# Early Selection for Black Tea Quality

By TADAYUKI TOYAO

Makurazaki Branch, National Research Institute of Tea

Good quality of fresh leaves is required for producing high-quality tea. To improve the quality of tea leaves, selection of suitable climatic condition, improvement of crop management including manuring, and plucking methods as well as genetic improvement of trees are needed.

Recently, growing of clonal varieties is taking place of traditional seed propagated varieties. The quality of green tea will be improved very much by this new method. Area under clonal varieties reached 36% of the total tea area in 1973. The clonal varieties have been selected with special emphasis on good quality and resulting economic profit.

Quality improvement by the use of excellent clonal varieties has been adopted not only for green tea, but also for black tea production. Excellent clonal varieties, therefore, are now greatly needed.

A procedure of selecting excellent genotype for black tea in an earlier stage of breeding process will be described with recent data[1),2)].

## Seasonal and clonal variation in fermentation ability and tannin content, and heritability estimates

Total polyphenol (tannin) content and polyphenol oxidase activity (fermentation ability) of tea leaves are major factors controlling the quality, because specific aroma and taste of black tea are produced in the process of oxidation of polyphenols.

The chloroform test has been used recently for the selection of individuals in the breeding of black tea since it is a simple and excellent method to examine the quality with small samples[3)]. Polyphenol oxidase activity can be indicated by distinct clonal differences of leaf color in the chloroform test[1)].

Ten groups of Assam hybrids were examined by this method to clarify the variability of fermentation ability and tannin content in relation to plucking seasons and samples.

Results are shown in Fig. 1, in which visual grading of fermentation ability was made with experiment Nos. 1 and 2, while the grading was made by aL value with experiment No. 3 through No. 5. (The aL value measured with lower surface of young leaves at 1.5 hours after the treatment has the highest correlation with polyphenol oxidase activity).

The fermentation ability showed no distinct difference by plucking seasons and groups.

On the other hand, tannin content showed a wide variation ranging from 11 to 29%. It was low in the first plucking season (I: spring plucking) and fourth plucking season (IV: autumn plucking) but high in the second and third plucking seasons (II, III: summer plucking).

Out of 13 clones of experiment 2 and 23 clones of experiment 5, clones which have complete data for 1, II, and III pluckings were selected to calculate analysis of variance.

It was found that both groups showed great clonal differences in fermentation ability, and great seasonal differences in tannin content.

Taking the variance component of clones × plucking seasons as an environmental variance, the order of heritabiilty estimates in broad sense can be expressed as fermentation ability>quality>tannin content. The fermentation abiilty, therefore, seems to be most stable and easily measurable throughout all plucking seasons.

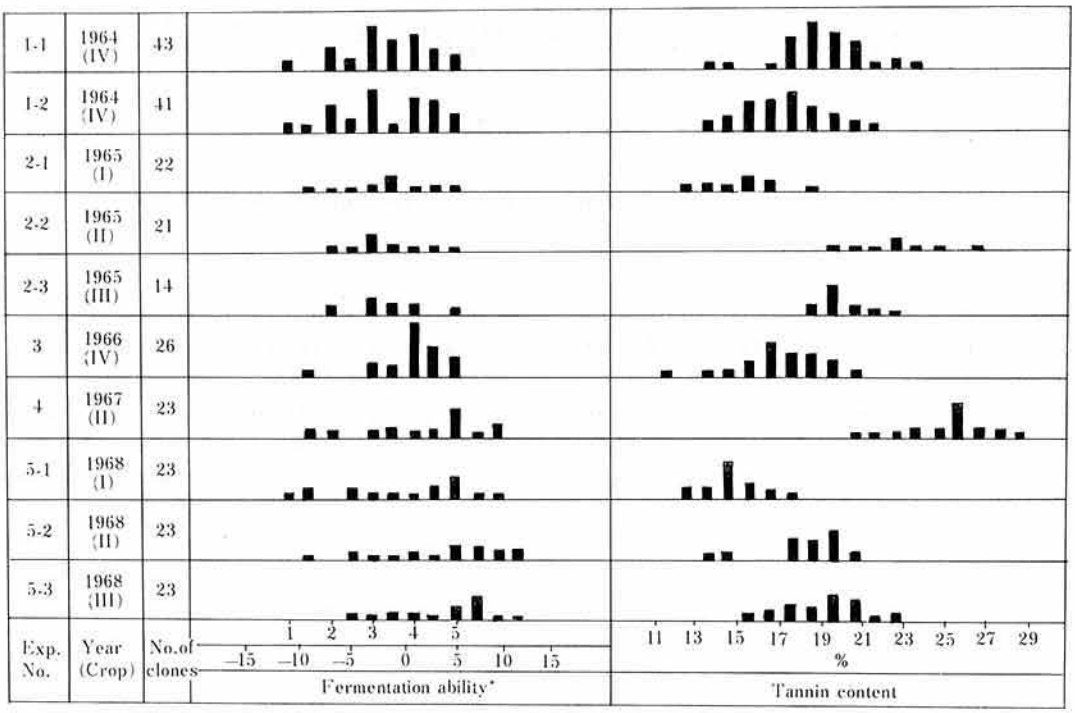


Fig. 1. Seasonal and clonal variation of fermentation ability and tannin content in tea plant
* Fermentation ability was shown in the range of 1 (=poor) to 5 (=good) in the chloroform test (Expt. Nos. 1 and 2), and also shown as values of aL (in an a–b expression manner according to HUNTER) measured with color and color difference meter (Expt. Nos. 3, 4 and 5).

## Path coefficient analysis of correlation between quality, fermentation ability and tannin content

Correlation coefficients between quality and fermentation ability or tannin content were calculated with 10 groups of material, and subjected to the path coefficient analysis according to the path diagram shown in Fig. 2. Direct and indirect effects of fermentation ability and tannin content on the quality and the determination coefficients of residuals were calculated (Table 1).

The correlation coefficient between fermentation ability and quality was significant irrespective of samples and plucking seasons. A further examination indicated that the correlation coefficient is low in the first and fourth plucking seasons while it is high in

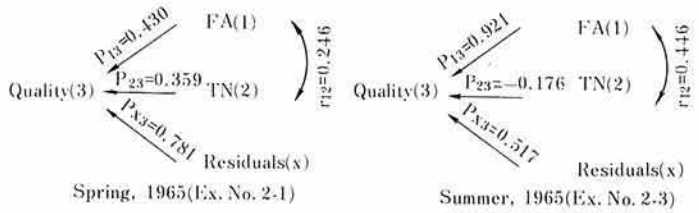


Fig. 2. Path diagram and coefficients of fermentation ability (FA) and tannin content (TN) influencing black tea quality (Quality) in spring and summer plucking seasons (1965)

**Table 1. Path coefficient analysis of correlation (r) to determine the direct and the indirect effects of fermentalion ability and tannin content on black tea quality potential**

| Expt. No. | Materials | | | Fermentation ability (1) | | | | Tannin content (2) | | | | Determi. coef. of residuals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of clones | Pluck. season | Year | $r_{13}$ | $p_{13}$ | $r_{12}p_{23}$ | mean (%) | $r_{23}$ | $p_{23}$ | $r_{12}p_{13}$ | mean (%) | $P^2x_3$ |
| 1-1 | 43 | IV (Oct.) | 1964 | 0.435** | 0.274 | 0.161 | 3.30 | 0.608** | 0.524 | 0.084 | 18.69 | 0.562 |
| 1-2 | 41 | IV (Oct.) | 1964 | 0.462** | 0.147 | 0.315 | 3.33 | 0.707** | 0.634 | 0.073 | 17.22 | 0.484 |
| 2-1 | 22 | I (Apr.) | 1965 | 0.519* | 0.430 | 0.088 | 3.65 | 0.465* | 0.359 | 0.109 | 14.90 | 0.610 |
| 2-2 | 21 | II (Jun.) | 1965 | 0.773** | 0.724 | 0.049 | 3.42 | 0.500* | 0.087 | 0.413 | 22.19 | 0.397 |
| 2-3 | 14 | III (Jul.) | 1965 | 0.841** | 0.921 | −0.080 | 3.35 | 0.244 | −0.176 | 0.420 | 20.05 | 0.268 |
| 3 | 26 | IV (Oct.) | 1966 | 0.389* | 0.369 | 0.020 | (1.50) | 0.669** | 0.658 | 0.011 | 16.92 | 0.416 |
| 4 | 23 | II (Jun.) | 1967 | 0.783** | 0.827 | −0.044 | (1.90) | −0.131 | 0.137 | −0.268 | 25.10 | 0.370 |
| 5-1 | 23 | I (Apr.) | 1968 | 0.645** | 0.542 | 0.103 | (−0.21) | 0.537** | 0.397 | 0.140 | 14.45 | 0.437 |
| 5-2 | 23 | II (Jun.) | 1968 | 0.708** | 0.712 | −0.004 | (3.65) | −0.112 | 0.021 | −0.133 | 18.26 | 0.498 |
| 5-3 | 23 | III (Jul.) | 1968 | 0.753** | 0.753 | 0.000 | (3.99) | −0.021 | 0.016 | −0.037 | 18.93 | 0.430 |

Remarks: Correlation coefficients of the variables on tea quality are significant at 0.05 (*) and 0.01 (**) level, respectively.

Path coefficient ($p_{13}$) expresses the direct effect of fermentation ability on black tea quality and the indirect effect via tannin content is $r_{12}p_{23}$, and both the effects of tannin content are $p_{23}$ and $r_{12}p_{13}$, respectively.

the second and third.

Although tannin content has been believed to have a close relation with the quality, significant correlation was observed only with the first and fourth plucking but not with second and third plucking.

Path coefficient analysis indicated that the correlation coefficient ($r_{13}$) between fermentation ability and the quality can be divided into two components: one is a direct effect ($P_{13}$) and the other is an indirect effect ($r_{12}P_{23}$) through the tannin content.

When the contribution of fermentation ability and that of tannin content to the quality were compared in terms of direct effect ($P_{13}$ or $P_{23}$), the value of $P_{13}$ was high with second and third plucking, but low with first and fourth plucking. On the contrary, the direct effect of tannin content ($P_{23}$) showed a reverse relation. Thus, it was found that the tannin content is not involved in the clonal variation of quality of summer plucking tea.

The determination coefficient of residuals ($p^2 \times 3$) which indicates effects of factors other than fermentation ability and tannin content ranged from 0.268 to 0.610, with mathematical means of 0.447. It shows that about 50 to 60% of the clonal variation in the quality of black tea are contributed by these two factors i.e. the fermentation ability and tannin content.

## Direct selection of black tea quality and indirect selection by means of fermentation ability and tannin content

A response to selection (Ry) of a character (Y) is shown by the product of selection differential (Sy) and heritabiilty ($h^2y$), and a response to indirect selection (CRy) by a correlated character (X) is expressed by the following equation[4].

$$CRy = ih_x h_y r_A \sigma_{py}$$

In an indirect selection of a character (Y) through other character (X), the response to selection (CRy) of Y is determined by the square root of the heritability of both characters (hx, hy), the coefficient of genetic correlation of both characters ($r_A$), the phenotypic standard deviation of Y ($\sigma_{py}$) and the intensity of selection ($i = S_x/\sigma_{px}$).

On the basis of this theory, effectiveness of direct selection and that of indirect selection,

**Table 2. Effectiveness of direct and indirect selection of black tea quality (Quality), fermentation ability (FA) and tannin content (TN) for black tea quality**

| | Experiment No. 2 | | | Experiment No. 5 | | |
|---|---|---|---|---|---|---|
| | FA | TN | Quality | FA | TN | Quality |
| Heritability ($h^2$) | 0.792 | 0.346 | 0.525 | 0.805 | 0.520 | 0.767 |
| Correlation (r) | 0.834 | 0.702 | 1.000 | 0.784 | 0.102 | 1.000 |
| Selection effectiveness | $h_x h_y r$ 0.538 | $h_x h_y r$ 0.299 | $h^2$ 0.525 | $h_x h_y r$ 0.616 | $h_x h_y r$ 0.066 | $h^2$ 0.767 |

as well as effectiveness of selections by correlated characters in the indirect selection can be compared with some assumptions.

Table 2 shows the effectiveness of selection for black tea quality determined by heritability estimates and correlation coefficients obtained from experiments 2 and 5.

Effectiveness of direct selection for the quality ($h^2_y$) was 0.525 in experiment 2 and 0.676 in experiment 5. Effectiveness of indirect selection through fermentation ability ($h_x h_y r$) were 0.538 and 0.616 respectively. The latter two values did not differ much from the formers, whereas the effectiveness of indirect selection through tannin content showed less values, 0.299 and 0.066 respectively.

The chloroform test is not costly, and this method offers an example that, in the selection of some characters such as yield or quality consisted of complicated component characters, an indirect selection through related and measurable characters (with high heritability) is far effective than direct selection.

## Selection procedure at each stage of breeding

*1) Selection of seedlings in nursery bed*

Hybrid seedlings in nursery bed are pruned at about 20 cm above ground six months after germination. After new shoots came out, one or two of them are sampled from each seedling for the chloroform test. The second test is carried out with new shoots sprouted after the first test. Then the seedlings which showed high fermentation ability are transplanted to fields.

*2) Three to four year-aged trees*

With individuals selected by a series of chloroform test, the Raikai manufacturing quality[5] is examined over more than two plucking seasons (with 50 g of fresh tea leaves).

Up to this stage, the fermentation ability and characteristics such as aroma and taste are assessed. Then the clonal testing with cuttings is started.

*3) Clonal testing*

Black tea quality and related characters are examined by the miniature roller manufacturing test (with 2 kg of fresh leaves), along with the chloroform test.

## References

1) Toyao, T. et al.: Improvement of the methods of early selection for black tea quality. *Bull. Nat. Res. Inst. of Tea* 7, 1–55 (1971) [In Japanese, English summary].
2) Toyao, T. & Katsuo, K.: Fluctuation in the effects of fermentation ability and tannin content on black tea quality. *Jap. J. Breed.*, 22, 33–39 (1972) [In Japanese, English summary].
3) Sanderson, G. W.: The chloroform test—a study of its suitability as a rapidly evaluating fermentation properties of clones. *Tea Quart.*, 34, 193–196 (1963).
4) Falconer, D. S.: Introduction to quantitative genetics. Edinburgh and London, Oliver and Boyd, 312–322 (1967).
5) Katsuo, K. et al.: Simple methods of judging the quality of black tea for individual selection work in the tea plant breeding III. Some considerations on the *Raikai* tea manufacturing. *Study of Tea*, 33, 13–24 (1966) [In Japanese, English summary].