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著者	TSUNODA Shigesaburo, KHAN Aminul, H.
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Differences among Strains of Rice in the Photosynthetic Tissues

I. A Comparative Leaf Anatomy of Indica and Japonica

Shigesaburo TSUNODA and Aminul H. KHAN*

Department of Agronomy, Faculty of Agriculture, Tohoku University, Sendai, Japan

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Summary

1. Leaf structures of three rice varieties, Mao-zu-tao (Indica), Hosogara (old Japonica) and Fujisaka-5 (modern Japonica) were compared.

2. In Mao-zu-tao, a typical Indica, a pretty large number of chloroplasts as well as of photosynthetic cells showed a parallel disposition to the leaf surface arranged sparsely in the mesophyll. The adaxial surface of the mesophyll was flatter.

3. In Fujisaka-5, a modern Japonica, the majority of chloroplasts as well as of photosynthetic cells are perpendicular to the leaf surface arranged compactly and regularly. The adaxial surface of the mesophyll was very wavy.

4. The differences stated above were most marked in the second leaves of the seedlings.

5. The differences stated above observed at the chloroplast-cell-tissue level seem to coincide with the differences observed at the leaf-plant-population level, and might be assumed to have a bearing to the varietal productivity including the responsibility to fertilization.

The differences in leaf characters such as leaf length, leaf angle and leaf color formed a basis on which cultivated rice varieties were classified into two sub-species of Indica and Japonica (1). Further, recent studies indicated the close relations of such leaf characters to the varietal differences in productivity and adaptability (2–5). But so far it seems no detailed observations have been reported on the differences in the internal structure of the leaves among strains of cultivated rice, although a number of studies which dealt with the specific differences in leaf anatomy from the view point of taxonomy of the *Gramineae* are traceable.

Recently Chonan (6, 7) in this Faculty improved the method of observing the mesophyll structure of rice leaves and made clear the effect of the growth stage as

* Present address: Agricultural Research Station, Pahartali, Chittagong, East Pakistan

well as of shading on the mesophyll structures in Japonica varieties. Getting his kind help the present authors carried out a comparative leaf anatomy of Indica and Japonica, and observed clear differences on several points which might have a bearing in their photosynthetic activity. The authors wish to express their sincere thanks to Mr. Nobuo Chonan for his kind cooperation.

Material and Methods

Three varieties 'Mao-zu-tao', 'Hosogara' and 'Fujisaka-5' were chosen for this study as the representatives of Indica, old-, and modern Japonica, respectively. These are similar to each other in their earliness. Mao-zu-tao is an early strain of Indica cultivated in the temperate regions of China which shows a higher yield under a limited supply of nitrogen with vigorous early growth. Hosogara was the predominant variety in the Aomori prefecture, northern Tohoku, Japan in the late nineteenth century. Fujisaka-5 is a named modern Japanese variety released in 1949 by the Aomori Agricultural Experiment Station which shows a very high yield under an abundant supply of nitrogen.

These three varieties were grown in pots filled with silt in the greenhouse in May-August 1967. Nitrogen, P_2O_5, K_2O were applied every 10 days at rates of 40, 20 and 30 mg per pot (9 cm diameter and 20 cm height), respectively, in a form of solution similar to that of Kasugai (8).

The second and the forth leaves of the seedlings, the eighth leaves at the tillering stage, and the second leaves from the flag leaf were fixed in FAA, dehydrated by an alcohol-xylem series and embedded in paraffin. Then the leaf structures were observed in transverse and longitudinal sections of 8 μ stained by safranin-fastgreen. In the case of the second leaves from the flag leaf, KOH treatment was adopted before dehydration (6). In all cases the middle part of the leaf was precisely observed.

Results

1. *The Thickness and the Compactness of the Mesophyll Tissues as Observed in the Mode of Arrangement of the Photosynthetic Cells and the Chloroplasts*:

The total mesophyll thickness at ribs as well as at furrows of the leaf did not differ significantly among the three varieties as seen in Fig. 1–3 (the second leaves of the seedling) and Fig. 10–12 (the second leaves from the flag leaf). The same was the case in the forth and the eighth leaves. On the other hand, marked varietal differences observed in the compactness of the mesophyll, Mao-zu-tao (Indica) showing a loose arrangement of the photosynthetic cells and the chloroplasts and Fujisaka-5 (modern Japonica) showing a compact arrangement of them in transverse as well as in longitudinal sections of all the leaves observed. Hosogara (old Japonica) showed an intermediate compactness compared with Mao-zu-tao and Fujisaka-5.

2. *The Wavy Arrangement of the Mesophyll in the Adaxial Side and the Degree of Development of the Mesophyll in the Abaxial Side*:

The wavy arrangement of the photosynthetic cells and the chloroplasts was observed in the adaxial side of the leaves in transverse sections in all the three varieties. However, the degree of waving was different among the varieties, especially in the case of the second leaves of the seedlings (Fig. 1–3).

Adaxial surface of the mesophyll is flatter in Mao-zu-tao (Indica). Whereas, in Fujisaka-5 (modern Japonica) the adaxial part of the mesophyll is rather perpendicular to the leaf surface. The ratio of the adaxial mesophyll surface area to the leaf area (MS/LA), an index adopted by Chonan (6), was about 1.2 in Mao-zu-tao, 1.3 in Hosogara, and 1.7 in Fujisaka-5.

The development of the mesophyll in the abaxial side of the leaf was most remarkable in Fujisaka-5 (modern Japonica) and weak in Mao-zu-tao (Indica).

3. *The Shape, the Direction and the Arrangement of the Single Photosynthetic Cells as well as of the Chloroplasts*:

In longitudinal sections a marked parallel disposition of the disk-like photosynthetic cells was observed in the two varieties of Japonica type, Fujisaka-5 and Hosogara, the broad surface of the cells being perpendicular to the leaf surface and the longitudinal axis of the leaf, with the exception of the intermediary tissue. The intercellular spaces between the adjacent cells were also perpendicular to the leaf surface, and a regular cyclic change of the cells and the intercellular spaces was observed in these Japonica varieties even in the leaves of younger plants (Fig. 8–9).

Whereas, as seen in Fig. 7, the shape and the disposition of the photosynthetic cells are different in the second leaves of Mao-zu-tao (Indica). In this case the cells are not necessarily of disk-like shape. Many of them are rather round or oblong. They are not necessarily perpendicular to the leaf surface. Some of them show rather a parallel disposition to the leaf surface. As a whole the mesophyll structure of the second leaves of Mao-zu-tao observed in longitudinal sections resembles to the spongy tissues of the dicotyledonous plants forming a sharp contrast to that of the Japonica varieties which rather resembles to the palisade when observed in longitudinal sections.

Accompanied by the differences in the photosynthetic cells mentioned above, the direction and the arrangement of the chloroplasts are also different between the Indica and Japonica varieties observed, especially in the second leaves of the seedling (7–9). The proportion of the chloroplasts which show a parallel disposition to the leaf surface is greater in Mao-zu-tao than in Hosogara and Fujisaka-5. A regular cyclic change of the rows of chloroplasts and the intercellular spaces observed in the Japonica varieties is not marked in Mao-zu-tao of Indica.

The above mentioned varietal differences were observed in the longitudinal

sections of the second leaf, the forth leaf and the eighth leaf. In the second leaf all the differences were quite clear whereas in the forth and the eighth leaves were not so marked. Moreover these differences almost disappeared in the second leaves from the flag leaf.

Discussion

Varietal differences in the form, direction and the arrangement of single leaves have been dealt with in other papers in relation to varietal yielding ability under different levels of fertilization, and it has been pointed out that fertilizer-responsive varieties have short ,"thick", dark-green, erect leaves arranged compactly and regularly, while varieties adapted to light fertilization have long,, "thin", pale-green, drooping leaves and a well expanded dispersing type leaf arrangement (2–4). Modern Japanese varieties of rice which yield high under heavy fertilization show generally the former plant type and typical Indica being low responders show generally the latter plant type. Here, "thick" and "thin" do not mean the actual thickness of the leaf, but the term "thick" stands for a high leaf areal dry weight or nitrogen content and "thin" for a low.

In this study the leaf structures, especially, the assimilation systems observed morphologically at the chloroplast-cell-tissue level were dealt with. As for the differences in the form of single chloroplasts no conclusions can be drawn out yet. However, as for the direction and the arrangement of chloroplasts and photosynthetic cells, marked differences were observed between an Indica and a modern Japonica at least in the second leaves of the seedlings. In Mao-zu-tao, a typical Indica and a low fertilizer-responder, a pretty large number of the cloroplasts as well as photosynthetic cells showed a parallel disposition to the leaf surface arranged sparsely in the mesophyll. The adaxial surface of the mesophyll was flatter. Whereas, in Fujisaka-5, a modern Japonica and a fertilizer-responder, the majority of the chloroplasts as well as of photosynthetic cells are perpendicular to the leaf surface arranged compactly and regularly in the mesophyll. The adaxial surface of the mesophyll was very wavy.

The differences observed in this study at the chloroplast-cell-tissue level seem to coincide with the differences observed at the leaf-plant-population level (2, 3), and might possibly have a bearing to the varietal productivity, including the responsibility to fertilization.

As was the case of the external leaf morphology, the varietal differences in leaf structures were most marked in the second leaves of the seedlings. Further studies seem to be needed to clarify the differences in the upper leaves quantitatively to reach a definite conclusion.

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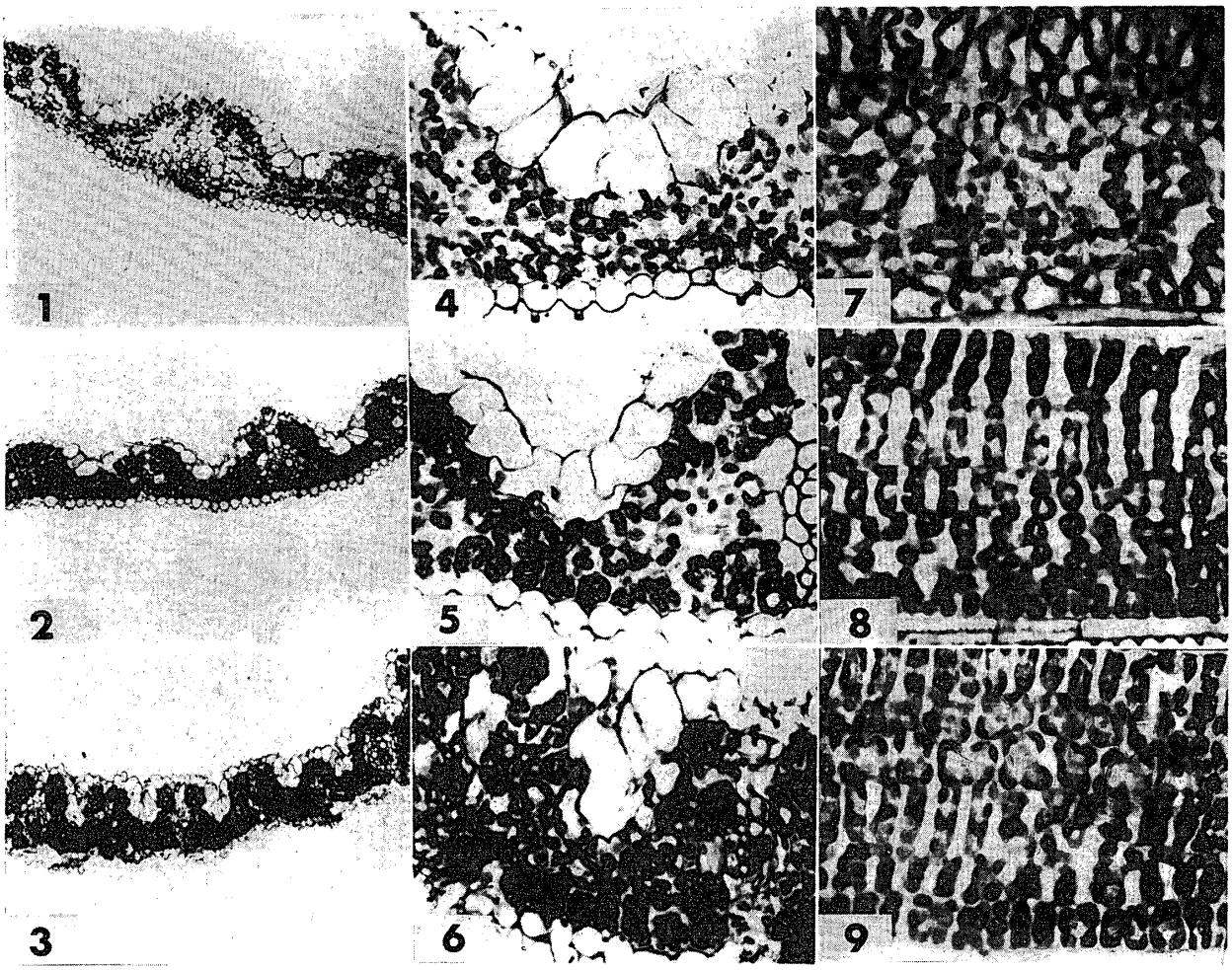

Plate 1

The Second Leaves of the Seedling

FIG. 1. Mao-zu-tao (Indica). Transverse section. × 80
FIG. 2. Hosogara (old Japonica).
FIG. 3. Fujisaka-5 (modern Japonica).
FIG. 4. Mao-zu-tao (Indica). Transverse section. × 320
FIG. 5. Hosogara (old Japonica).
FIG. 6. Fujisaka-5 (modern Japonica).
FIG. 7. Mao-zu-tao (Indica). Longitudinal section. × 320
FIG. 8. Hosogara (old Japonica).
FIG. 9. Fujisaka-5 (modern Japonica).

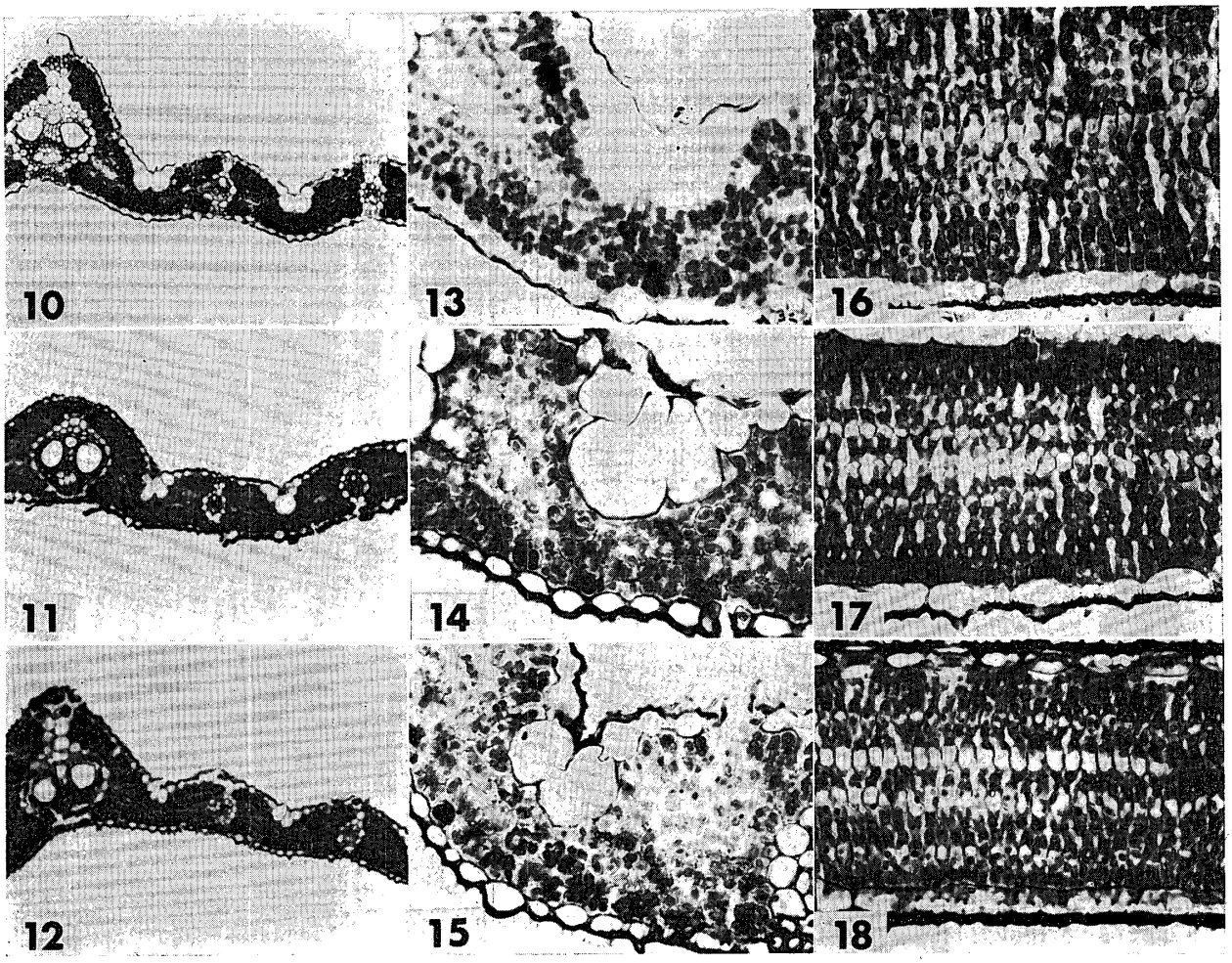

Plate 2

The Second Leaves from the Flag Leaf

FIG. 10. Mao-zu-tao (Indica). Transverse section. × 80
FIG. 11. Hosogara (old Japonica).
FIG. 12. Fujisaka-5 (modern Japonica).
FIG. 13. Mao-zu-tao (Indica). Transverse section. × 320
FIG 14. Hosogara (old Japoncia).
FIG. 15. Fujisaka-5 (modern Japonica.)
FIG. 16. Mao-zu-tao (Indica). Longitudinal section. × 320
FIG. 17. Hosogara (old Japonica).
FIG. 18. Fujisaka-5 (modern Japonica).