Crystallinity Change in the Growing Stage of Bamboo (*Phyllostachys mitis*)*

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Abstract——Crystallinity change in the bamboo internode in the growing stage was measured x-ray technique. The following results were obtained;

(1) X-ray fibre diagram of bamboo in the growing stage from juvenile to mature showed that the amorphous pattern was appeared at first and the orientation of the fibre was appeared gradually.

(2) The amount of the crystalline substance was higher in the parts where the bamboo sheath was stripped off than in the parts covered with the bamboo sheath and decreased rapidly toward upper parts of the bamboo shoot.

(3) In the stage of internodial growth, crystallinity in a given internode decreased from the upperside to the underside of the internode.

Introduction

This study is made to characterize the microscopic features of the growth and the development of a bamboo in its life cycle.

For the changing rate of the vegetative and reproductive growth from juvenile to a senscent state through adulthod, bamboo is much more remarkable than the other woody plants. For example, Mouso-chiku (*Phyllostachys mitis*) and Madake (*Phyllostachys bambusoides* SIEB. et ZUCC.) are grown up 16 to 17 meters in height only about 40 to 60 days and then stop their elongation.

It is pertinent to use the bamboo for the most suitable material in order to clarify the mechanism of woody plants by physical, chemical and morphorogical method.

The chemical properties were studied by KOMATSU[17], TAKENOUCHI[1], MIGITA[2] and TANIGUCHI[6]. In the growing stage of Madake, α-cellulose was almost constant from a week to three years, but lignin increased steadily from 8.4 to 24.0% in this period[2]. Physical and mechanical properties were studied by SHIGEMATSU[7], OTA[8], KITAMURA[9,10] and SUZUKI[11].

From the analytical point of view, the bamboo was studied by TAKENOUCHI[1], NISHIDA[12] and GROSSER[13]. NISHIDA[12] et al. measured the fibre length and the fibre width of Madake and obtained the result that fibre length was short both the internode near

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the ground and the internode at the parts of the top, but it was long in the middle part of the bamboo. The micell length and width showed a similar result, too[14].

But, information about the ultrastructural changes of bamboo during their growth period was only reported by TANIGUCHI[6] with the chemical analysis. It was reported that fine structures of cellulosic materials vary with growth of bamboo shoots and the crystalline region increased a little in the shoots covered with the bamboo-sheath, but when the bamboo-sheath was stripped off, it increased rapidly[6].

It is known that the bamboo shoot is grown up each internodial growth but then stepwisely from the first internode to upward. Therefore every stage of the ultrastructural formation may be observed on every internode of the bamboo culm in a growth period of bamboo shoot.

We should like to answer about the following question; How does the cellulosic substance change in three stages, cell division, cellelongation and lignification? Whether cellulosic substance is formed into an amorphuos state at the first stage of its formation and then crystallize or directly formed crystalline state partly at the first stage.

In this paper, in order to obtain a new information for answering the questions which mentioned above, we report on the quantitative change of the crystalline substance in each internode of one shoot and in the different parts in a given internode by x-ray.

Materials and Method

Preparation of samples for the experiment

Three young bamboo shoots at the growing stage of 2, 4 and 5 weeks were collected. Their height was 118, 349 and 865 cm respectively. For comparing with these samples, a matured bamboo and a sprout were used also. They were collected from the Experiment Station, Kyoto Prefecture.

The bamboo shoots removed the bamboo-sheath and were measured the internode length and the internode diameter of them. Then, the samples were cut and stored in 70 % methanol. After 5 months storage, each internode was cut and crushed into powder with a Willy mill. The powder which passed through 200 mesh screen was dried at room temperature. This 300 mg powder was compressed in a desc, 20 mm in diameter and about 0.85 mm in thickness.

For x-ray photograph, the samples, 1 mm thick along the radial direction and 1 cm width along the tangential direction, were cut and freeze-dried.

X-ray photograph and Crystallinity measurement

X-ray photograph was taken with a flat plate camera. The experimental condition was as follows: Focus; Point focus, 1 mmϕ pin hole collimeter. Distance from samle

to film was 5 cm. X-ray source; Cu-Kα radiation with Ni-filter, using a Rotarflex, RU-3L x-ray diffractometer (Rigaku Denki Co., Ltd.).

Crystallinity of the bamboo samples was measured by x-ray reflection method, using a Rotarflex. The source of x-ray was Cu-Kα radiation with Ni filter. It was operated at 50 kV and 80 mA with line focus. The recording of the scattering intensity along the equatorial plane was made by scintillation counter scanning from $2\theta=5°$ to 30° of the scattering angle.

Since x-ray diffraction pattern of the edible sprout, whose height was about 15 cm from the first node to the top, showed an amorphous halo, it was used to determine the amorphous curve.

The degree of crystallinity is obtained by the following equation;

$$\text{Degree of Crystallinity}=\frac{B}{A+B}\times 100\%,$$

where A is the area under the amorphous curve, and B is the area of the crystalline region.

Results and Discussion

Photo. 1 and 6 show the x-ray diagram of an edible sprout, the 17th, 12th, 6th and 2nd internode of 4 weeks bamboo shoot and a mature one respectively. Photo. 1 and 6 show a typical amorphous halo and a distinct fibre diagram respectively. The 17th internode is the most elongating part and the x-ray fibre diagram shows a little orientation perpendicular to the fibre axis as compared with the fibre diagram of edible

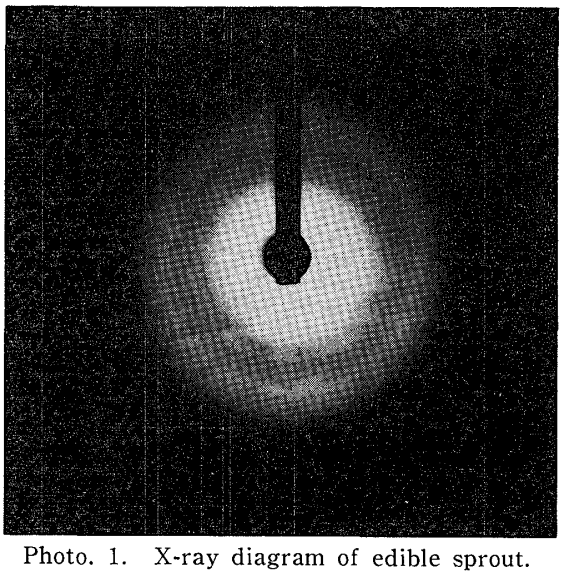

Photo. 1. X-ray diagram of edible sprout.

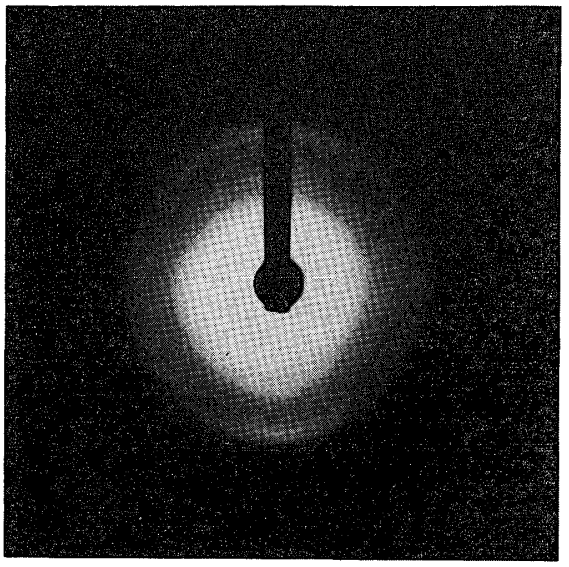

Photo. 2. X-ray diagram of 17 th internode (4 weeks).

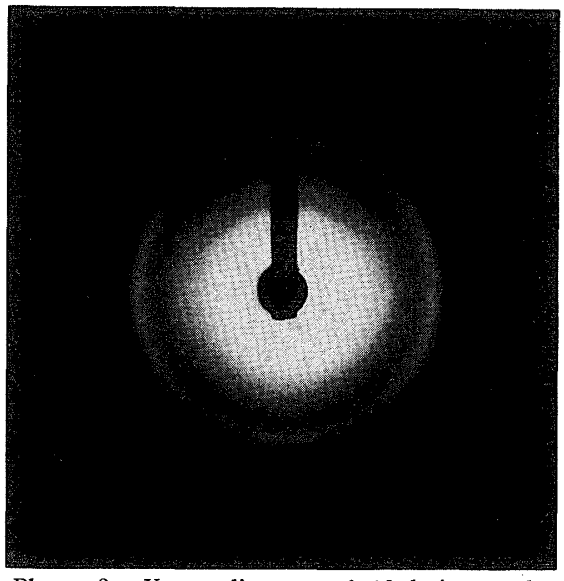

Photo. 3. X-ray diagram of 12 th internode (4 weeks).

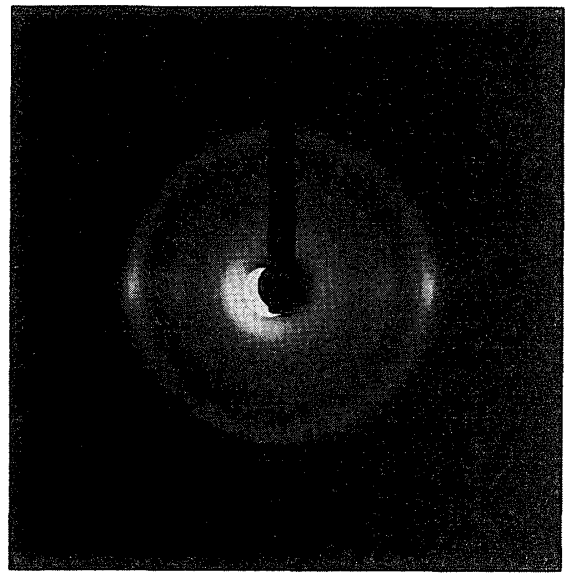

Photo. 4. X-ray diagram of 6 th internode (4 weeks).

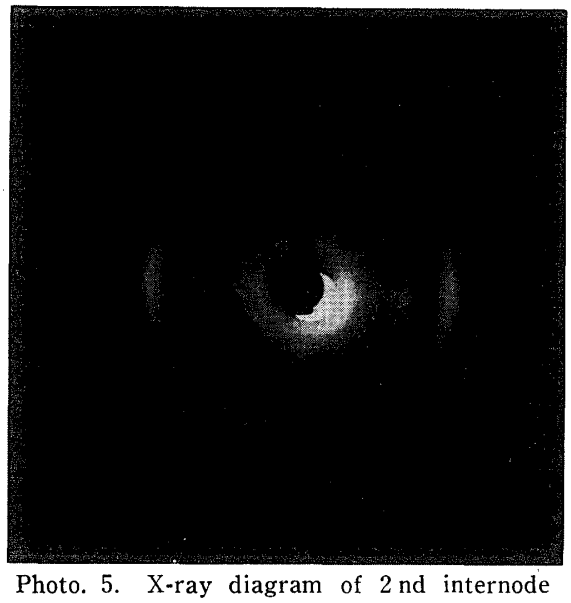

Photo. 5. X-ray diagram of 2 nd internode (4 weeks).

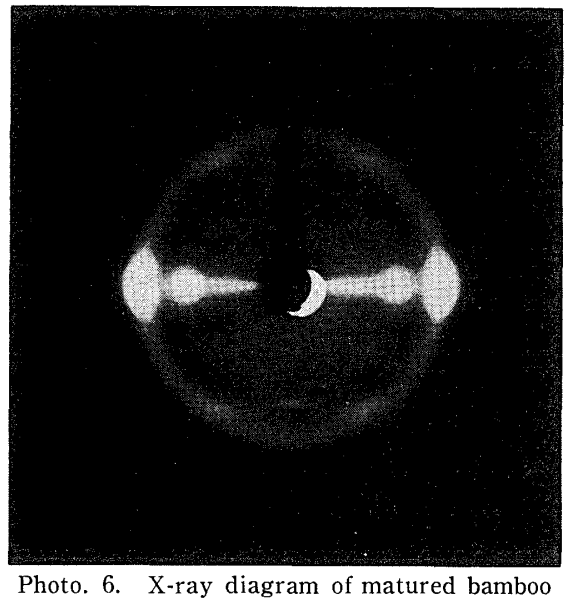

Photo. 6. X-ray diagram of matured bamboo (10 years old).

sprout, that is, the sickle-shaped interferences appeared on the meridian (Photo. 2). The 12th internode is on the state almost stopped the internodial growth and progressed in the lignification. X-ray fibre diagram of the 12th internode shows the sickle-shaped interference on the equator (Photo. 3). In the 6th and 2nd internodes in which the internodial growth was completed and the bamboo-sheath was stripped off, the fibre diagram show the orientation to the fibre axis increases and the fibre diagram become to be resemble to the mature one gradually.

Fig. 1, 2 and 3 show the crystallinity change in each internode and the distribution of internode length within the vegetative process of bamboo at 2, 4 and 5 weeks respectively. In the distribution curve of internode length, the leftside of the peak show the part in which the internodialgrowth almost stopped and the rightside of the peak show the part where the internodial growth is going on.

The relation of the internodial growth to th growth days is schematically shown in Fig. 4. In this figure, the smooth line shows the distribution of the internode length when Mouso-chiku is grown up at about 8 weeks and comes to maturity. Dotted lines show the distribution of the internode length in each growing stage.

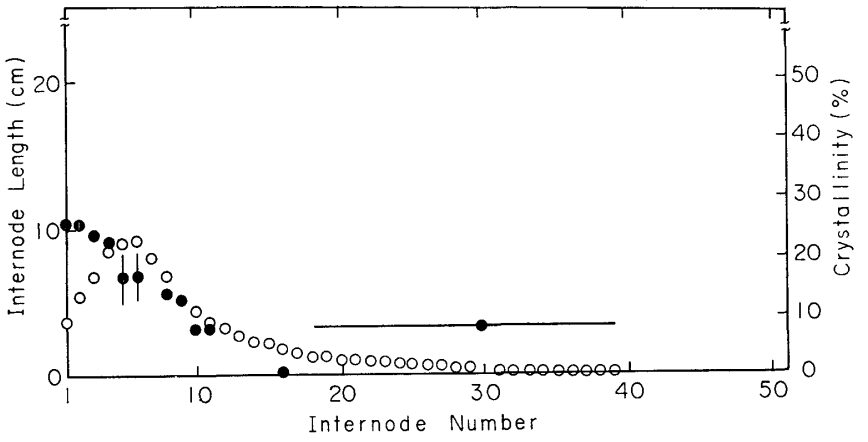

Fig. 1. Distribution of crystallinity and internodial length. Two weeks sample on the growing stage. 118 cm height.
●: crystallinity, ○: internode length.

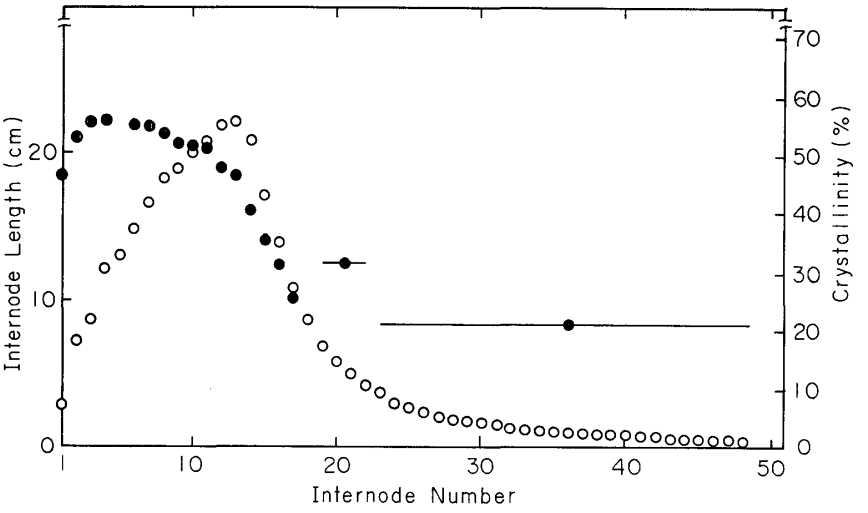

Fig. 2. Distribution of crystallinity and internodial length. 4 weeks sample on the growing stage.
●: crystallinity, ○: internode length.

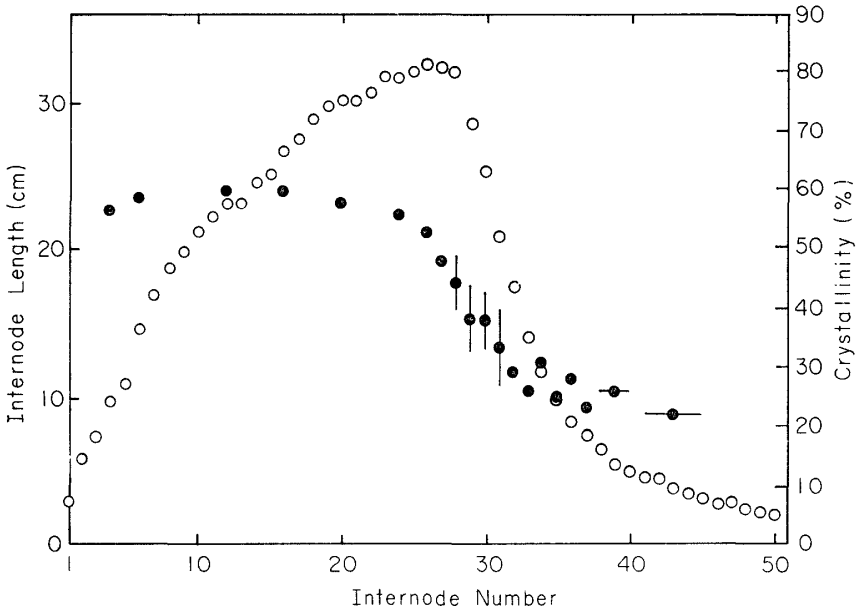

Fig. 3. Distribution of crystallinity and internodial length.
Five weeks sample on the growing stage.
●: crystallinity, ○: internode length.

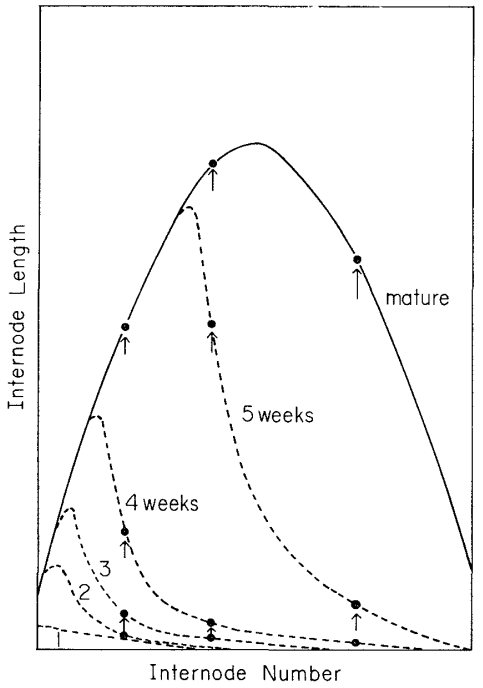

Fig. 4. Schematic description of the distribution of internode length on each growing stage.

Each growing internode elongates to the direction of the arrows and attains to its matured length shown on the smooth line.

The bamboo shoot in the growing period of two weeks is covered with the sheath

entirely. Crystallinity are decreased from the first internode to the value 0 on the 16th internode (Fig. 1).

The sample containing from the 17th internode to the top contains both the node and the internode. In these parts, crystallinity is heigher than in the part of the 16th internode.

Perhaps we may infer from the result that the part of the node have higher crystallinity than the part of internode in the same growing stage.

Fig. 2 shows the change of crystallinity and the internode length for the sample of the total length of 349 cm at the 4 weeks. The internode is almost completed to the 12th internode and the sheathes begins to be stripped off near the 10th internode.

It is shown from this figure that the parts in which the sheath is stripped off have almost constant crystallinity, except the first internode, but the crystallinity decreases toward the upper parts which are covered with bamboo sheath.

Fig. 3 shows the result of the sample at 5 weeks which in 865 cm height. In this growing period the bamboo sheath begins to stripp off near the 20th internode and crystallinity in the parts of which the bamboo-sheath is stripped off is almost constant ane higher than the parts of which the bamboo-sheath is not stripped off.

It is concluded from these results that when the bamboo-sheath is stripped off from the culm, the internodial growth is completed and the crystallinity is also almost completed.

On the parts of which the bamboo-sheath is not stripped off, crystallinity is decreased gradually toward upper parts of the bamboo shoot.

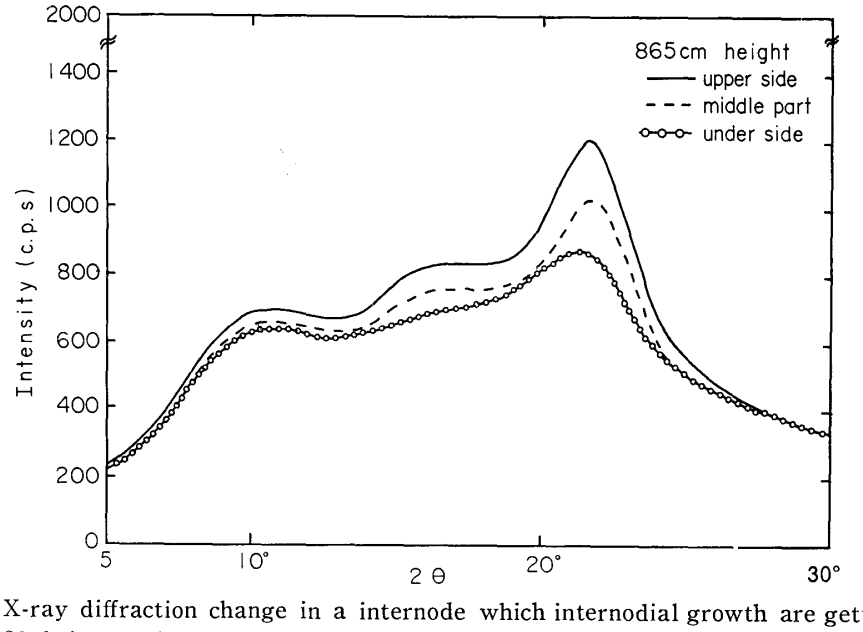

Fig. 5. X-ray diffraction change in a internode which internodial growth are getting on. 30 th internode of 5 weeks stage sample.

The parts from the 28th to the 36th internode shown in Fig. 3 is supposed to be the most vigorously growing part. And then the lower parts of these internodes are still soft but the upper parts are harder. The x-ray analysis of the distribution of the crystalline substances of one internode in this range was carried out.

The samples examined were prepared from these internodes of one shoot at 5 weeks and each internode cut into three parts, that is, the upper in which lignification occured, the middle and the lower part.

The result of the 30th internode of is shown in Fig. 5.

It is shown that the crystallinity is higher in the upper part and decreases gradually toward the lower part.

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