THE EFFECT OF MANURIAL DRESSINGS, WEATHER CONDITIONS, AND MANUFACTURING PROCESSES ON THE QUALITY OF TEA AT TOCKLAI EXPERIMENTAL STATION, ASSAM.

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Introduction.

This paper gives the results of the experiments conducted at the Tocklai Experimental Station, Assam, during 1934 on the effect of various cultural factors on the market price of tea. The whole of the experimental work was done by C. J. Harrison, and the statistical analysis by S. S. Bose in conjunction with the other collaborator.

The leaf for this experiment was obtained from two blocks of tea at Borbheta, District Sibsagar, Assam. Both were planted in 1921 from the same nursery of Tingamira (light leaf Assam) variety. One block A, on which the effects of various nitrogenous manures are being compared, was medium pruned at 18 inches in 1923 and since top pruned, while the other block B, devoted to comparisons of the effects of various quantities of cattle manure on yield, was collar pruned at the same time, and since then top pruned.

The plucking and manufacturing period lasted from the first week of June, 1934 to the first week of August of the same year. The climatic conditions during these two months of the experiment together with their bearing on the manufacture of tea are given in Table 1.

Table 1. Climatic Conditions.

Date	Average valuations in *annas* and *pies*	Condition of leaf plucked	Temp. at 8 A.M. on the day of manufacture.	Conditions for withering during the previous afternoon and evening.
June 8	11—9·9	dry	86° F	Very good (8 hours sunshine, light breeze).
,, 15	11—3·6	wet	72°·5 F	Poor (no sun or wind).
,, 22	10—11·7	wet	73° F	Very poor (no sun or wind).
,, 29	11—9	Slightly wet.	79° F	Very good, surface water on leaf dried in 2 hours on chungs.
July 13	11—9·1	dry	79°·5F	Poor wither (only 2 hours sunshine and 84° F. max. temp.).
,, 20	11—4·6	dry	81° F	Very quick wither, some leaf blackened, max. temp. 97° F. 6¾ hours sunshine.
,, 27	11—7·2	dry	80° F	Good drying wind though temp. low (81°F. and no sunshine)
Aug 4	10—9·2	wet	78° F	Max. temp. 90° F., 6 hours sunshine, very little breeze.

It will be seen from Table 1 that tea was plucked on 8 occasions at intervals of 7 days. On each occasion (*i.e.*, date) eight samples of leaf were plucked from the following 8 series of plots, each of which was under one definite manurial treatment.

Block A. (1) Unmanured (A).
(2) Amon. Sulphate.
(3) Calcium Cyanamide.
(4) Oil Cake.
(5) Blood meal.
(6) Horn meal.
Block B. (7) Unmanured (B).
(8) 5 tons Cattle manure.

Methods employed in Manufacture Experiments.

The leaf samples were brought into the withering shed about midday and spread in turn on bamboo racks covered with cloth, (which was always boiled each day before manufacture). Rolling started next morning at 4 A.M. in the hot weather experiments and at 6 A.M. during the cooler weather in October and November. Thus the leaf had a minimum of 15 hours wither. The leaf was spread for withering in the same order as that of rolling.

There are two rollers, designated East and West rollers. They are of the same type, but even when running at identical speeds and with the same pressure, do not produce identical effect, *i.e.*, the same bruising and twisting action, on the leaf.

The East roller, on account of slightly larger clearance between box and table, allows considerably more leaf to escape and be ground up between the edge of the box and the table. This leaf is continually swept back, but the resultant effect is to cause more bruising and breaking up of the leaf.

The rolling system was:—first roll of one hour, starting with 10 minutes no pressure and then alternately 10 minutes pressure and 5 minutes no pressure. The leaf was then dropped, balls broken up by hand, and the leaf returned to the same roller. The time occupied between stopping the first roll and starting the second was 5 minutes. The second roll was for half an hour with alternately 10 minutes pressure, and 5 minutes no pressure.

As the pressure cap is a wooden one about 20 inches square and 5 inches deep and is not held down by any spring, the maximum pressure obtainable is not very great, small in fact, in comparison with that of the larger types of roller used in factories.

The dryer is a Single Tilting Tray Sirocco, divided into two equal portions so that two samples can be fired simultaneously.

Eight different treatments were under trial. Now supposing eight samples of leaf which had had identical treatments are to be manufactured, the most convenient way is to roll, ferment and fire them in pairs, one of each pair in the East and one in the West roller. There would thus be 4 pairs of rolls, at 95 minutes intervals (allowing 90 minutes for each roll and 5 minutes for filling the roller).

If, as in the case of our experiments, the eight samples of leaf are from plots differing in manuring, plucking, or some other way, the relative values of the resulting teas could not be expected to represent truly this treatment, but should be affected by the order in which the samples were rolled, or by the roller used.

Firstly, the 4 teas rolled in the East roller might differ from those rolled in the West roller, and secondly the four pairs of teas might differ according to the order in which they were rolled, since the second pair gets 95 minutes, the third 190 minutes, and the fourth pair 285 minutes longer withering than the first pair, and moreover, the later rolled teas are rolled and fermented usually at higher temperatures than those earlier rolled.

When treatment is such as to produce very wide differences in the teas, the effect of a difference of 3 or 4 hours in withering, or of the different actions of the rollers, is to a great extent masked. When however the treatment produces very much smaller differences as in Manuring experiments, the effect of the rollers and order of rolling shows up.

It is impossible to eliminate these outside factors, nor is it necessary to do so. By manufacturing the samples a sufficient number of times we can arrange for all the samples to occupy every position in the order of manufacture the same number of times, and to be rolled an equal number of times in each roller. If the eight samples are all manufactured on eight occasions, each sample can be rolled 4 times in the East and 4 in the West roller ; each sample can also occupy on two occasions, each of the first, second, third and fourth positions in order of rolling.

After the tea has been fired, it is cut by passing it through a Savage Cutter with $\frac{1}{2}''$ cells, and then through the same cutter with $\frac{1}{4}''$ cells. The dust and very small "fannings" are sifted out and comprise about 7% of the total bulk. The very coarse leaf, comprising about 6% of the total bulk, is also sifted out. Thus the tea from which samples are taken comprises at least 85% of the original leaf manufactured, and consists of particles of fairly even size so that little difficulty occurs in taking true samples for valuation by the Taster or for analysis.

The percentages of dust and of coarse tea were identical for all samples on any particular manufacture.

Statistical Design of the Experiment.

As already mentioned, the eight samples of tea were rolled in 2 rollers in 4 pairs with 1 hour 35 minutes between successive pressings. For ensuring uniformity, the arrangement of the experiment was such that, during the course of whole series, each sample occupied each position in the order of the manufacture twice, and was rolled an equal number of times under each of the rollers. The manufactured tea was finally tasted by four different Tasters in Calcutta who awarded marks to each sample in terms of valuations in annas and pies.

We thus have five factors of variation with regard to the valuation of tea :—

(1) Manurial treatments.
(2) Date of Manufacture.
(3) Order of Manufacture.
(4) The East and the West Rollers.
(5) Judgment of Tasters.

The design of the experiment was in the form of a Latin Square for each Taster, in which the columns and rows were the dates of manufacture and orders of manufacture and roller respectively. The results of the four Tasters may be analysed just as in four Latin Squares, the assumption being that valuation estimates by Tasters are more or less normally distributed. A similar assumption is made with regard to yields in agricultural experiments in using R. A. Fisher's Analysis of Variance. One point of difference however must be kept in mind. In field experiments, the residual variance includes the interaction of treatment and blocks (or of rows and columns in Latin Squares), and it is only on the hypothesis that such interaction is absent or negligible that the residual variance can be considered to be an estimate of the sampling variance of the experiment. In the present material, however, we are not sure whether the interactions between Tasters and other factors of variation are really negligible; in fact some of them are possibly significant. Again the structure of the experiment was such that the interactions between order and dates of manufacture as well as the interactions between treatments and orders and dates of manufacture were confounded and cannot therefore be estimated. The variances due to these interactions are thus included in the residual variance.

Statistical Analysis.

In the present experiment, the valuations have been analysed separately for each Taster (Table 2) and a combined analysis is shown in Table 3.

Table 2. Analysis of Variance: Mean Squares (in Squares of half pies)

Significant at the level of 5% probability marked (*), 1% probability marked (**)

Factors	Degrees of Freedom	Taster A	Taster B	Taster C	Taster D
Treatment ...	7	238·8	35·4	8·5	74·7
Date ...	7	2263·7**	4431·8**	297·0**	607·9**
Roller ...	1	375·4	192·5	43·9	420·3*
Order ...	3	952·2*	337·4**	15·1	200·3*
Roller × Order	3	476·9	116·7	5·1	90·9
Residual ...	42	201·5	59·7	13·9	95·2

Table 2 shows that all the 4 Tasters agree in three points namely:—

(1) Want of response of the manurial dressings.

(2) Significant differences between different dates of manufacture.

(3) Absence of any interaction between position of roller and the order of manufacture.

But there was some divergence of opinion regarding the two other effects:—

(4) The action of the roller.

(5) The order of manufacture.

Thus, while Tasters A, B and C do not show any significant difference in the quality due to the action of the roller, Taster D finds some difference. Again, Taster A, B and D agreed that the order of manufacture did produce an appreciable difference in the quality, while Taster C noticed no such difference.

These differences in the estimate of quality among the Tasters is also seen in the combined analysis of variance given in Table 3.

TABLE 3. ANALYSIS OF VARIANCE: COMBINED EXPERIMENT.

Significant at the level of 5% probability marked with (*), and at the level of 1% probability marked with (**).

Factors	Degrees of Freedom	Mean square in half pies	Ratio of Variances
Taster ...	3	16916·49**	182·76
Treatment ..	7	80·34	0·86
Treatment × Taster	21	92·35	0·96
Date ...	7	3120·70**	33·71
Date × Taster ...	21	1493·21**	16·13
Roller ...	1	911·28**	9·85
Order ..	3	675·69**	7·29
Roller × Order ...	3	317·95**	3·43
Roller × Taster ...	3	40·25	0·43
Order × Taster ...	9	276·44*	2 98
Roller × Order × Taster ...	9	123·88	1·34
Residual ...	168	92·58	——

The data for all the Tasters have been here pooled together; the results are more precise because of the large number of replications with regard to treatments, date and order of manufacture and the position of the roller. In addition, these results show the differential response of the Tasters with regard to the primary effects. We notice that:—

(1) Treatments (manurial dressings) had no effect on quality, all the Tasters agreeing on this point.

(2) Dates of manufacture produce a significant effect on quality, but such effect was assessed differently by different Tasters.

(3) The roller and the order of manufacture significantly affect the quality, and possibly also their interaction, the different Tasters being in general agreement in this matter.

(4) The Tasters however differ very considerably in their estimates of quality under different conditions.

Manurial Dressings.

The detailed results for manurial dressings (treatments) are given below.

Table 4. Manurial Dressings (Mean Values of Tea in Pies).

Manurial Treatments	Taster A	Taster B	Taster C	Taster D	Mean
Unmanured (A) ...	142·12	142·94	129·31	134·63	137·25
Amon. Sulph. ...	145·00	142·94	128·56	133·38	137·47
Cal. Cyanamide ...	138·25	141·62	128·63	133·63	135·53
Oil-cake ...	146·62	140·50	129·38	134·25	137·68
Blood meal ...	142·12	143·06	129·38	135·00	137·39
Horn meal ...	140·12	141·37	128·88	136·75	136·78
Unmanured (B) ...	140·75	142·50	128·06	132·13	135·86
Cattle manure ...	143·94	143·62	128·25	136·63	138·11
Mean ...	142·36	142·32	128·80	134·55	137·00
Standard Error ...	2·51	1·37	0·66	1·68	0·85

The treatment differences are within the limits of sampling error and cannot be considered significant. We find therefore that the manurial treatments studied here have no appreciable effect on the market value of the tea.

Dates of Manufacture.

The dates of manufacture, which ranged over 8 weeks from June 8 to August 4, affected significantly the valuation of tea as will be seen from the mean values given in Table 5. There is however no steady time trend in the variation of the quality. On the

Table 5. Dates of Manufacture. (Mean Values of Tea in Pies).

Dates of Manufacture	Taster A	Taster B	Taster C	Taster D	Mean
June 8 ...	155·82	150·00	133·75	128·25	141·9
,, 15 ...	141·75	135·00	130·75	135·00	135·6
,, 22 ..	139·12	126·38	125·06	136·13	131·7
,, 29 ...	149·25	157·69	124·56	132·38	141·0
July 13 ...	146·62	153·00	127·56	137·25	141·1
,, 20 ...	141·00	139·50	130·31	135·75	136·6
,, 27 ...	137·62	148·87	129·75	140·62	139·2
August 4 ...	127·75	128·13	128·69	128·13	129·2
Mean ...	142·36	142·32	128·80	134·55	137·00
Standard Error	2·51	1·37	0·66	1·68	0·85

whole June 8 gave in the present investigation the best quality of tea. It was followed by regularly worse quality for two weeks, after which the tea is once more found to be of a high quality approaching that of June 8.. This was maintained for two weeks only, after which there were irregular fluctuations. This is however deduced from the mean values of all the Tasters concerned. Individually there were marked discrepancies among the Tasters, and in many cases the very order of the quality (as given by the respective valuation) exhibited considerable variations from Taster to Taster.

A detailed comparison with weather conditions bring out interesting facts. We observe that June 8 and 29 were particularly suitable for withering of tea, and on both these occasions, tea was of the highest quality. On June 15 and more so on June 22, there was no sun or wind and the quality was definitely inferior on both these dates. July 13 had only 2 hours of sunshine with a maximum temperature 84°F, so that the wither was expected to be poor and we find that according to Tasters A and B there was a significant deterioration of quality although this difference was not observed by two other Tasters C and D. There was a high temperature (Max. 97°F) together with $6\frac{3}{4}$ hours of sunshine on July 20, in fact the heat was so great that some of the leaves were blackened and we notice that Tasters A and B found teas manufactured on this day to be distinctly of a poor quality. The seventh occasion (July 27) had a good drying wind although the temperature was rather low (81°F) and sunshine was practically nil. Tasters B and D found it good for tea while Taster A noticed a distinct falling off in quality. On the last occasion (August 4), a high temperature (90°F) with very little breeze yielded one of the worst qualities of tea in this experiment.

Conditions of sunshine, breeze and temperature are thus found to play a very important part in determining the quality of the manufactured tea. It is interesting to notice that Tasters A and B agreed more closely in their judgments with the expectations from weather conditions than the other two.

Rollers.

There were two rollers, the East and West ; the results indicate that the east roller is distinctly superior to the other so far as the quality of tea is concerned. The tasters were all in fair agreement with regard to this fact as will be seen from Table 6 ; in fact the differences in valuation between east and west rollers remained roughly of the same magnitude for the different tasters.

Table 6. East and West Rollers. (Mean Values of Tea in Pies)

Rollers	Taster A	Taster B	Taster C	Taster D	Mean
East Roller ...	143·58	143·19	129·22	135·47	137·37
West Roller ...	141·16	141·45	128·39	132·91	135·97
Standard Error	1·26	0·68	0·33	0·84	0·43

This difference may be attributed to the fact that the East roller had a little more clearance between box and table. It allows leaf to escape which gets ground up between table and the lower edge of the box, and this would be expected to give a slightly stronger tea on infusion.

Order of Manufacture.

It has already been stated that the samples of tea were rolled in 4 pairs at an interval of 1 hour 35 minutes at the following hours:—

First Rolling	...	... 4- 0 A.M.
Second ,,	...	... 5-35 A.M.
Third ,,	...	... 7-10 A.M.
Fourth ,,	...	... 8-45 A.M.

Mean valuations given in Table 7 indicate that teas manufactured at the second (5-35 A.M.) and third (7-10 A.M.) rolling were practically of the same quality; while those rolled first (4-0 A.M.) and last (8-45 A.M.) were of significantly poorer quality.

Table 7. Order of Manufacture. (Mean Values of Tea in Pies).

Time of Rolling	Taster A	Taster B	Taster C	Taster D	Mean
First : 4-0 A.M.	138·00	139·62	128·09	135·75	135·3
Second : 5-35 ,,	146·37	143·28	129·16	135·38	138·6
Third : 7-10 ,	144·72	144·94	128·91	133·75	138·0
Fourth : 8-45 ,,	140·37	141·44	129·06	131·88	135·7
Standard Error	1·78	0·96	0·45	1·18	0·68

It may be observed that the tea rolled at 8-45 A.M. (*i.e.*, the last rolled) gets an over-high temperature before fermentation is finished at 12-15 P.M. Regarding the first rolled stuff, it is likely that the leaf had not withered long enough before rolling. This may partially explain the differences observed in the quality of tea under the four orders of manufacture, but it should be noticed that the Tasters showed appreciable divergences in their respective valuations (Table 7).

Roller and Order.

Table 3 shows that there is an appreciable interaction between rollers and order of manufacture, but the second order interaction (Roller-Order-Taster) is not signigcant. Evidently the Tasters were in agreement regarding the existence and magnitude of the Roller and Order interaction. The results may therefore be shown on the basis of the mean of the four Tasters, and are given in Table 8.

TABLE 8 INTERACTION BETWEN ROLLER AND ORDER. (MEAN VALUES OF TEA IN PIES).

Roller	First	Second	Third	Fourth	Mean
East Roller ...	135·0	139·0	140·0	137·5	138·0
West Roller ...	136·0	137·5	136·0	134·0	136·0
Difference (E—W)	1·0	1·5	4·0	3·5	2·0
Standard Error of Difference ...	1·78	0·97	0·47	1·22	0·61

In the first and second order of manufacture, both the rollers gave practically identical results, but in the third and fourth orders the East Roller was decidedly superior. This gives it the superiority in the average mean value. Apparently the larger clearance between box and table in the East Roller is effective only in the two later rollings but not in the two early morning ones.

JUDGMENT OF TASTERS.

The mean valuations by each Taster are shown in Table 9.

TABLE 9. JUDGEMENT OF TASTERS. (MEAN VALUES OF TEA IN PIES).

Tasters	Mean valuation of Tea in pies.	Percentage
Taster A	142·4	104·2
,, B	142·3	103·9
,, C	128·8	94·0
,, D ...	134·2	98·0
Mean	136·9	100·0
Standard Error ...	0·68	0·05

Tasters A and B on the whole gave equal mean estimates. Taster D was more stringent, while Taster C gave the lowest estimates of prices. Percentage figures for comparison are also shown in column 3 of Table 9.

CORRELATION BETWEEN TASTERS.

The valuation of tea by Tasters is essentially subjective ; it is therefore important to investigate how far the valuations by independent Tasters agree among themselves. This

has been done for the present material by using the method of analysis of covariance given in Table 10.

TABLE 10. CORRELATION BETWEEN TASTERS.

Factors	Degrees of Freedom	Pairs of Tasters						Expected 5%
		A.B.	A.C.	A.D.	B.C	B.D.	C.D.	
Treatment ...	7	·0138	·2410	·1621	−·3290	−·3414	·5952	·7067
Date ...	7	·7086*	·2124	·1173	·3410	·0129	−·2366	·7067
Roller and Order	7	·6697	·2753	·4380	·7503	·1582	·2541	·7067
Residual ...	42	·4702*	·2102	·2556	−·1513	·3891*	−·5835*	·3044

Most of the coefficients of correlation given in Table 10 are statistically negligible. Although this is no doubt partly due to the number of degrees of freedom available being small, the results suggest an appreciable lack of agreement between the judgments of different Tasters. It is desirable to investigate this question in greater detail with the help of adequate statistical methods.

In conclusion, it is a pleasure to express our indebtedness to Mr. H. R. Cooper for his valuable assistance and criticism during this investigation.

SUMMARY.

Tea leaf from eight different plots under various manurial treatments (Unmanured, Amon. Sulphate, Calcium Cyanamide, Oil Cake, Blood meal, Horn meal, Cattle manure) was collected on different dates (June 8, 15, 22, 29 ; July 13, 20, 27 and August 4, 1934). The eight samples of tea were rolled under two (East and West) rollers in 4 pairs with 1 hour 35 minutes between successive rollings. The manufactured tea was finally tasted by four different Tasters in Calcutta, valuation being given in annas and pies. The statistical design of the experiment was in the form of a Latin Square for each Taster with dates and order of manufacture as rows and columns respectively. Interactions between order and dates of manufacture, and between treatments and order and dates of manufacture were confounded, so that the variances due to these interactions were included in the residual variance.

Manurial treatments had no effect on the valuation, all the Tasters agreeing on this point. Dates of manufacture affected the valuation appreciably, as the quality was controlled to some extent by climatic factors ; but the Tasters showed individual differences in the agreement of their valuations with expectations from weather conditions. This was to a large extent due to the fact that, although all tasters received samples by the same post, they did not all taste at once, and there were occasionally drops in market prices in the interval. Teas manufactured at the second and third rollings were distinctly better in quality, and the East roller showed an appreciable advantage, but this superiority was effective only at the third and fourth rollings. The Tasters showed considerable variation in their individual judgments.

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