all doubt that the stalk contains more water than the leaves but there does not exist any sort of relationship. The difference in the moisture content can be as much as 20 per cent. or as little as 5 per cent. Table 2 gives some figures for the moisture contents in the leaves and stalk of flush. (T. R. I. Bull. 9, p. 11.)

Table 2. *Variation in the percentage moisture content of stalk and leaves of a flush.*

Sample	MOISTURE CONTENT		
	Stalk	Leaves	Difference
1	91%	71%	20%
2	78%	73%	5%
3	83%	74%	9%
4	81%	73%	8%

These figures, it must be noted, were obtained with a fine pluck of 2 leaves and a bud. It is thus evident that the variation in the outturn of made tea to green leaf cannot be gauged merely from the standard of plucking. Apart from a variation in the moisture content of the main components of a shoot, the stalk and leaves themselves do not always exist in the same proportion to each other, as shown in Table 1. Flush from rapid growth, for instance, will have stalk of a longer length than say banji flush, but not necessarily of a higher moisture content. The extra length of stalk, however, in the former will naturally increase the moisture content of the whole shoot.

The variation in the size of the leaf does not appear to exert such a marked influence as stalk, except when it is wet. In wet weather, the moisture content of a stalk varies little but the leaves, on account of their ability to retain surface moisture, make an important contribution. It is not perhaps realized that a tea leaf in its maximum condition of wetness can hold as much as 30 per cent. surplus water or more. Therefore, the bigger the surface area of the leaf the lower the outturn in wet weather, all other conditions being equal. To understand the significance of surface moisture the following example is given. Assume that, prior to wetting, the stalk contained 83 per cent. moisture and the leaves 76 per cent. moisture and that the proportion by weight of stalk was 15 per cent. A plucked shoot of this description would have a moisture content of 77 per cent. Now if this shoot is thoroughly wetted the leaves would retain 30 per cent. of water but the stalk practically nil. The moisture content of the stalk would therefore remain unchanged, but that of the leaves would increase to 81.5 per cent. The final moisture content of the shoot would then be approximately 82 per cent. That is to say, the outturn would drop from 23 per cent. to 18 per cent. Larger leaves capable of holding more surface moisture would cause a further reduction.

Another and interesting point of note is that in a period of drought, as experienced in some upcountry areas, the moisture content of the leaves may actually fall to 66 per cent. whilst that of the stalk may not show such an appreciable change. The standard of plucking, jat and age from pruning will, accordingly, considerably influence the maximum percentage outturn recorded on an estate. It is for this reason that two neighbouring estates under exactly the same weather conditions may obtain dissimilar outturns on a single day.

The error which can be introduced by ignoring the variations in the composition of the plucked shoot is no small amount and the necessity for considering it in the examination of data for outturns is clear. The two following examples will give a fair idea of how stalk, in particular, affects outturn.

Example 1:—Assume proportion of stalk by weight is 20 per cent., and moisture content of stalk and leaves 86 per cent. and 76 per cent. respectively. The percentage dry matter of the whole shoot will then be equal to

$$20 \times \frac{14}{100} + 80 \times \frac{24}{100} = 22 \text{ per cent.}$$

Example 2:—If the proportion of stalk was 30 per cent., the percentage dry matter by a similar calculation would be 21 per cent. Under actual practical conditions it would be still less because generally an increase in the proportion of stalk is associated with an increase in its moisture content.

From data collected on St. Coombs the proportion by fresh weight of stalk in a plucked shoot varies from about 15 per cent. to 35 per cent. Expressed as percentage of the dry weight of the shoot the relative proportion of the stalk therefore fluctuates between 10 per cent. and 25 per cent. or thereabouts. Since stalk contains considerably more moisture than the leaves, the contribution it makes to the outturn is indeed significant.

The Weather.—The part played by the weather is much more complicated than it appears at first sight. It is not merely a question of the total rainfall or the number of hours of sunshine recorded; the state of the weather preceding plucking and during plucking has to be considered as well. Leaf plucked on a dull, cloudy day, for instance, would have a higher moisture content than leaf plucked following a long period of drought. During a very dry spell rapid transpiration occurs, quicker than the rate at which the bush can take up moisture from the soil, and this will result in a considerable reduction in the moisture content of the leaf. Under humid conditions, as frequently experienced in the low-country, the leaf even though exposed to the sun's rays would lose relatively less moisture and so contain more moisture. Further, in a very wet spell it is not only the surface moisture on leaf which affects the percentage moisture content but the internal moisture as well. Thus the heaviest rainfall at the end of an extremely dry spell will not lower the percentage dry matter to the same extent as continuous wet weather normally experienced in up-country western districts during the south west monsoon.

The two points therefore to be considered in examining the influence of weather are (*a*) internal moisture (*b*) external moisture. They cannot be considered apart because the internal moisture of leaf, whether wet or dry, is not constant. From the evidence available this may vary from 78 per cent. in wet weather to 69 per cent. in dry weather. External moisture may be as much as 30 per cent. of the total weight, depending on the weather and the size of the leaves. In this condition of extreme wetness the total dry matter of a plucked shoot may be reduced to 16 per cent. (84 per cent. moisture). Even a slight deposition of moisture on the surface of the leaf is sufficient to cause a noticeable reduction in the percentage dry matter. For example, assume that as a result of slight wetting by rain, mist or dew the weight of a flush increases by only 5 per cent. and that it had initially 76 per cent. moisture (or 24 per cent. dry matter). It would mean then that 100 lb. of such leaf would have increased in weight to 105 lb. Now if this were manufactured the product would still weigh 24 lb. The percentage outturn of made tea to the wetted leaf would thus be $\frac{24}{105} \times 100 = 22.8$, a drop of 1.2 per cent. This example is striking enough to show the marked influence of surface moisture on percentage outturn. Roughly speaking, percentage outturn drops 1 per cent. for every 4 to 5 per cent. increase in weight of leaf brought about by surface moisture.

In practice, the relation between the physical state of the leaf and percentage outturn appears to be as shown in Table 3.

Table 3. *Relationship between the physical condition of green leaf and percentage outturn of made tea.*

Condition of leaf	Percentage outturn of made tea to green leaf.
Surface dry	22 to 28
Slightly wet	21 to 22
Wet	19 to 21
Very wet	17 to 19

This table should not be used indiscriminately since the composition of the plucked shoot is another factor.

A second important point to be taken into consideration is that the variation in the percentage outturn of wet leaf need not be entirely due to a variation in the amount of surface moisture. It is also dependent on the internal moisture content, which itself varies according to the weather. For example, assume two lots of identical leaf, one plucked during continuously wet weather and the other in a shower following a dry spell. The internal moisture content would not be the same in both cases.

Suppose the former was 78 per cent. and the latter 76 per cent. and that surface moisture in each case was 10 per cent. of the total weight. The percentage outturns would then by a simple calculation be found to be 20 per cent. and 22 per cent. respectively, although, it will be noted each was wetted to the same extent.

To such complex factors must be added the variation of the weather in the course of plucking. The same amount of rainfall may be recorded on two successive days but the outturns may be entirely different. A few hours of sunshine or a variation in the intensity and distribution of rain will bring about quite a marked change in the moisture content of the plucked leaf and so alter the daily outturn. This aspect is well illustrated by the figures given in Table 4, taken from the results obtained from an experimental block at St. Coombs for three typical seasons.

Table 4. *Variation in percentage dry matter of the leaf in the course of plucking.*

	PERCENTAGE DRY MATTER		
	1 Dry weather	2 S. W. monsoon (continuous rain)	3 N. E. monsoon (morning sun and afternoon rain)
Morning pluck	23	19	20
Noon ,,	25	19	24
Afternoon ,,	27	19	19
Total for the day	25	19	21

In the first example the increase in the percentage dry matter towards the end of plucking has been caused by transpiration losses. The steady figures in the next are easily explained by the effect of continuous rain and absence of sunshine. The fluctuations in the third have been due to deposition of dew the night before, a bright morning and the advent of rain in the afternoon during plucking.

These figures, besides showing the effect of weather during the course of one plucking, focus attention on quite another important aspect of this question, namely, the variation of the total percentage dry matter for the day. It will be noted that in examples 2 and 3 the total for the day is 19 per cent. and 21 per cent. respectively, but the rainfall recorded between the hours of 8-30 a.m. and 3-30 p.m. was actually less in the former case. It may be of interest to mention that only 0.05" of rain fell on the day 19 per cent. was obtained whereas the higher figure of 21 per cent. was associated with 0.70". Why a simple formula cannot be worked out to express quantitatively the correlation between rainfall and percentage outturn is obvious and therefore makes further comment unnecessary.

Another and most significant question, which emerges from considerations of the moisture content of green leaf, is the practice on some estates of permitting in the factory a system of allowance for surface moisture in wet leaf, with a view to either insisting on a fixed outturn or obtaining a flattering outturn. It has already been shown that the moisture content of surface dry leaf plucked directly from the bush is not a constant figure. It is therefore evident that, even if the moisture content of wet leaf is determined, it will be impossible to say with any accuracy how much of that water is due to surface moisture alone. How much bigger must be the error to rely upon an empirical correction to counterbalance surface moisture? If too much is deducted the outturn will be too high while if too little is taken away from the actual weight of green leaf received for manufacture the outturn will be lower than the figure aimed at. Since the figure for percentage outturn can be made to be almost anything one pleases by altering the weight of green leaf, any system of allowances is not only unsound but subject to abuse as well. The folly of such a procedure has now come to be realized by many estates and the sooner actual outturns are recorded the better.

Age from Pruning.—One very serious difficulty, always present when attempting to assess the effect of the age of leaf from pruning on an estate, is caused by the general type of weather experienced at the time the observations are made. Figures for percentage outturn will be entirely untrustworthy if for example 'old' and 'young' leaf have been plucked at different times of the year, and on different days, as is the case on every estate. Other errors introduced are the inherent differences which exist between one field and another in relation to rate of growth and the composition of the flush.

It is quite impossible, even should careful data be recorded from say two similar fields of different ages, to know precisely how much of the difference noted between outturns is due to a difference in age or a difference in weather conditions or both. If they are plucked on different days, comparison of made tea outturns will be an useless undertaking. The weather is not consistent from one round to another, let alone during the course of plucking from morning to evening. It is obvious, therefore, that an accurate examination can be made only on the same type of leaf and at the same time of the day.

Table 5. *Effect of age from pruning on percentage dry matter for each pluck.*

Date of Pluck	PERCENTAGE DRY MATTER		
	Pruned September 1931	Pruned May 1932	Difference (to nearest ½%)
22-10-32	22.1	21.0	1
31-10-32	20.7	20.7	0
9-11-32	21.9	21.5	½
18-11-32	22.5	21.7	1
27-11-32	22.6	21.9	1
6-12-32	23.7	22.3	1½
15-12-32	20.6	20.4	0
24-12-32	23.7	22.4	1½
2- 1-33	25.1	23.6	1½
11- 1-33	22.9	22.0	1
20- 1-33	22.5	21.3	1
29- 1-33	23.0	21.8	1
7- 2-33	23.7	22.9	1
16- 2-33	25.8	23.9	2
25- 2-33	24.4	23.0	1½
6- 3-33	25.8	24.7	1
15- 3-33	26.3	24.6	2
24- 3-33	25.4	23.6	2
2- 4-33	25.0	23.7	1½
11- 4-33	23.5	21.9	1½
20- 4-33	25.6	22.6	3
29- 4-33	23.7	21.9	2
8- 5-33	22.4	21.6	1
17- 5-33	20.4	20.4	0
26- 5-33	19.7	19.8	0
4- 6-33	20.3	19.8	½
13- 6-33	22.2	22.0	0
22- 6-33	20.7	19.8	1
1- 7-33	20.6	21.6	-1
16- 7-33	23.6	22.9	1
19- 7-33	22.0	22.3	0
28- 7-33	23.9	23.3	½
6- 8-33	23.6	20.8	3
15- 8-33	22.8	21.5	1½
24- 8-33	21.3	20.7	½
2- 9-33	20.3	19.7	½
11- 9-33	24.4	23.6	1
20- 9-33	22.9	22.0	1
29- 9-33	21.9	22.0	0
8-10-33	21.1	20.6	½
17-10-33	22.0	21.0	1
26-10-33	23.8	22.8	1

Records from a pruning experiment, conducted by the Plant Physiology Department in 1931 and designed solely to study the effect of time of pruning on yield, provided some useful information. By calculating the percentage dry matter for two areas pruned at different times of the year the effect of age from pruning was estimated to within a reasonable degree of accuracy. Since treatments were replicated and plucking carried out on identical days, errors due to difference in weather and leaf were eliminated. Results were therefore strictly comparable. Although the difference in age was only 8 months, one area being pruned in September 1931 and the other in May 1932, differences in the percentage dry matter (percentage outturn for all practical purposes) were noted. The variation in the percentage dry matter is shown in Figure 1. Besides showing the effect due to age from pruning over a period of 3 years the graph shows the rise and fall in level caused by weather changes.

At first sight the general character of the fluctuations seems to follow a definite pattern but on closer examination it will be seen that the difference in outturn is only marked at the beginning of the pruning cycle, gradually becoming insignificant towards the end. It thus appears that, after a certain age from pruning, leaf can be expected to give more or less the same outturn as much older leaf. The prevailing idea that the older the bush the higher the outturn is thus not entirely confirmed by these results. It is evident, however, that in the early stages of a pruning cycle leaf quite definitely gives a lower outturn, which according to this graph can be as much as 2 per cent. on a monthly basis. An analysis of the figures obtained for each pluck for the first year of plucking of the area pruned in May 1932 compared with the other gives a clearer picture of the effect of age from pruning. Table 5 shows the variation.

Another interesting feature disclosed by the graph is that, though the general trend is for the percentage dry matter to be inversely proportional to rainfall, it is not always necessarily so. For instance, in October 1933, during which the rainfall was 16", the monthly outturn was not much different from that in September 1934 when only 3" was recorded. It will also be noted that the lowest monthly outturn in the whole cycle was 20.6 per cent., which was recorded in a month during which only 9.5" of rain had fallen, whereas in the previous month, during which the rainfall was as much as 36.4", the outturn was actually slightly higher. These figures provide a good example of the absence of any strict relationship between rainfall and outturn.

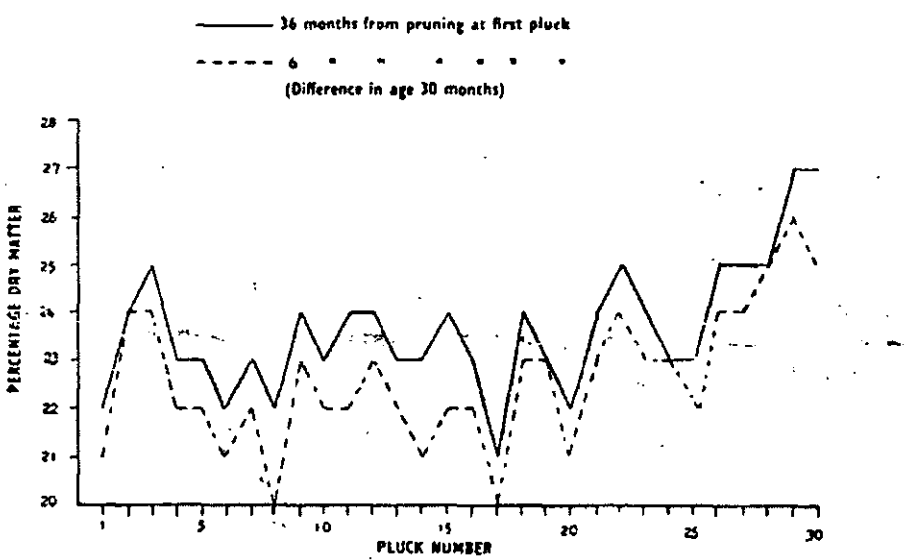

Fig. 2. Effect of age from pruning on percentage dry matter of each of 30 consecutive plucks (Clonal material).

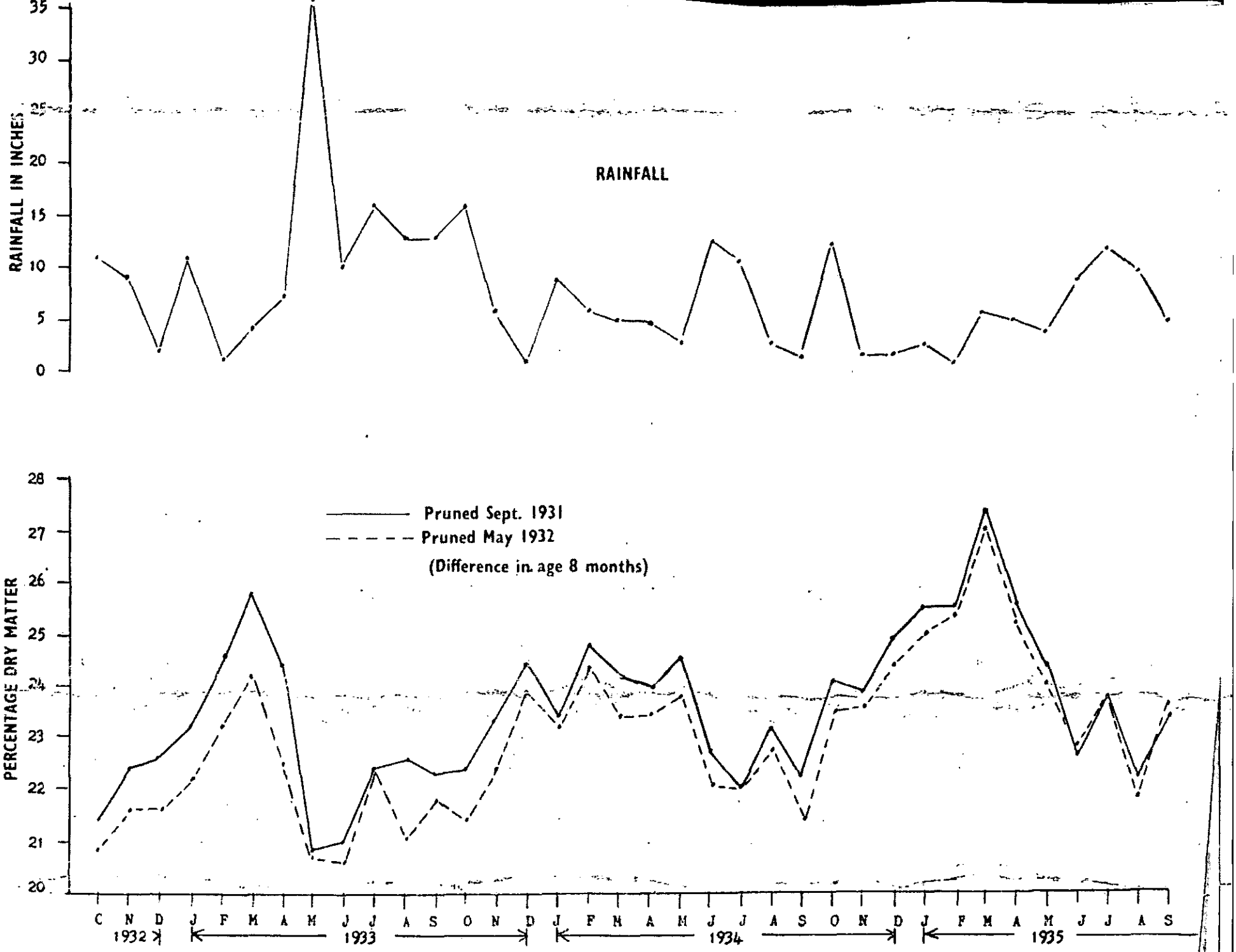

Fig. 1. Effect of age from pruning on monthly percentage dry matter for a period of 3 years (Graph also shows seasonal variation)

From observations made for each pluck on clonal material, which differed in age by 2½ years, further proof was obtained that mature leaf contains a higher percentage of dry matter, but not as high as generally believed. The maximum difference noted was 2 per cent. Figure 2 represents the percentage dry weight of the leaf in question for 30 consecutive plucks of 500 bushes comprising 47 different clones.

The seasonal fluctuations are again prominent and it was observed once more that the increases and decreases were not in the same proportion as the rainfall. These investigations do show, however, that on the whole age from pruning has a definite effect on the outturn of made tea to green leaf but the difference in outturn may be anything from 0 to 3 per cent. There is no evidence to indicate what causes this variation.

Going over the ground covered so far it is clear why golden rules cannot be laid down. In addition to the many complex factors which have been discussed there are others which make themselves felt in the course of manufacture. The more important of these are:—

(*a*) loss in dry matter during withering,

(*b*) final moisture content of the made tea,

and (*c*) standard of plucking.

Loss in Dry Matter during Withering.—According to Evans (T. R. I. Bull. 9, p. 7) "The actual dry weight of the leaf diminishes according to the time spent in withering and if the wither is very slow such as occurs in wet weather this loss of dry matter is considerable". The figures he obtained are given in Table 6.

Table 6. *Effect of period of withering on dry matter.*

Period of withering	weight of dry matter
Fresh leaf (100 lb.)	18.8 lb.
20 hours	18.5 lb.
40 hours	18.0 lb.
48 hours	17.6 lb.

Up to 20 hours the loss in dry weight is 0.3 per cent. but on prolonging the wither the loss increases to a significant figure of 1 per cent. Calculated in terms of tea made, or crop, these figures are equivalent to a loss in crop of up to about 1 per-cent. for short withers and 5 per cent. for long withers, and cannot be considered negligible.

Since it is respiration which gives rise to the loss of dry matter there is reason to believe that temperature and physical condition of the leaf also play an important part. High temperatures and sappy leaf can therefore be expected to increase the loss of dry matter and thus reduce the outturn of made tea to green leaf.

Final Moisture Content of the Made Tea.—The hygroscopic properties of tea are well known. Under the conditions obtaining in any factory, tea must absorb moisture after it is fired. The amount it will take up before it is packed will depend on the period of exposure during sifting and picking and of storage in the bins. It is perhaps not realized that for an increase of only 2 per cent. in the moisture content of the tea the percentage outturn of made tea to green leaf inevitably increases

by approximately 0.5 per cent. This is no insignificant increase considering that estates as a rule attach undue importance even to small differences in the decimal fraction of an outturn figure. If final firing prior to packing is carried out the outturn is lowered.

In examining figures for outturn it is therefore essential to know whether they are computed from (*a*) fired tea (*b*) sifted tea (*c*) stored tea or (*d*) tea that has been final fired.

Standard of Plucking.—The product obtained after firing comprises fibre, fluff, stalk and waste tea, components which are removed in the sifting operation. Made tea as it is understood to be, consists of what is left. It is plainly clear therefore that the final figure for percentage outturn is dependent on the amount of refuse discarded, which may be negligible for a very high standard of leaf but as high as 6 per cent. for coarse plucking.

To sum up, weather is undoubtedly one of the important considerations but the other factors are equally important and must not be lost sight of. It is for this reason that it is impossible to pre-determine the percentage outturn of made tea to green leaf by determining the moisture content of leaf arriving at the factory. In any case it is not practicable since each sack of leaf will have to be considered if a representative sample of the day's leaf is to be taken. Accordingly, percentage outturn is a figure most difficult to check. The magnitude of such an undertaking will be better appreciated by a study of the figures given in Table 7. These have been abstracted from records of manurial experiments carried out under the supervision of the Plant Physiology department.

Table 7. *Variation in percentage dry matter of green leaf.*

Age from pruning		PERCENTAGE DRY MATTER				
		A	B	C	D	E
4-5 months	Minimum	20	19	19	20	18
	Maximum	26	28	26	26	27
6-12 months	Minimum	16	18	17	17	17
	Maximum	26	30	26	30	25
36-48 months	Minimum	—	17	16	18	15
	Maximum	—	28	27	27	28

The considerable deviations shown in the foregoing table are not only the result of weather conditions but also of the character of the plucked shoot. A number of causes may be all operating together to give the fluctuations noted. It will be of interest to note that tipping leaf may very well give an outturn as high as mature leaf, as these figures reveal.

In conclusion, it only remains to give a brief summary of actual outturn figures recorded at St. Coombs Estate and the extent of the variations. The lowest daily outturn obtained has been 17 per cent. and the highest 29 per cent.; the lowest monthly outturn 20 per cent. and the highest 28 per cent.; the lowest annual outturn 22 per cent. and the highest 23½ per cent. No useful purpose will be served by giving further details, but a frequency distribution of outturns for a period of 12

consecutive months may interest the reader. This is set out in the form of a diagram, Figure 3, in which each column is proportional in height to the number of days a particular outturn has been recorded.

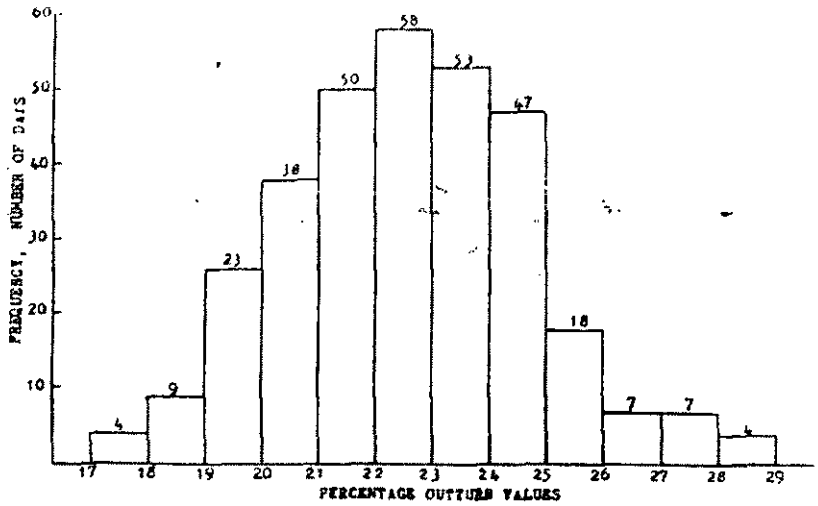

Fig. 3. Frequency distribution of daily percentage outturn for one year. (Total rainfall 120").

The total rainfall for the period in question was 120", the highest monthly rainfall being 36" and the lowest 0.5". Total number of wet days was 260.

The main things to notice about this diagram are that there is a peak showing a tendency for outturns to be concentrated between 20 per cent. and 25 per cent. and that outturns below and above these values are rare. All these figures and those quoted in the preceding paragraph have been calculated from 'graded' tea (broken mixed included) and leaf from which no deductions have been made. Refuse tea has not been included.

It may or may not be possible to generalize from the results obtained at St. Coombs, but it would appear highly improbable from this evidence and what is available from estates in different districts that any average estate would be able to declare an annual, *true* outturn varying much from 22 to 23 per cent. In certain dry areas in Uva, where at times the annual rainfall does not exceed 50", an annual outturn close upon 24 per cent. may not be unusual, whilst in the very wet districts with an annual rainfall approaching 200", an outturn of 22 per cent. may be difficult to obtain. However, in contemplating the final figure arrived at, the circumstances under which it has been recorded must be duly considered, because it is all too easy to forget the way in which it is derived.

I should like to express my indebtedness to the Plant Physiology department for some of the figures published in this article.