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Gilles Lessard and
Amy Chouinard

Organized by the
International
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Organizations

Bamboo Research in Asia

CANADA

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The cover artwork, which has been reproduced throughout the book, is a line drawing based on a painting by Hui Nien, which has been used in several works on bamboo.

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Bamboo Research in Asia

**Proceedings of a workshop held in Singapore,
28–30 May 1980**

Editors: Gilles Lessard and Amy Chouinard

*Organized by the International Development Research Centre
and the International Union of
Forestry Research Organizations*

Contents

Bamboo Cultivation

Etsuzo Uchimura[1]

Native bamboo species are widely distributed on all the continents except Europe; however, about 80% of the bamboo-growing areas are distributed in South and Southeast Asia. In Japan, the area of useful bamboo forest covers only 0.5% of the total forested area. For this reason, bamboo is generally considered a minor forest product, even though it is a very valuable resource in Japanese daily living. It is used in agricultural and fisheries materials, some instruments, furniture, handicrafts, etc.; therefore continued and increased production of bamboos is required. At present, however, there is too little known about bamboos to guarantee production, and ecologic and physiologic studies are badly needed. Some of the aspects, which are discussed in this paper, include ecological distribution of clump-forming and nonclump-forming types of bamboo; the habits of bamboo genera; the propagation of two types of bamboo through asexual reproduction from rhizome-cuttings (offset planting), culm cuttings, layering, and grafting and through sexual propagation by use of seeds; bamboo cultivation methods as a reflection of meteorologic site, growth of culm and rhizome, stand density, biomass, and fertilizer application; bamboo flowering; and genetics and breeding.

Native bamboos are distributed on all continents except Europe. At present, approximately 50 genera and 700 species of Bambusaceae cover more than 14 million hectares of land, 80% of which is in the South and Southeast Asian tropical regions. Bamboo is important as a resource for food, manufactured goods, etc. It should be considered an important subject for research.

The forest area of Japan covers about 25 million hectares, 67% of the total land area; the useful bamboo forest is only 0.5% of this. Although bamboo is generally considered a minor forest product, it provides important materials for use in house and furniture construction, agricultural or fisheries goods, interior decoration and various handicrafts. In other words, it is indispensable in Japan. Bamboo has also been tried in pulp making but for this purpose requires continuous, large-scale production — a requirement not met in Japan. Recently, studies on the manufacturing process of bamboo charcoal have been taken up in earnest. With all these uses for bamboo, efforts to increase its production both in diameter of individual stalks and in number of shoots have been intensified.

Distribution of Bamboo Forest and Production of Culms

Bamboo is generally capable of propagating asexually in the form of buds

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growing between rhizomes and culms. The propagation forms of bamboo distributed throughout the world are classified into nonclump-forming and clump-forming types.

The nonclump-forming type includes *Phyllostachys, Semiarundinaria, Sinobambusa, Tetragonocalamus*, and some other genera distributed mainly in temperate and subtropical regions. This type of bamboo is characterized by monopodial rhizomes and culms; some buds of the nodes of the rhizome protrude through the earth every year to become the culm, whereas the buds at the apex of the rhizome become new rhizome creeping underground. Thus, bamboo culms emerge sporadically and are widely spaced. Most bamboos of this type are erect and long.

The clump-forming type includes genera like *Bambusa, Dendrocalamus, Schizostachyum,* and other genera that grow in the tropical regions. Characteristic of this type of bamboo is the fact that the larger buds at the lower portion of the culm located underground sprout directly above the ground and the sprouts grow into culms, forming a clump of culms with a short rhizome. The sprouting period of this type is much longer than that of the nonclump-forming type.

The distribution of these two types of bamboo clearly relates to the annual precipitation and temperature of areas where they grow. In general, high temperatures accelerate the growth of bamboo and low temperatures inhibit it, although the *Sasa* species grow rather well in the districts of low temperature.

Useful bamboo species commonly grow at the foot of mountains, on the riverside or riverbank, near farmers' homes, and so on. Most bamboo forests are cultivated in Japan, but some in the mountains have developed naturally over a long period.

The total bamboo-growing area is 123 000 ha, mainly distributed in the southern and western part of Japan (Kyushu, Shikoku, Chugoku, and Kinki regions). In the northern and eastern part of Japan, such as Hokkaido and Tohoku regions, the bamboo-growing area is small because of low temperatures; 98% of the total bamboo forest is on private land and is managed by farmers.

Phyllostachys bambusoides, locally known as *Madake*, occupies 42.5% of the total, and *P. pubescens* (locally, *Mosochiku*) constitutes 40.6%. Next is *P. nigra* forma *henonis* (common name, *Hachiku*) with 0.4%. *Pleioblastus* genus, which is used for fishing rods, handicrafts, and furniture, accounts for 5.3%, and many other species make up the remainder.

Bamboo is distinguished from *Sasa* by its habit of shedding its culm sheaths when the culms reach full size. In *Sasa*, they remain for 3–4 years. *Sasa* species are not as useful as bamboo, and they hinder the growth of trees; therefore, they are not discussed in this paper.

There are 5 genera, 52 species of nonclump-forming bamboos grown in the mild districts of Japan and 3 genera, 15 species of clump-forming bamboos in the warmer districts.

Some genera of bamboo and their characteristics have been reported (230, 263, 371, 401, 411, 412, 425, 442).

In Japan, *Phyllostachys* is usually characterized by caducous culm sheaths; large, cylindrical culms grooved on alternate sides; two (seldomly one) branches at a node; three stamens; and compound spikelets at inflorescence. It usually sprouts in spring (April–May); 8 species, 10 forms, and 14 varieties occur in Japan.

Semiarundinaria also exhibits caducous culm sheaths, but the culm is medium-sized. There are 3–5 branches at a node, the branches almost in bundles and cylindrical without grooves. Inflorescences are simple spikelets. Shoots appear in spring (May); seven species and eight varieties occur in Japan.

Sinobambusa is similar to *Semiarundinaria*, although it has long purplish hair at the nodes of new culms and side branches longer than one-half of its main branch. The culm sheaths are ciliate, and the internodes are long; outer glume is present. It sprouts in late spring (May–June); one species and one form occur in Japan.

Shibataea has caducous culm sheaths, undeveloped leaf sheaths, and 3–5 short branches at each node. The culms are slender and low, grooved on one side at the base of the internodes. This genus sprouts in spring (April–June); one species occurs in Japan.

Tetragonocalamus has caducous culm sheaths without appendages, square culm, and aerial roots at the lower nodes. It sprouts in autumn (September–November); one species occurs in Japan.

Bambusa has very short rhizomes and leaves that are not tessellate; it sprouts in autumn (October–November); four species and four forms occur in Japan.

Propagation of Bamboo

Natural propagation of bamboo is mainly asexual, in the form of branching rhizomes. Asexual artificial methods of propagation include offset planting, culm cutting, layering, and grafting of rhizome cuttings. Sexual propagation is by use of seeds gathered after the bamboo has flowered. Asexual propagation has the advantage that the genetic quality of the planting material is known because it is the same as the source plant; its disadvantages vary for the different methods. Offset planting requires very hard work for the digging of the rhizomes; it entails considerable risk of damage to the roots and buds of the mother plant, particularly in clump-forming bamboos for which there is no sharp distinction between the rhizome and the culm. Of the other asexual methods, culm cutting is the only one that has had success thus far. It has proved suitable for the clump-forming types of bamboo that root easily but not for the nonclump-forming types. As a result, offset planting is widely used for propagation of the nonclump-forming types and culm cutting for the clump-forming types. Sexual propagation has the advantage of high success rates; its drawbacks are that the genetic quality of the seeds is less certain than with asexual propagation and that the seed is only available when the mother plant flowers and produces it (429, 437).

Offset Planting

The planting material for offset planting may be the culm with roots and rhizome, the stalk with roots and rhizome, or just the rhizome. The selection of the rhizome is important in any of the methods.

The results of an investigation carried out in a *Phyllostachys bambusoides* forest showed that the diameters of culms in a clone of this plant varied from 4 to 13 cm and were closely associated with the age and diameter (Fig. 1) of the rhizome from which they grew. Rhizomes older than 3 years produced buds with reduced vigour and shoots that did not grow tall. The older the rhizomes, the less vigour in the buds. Also, the results showed that, of comparably aged rhizomes, those with larger diameters were better as planting material. The findings

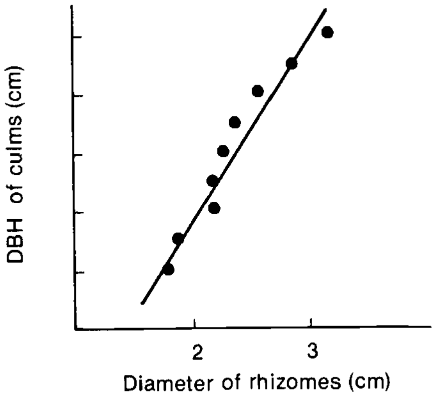

Fig. 1. *Relationship between diameter of culm and rhizome of P. bambusoides.*

indicated that planting material for *P. bambusoides* should be 2–3-year-old rhizomes having a large number of fibrous roots and golden buds. The rhizome sheaths should be used as an indicator of the age of the rhizome.

The length of the rhizome affects the survival of the shoot. The longer the rhizome, the more nutrients it contains to support the shoots. However, as the digging of rhizomes is very difficult, it is necessary to determine the minimum length needed to support the growth of the culm. In general, bamboo species with large-diameter culms require longer rhizomes, the length being about five times the basal girth of the culm. Rhizomes of *P. bambusoides*, if they are without the culm, must be at least 1 m to grow a mature bamboo shoot; the length for *P. pubescens* is 2 m. The survival rate is higher for rhizomes with culms.

Because nutrients released from the culm to the rhizome are always transported in the direction of the growth of the rhizome — a fact that was ascertained with radioactive phosphorus (^{32}P) — the basal part of the rhizome is preferred as planting material.

The rhizome should be cut carefully with a saw; it should not be dug during elongation, which, in nonclump-forming types, begins about 2 or 3 months after the growth of the culm shoot and continues for approximately 3 months. During this period, the nutrients that are stored within the rhizomes are absorbed in the process of growth of the new rhizome and are used up by the time the growth is completed. The rhizomes should be cut after the growth is completed.

When rhizomes are dug with the culm, the upper part of the culm and its branches are removed, but a portion consisting of several nodes and their branches is left as protection against the wind. The optimum months for offset planting in Japan are February and March, and the best time is when the buds on the rhizome show a slight swelling.

The greater the number of rhizomes planted per hectare, the earlier the bamboo forest becomes completely established and is ready for harvest. When the soil is fertile or the species is characterized by large-diameter culms, planting is less dense than it is with poor soil or small-diameter culms. For *P. bambusoides* and *P. pubescens* 400–500 pieces per hectare is recommended.

When planting the pieces, workers must be careful not to injure the junction of the culm and rhizome. The bamboo should be planted as soon as possible after being dug, and after the planting, irrigation should be applied.

Culm harvesting is usually not before 8–10 years after the planting even if 400 pieces/ha have been planted, because rhizomes elongate 1–3 metres a year, and the new culms sprout 1 year after on the growth of rhizomes.

Propagation by Seeds

In general, sexual propagation by seeds is feasible although not always practical because of the unusually prolonged flowering cycle for most species of bamboo. An interesting and curious phenomenon of bamboos is that some species die within 1 year after flowering, whereas other species survive but their vegetative growth slows down during flowering. Seeds can be collected from almost all bamboo species, but some species are more productive than others. In Japan, the seeds are sown in nurseries or in pots or planted directly in the field after germination at a temperature of 20–25 °C in a germination tester. *P. pubescens* seeds germinate 2–3 weeks after being planted in nurseries but take less time (3–5 days) in the tester.

Normally, it takes 10 years for nonclump-forming types of bamboo to reach a size suitable for harvest, but the time is shorter for the clump-forming types.

Fundamentals of Bamboo Cultivation

Of the physiologic and ecologic activities of bamboos, the most important are the growth pattern of culm, translocation of nutrient, and the flowering and regeneration processes. An understanding of these processes permits bamboo cultivators to increase productivity by harmonizing the forest site with the physiology and ecology of bamboo. In Japan, much progress has been made in this area. The growth of culms and rhizomes has been described amply in other publications and reports. This paper summarizes investigations of the effects on productivity when different cultivation methods, stand densities, biomasses, fertilizer applications, etc. are used.

Site Conditions

A good knowledge of the site conditions of bamboo forests is necessary. The minimum temperature should be considered; for instance, *P. bambusoides* does not grow well in areas where the temperature drops to lower than -5° C, and *P. pubescens* is better grown in areas where the temperature is never lower than -3° C and never higher than 33° C.

The best regions for vigorous growth of rhizome and cultivation of culm are those where there is a longer warm period in autumn than in spring so that nutrients accumulate in the rhizomes. In areas where there is snowfall, there is risk of injury to the bamboo in early spring when the snow tends to be greater in specific gravity and is a heavier burden for the plants. Rainfall should be 100 mm in the month when the shoot emerges and 200 mm or so during late summer (August–September) for the growth of the rhizomes. Total rainfall should be more than 1000 mm a year.

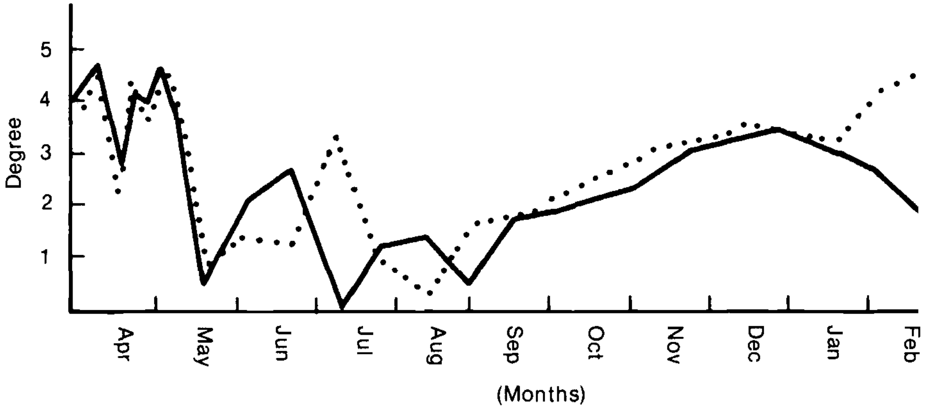

Fig. 2. *Seasonal changes of reserve starch in rhizome.*

Bamboos grow well in gently sloped lowlands or hilly districts, although steeper slopes are more suitable for *P. bambusoides* and *P. nigra* var. *henonis* than for *P. pubescens*. Fertile, well-drained soils with sandy loam or gravel are suitable for *Phyllostachys*. *P. pubescens* grows in highly humid soils, and it rather prefers soil mixed with clay. In contrast, *P. bambusoides* and *P. nigra* grow well in soil that is more or less sandy and moderately moist. *P. nigra*, which produces slender, black culms, and *P. nigra* var. *henonis* form. *boryana*, which has clear, dotted culms are suited to dry soils.

Soils with high moisture content and good water-holding capacity support bamboo well, whereas those with high volume : weight do not. Soils high in N, P_2O_5, K_2O, CaO, and SiO_2 promote the best growth, and the culms seem to grow very well even in acidic soils (pH 4.5).

Growth of Bamboo Culm and Rhizome

A study of the relationship between rainfall and the elongation of the culm has indicated that rainfall promotes growth of the culm during greatest elongation but not toward the end of the process. In contrast, the growth of the rhizome is not influenced by rainfall even though the period for elongation of the rhizome is relatively long. The action of reserve nutrients must be considered as one of the factors that influences the growth of bamboo culm and rhizome. For example, the results of a study on the progress of reserve starch in the culm disclosed that the reserve starch in 1-year-old culms was greatest just before sprouting occurred; it decreased during the period of greatest growth of the sprouts and increased after the growth was finished; finally, the amount of reserve starch in the culm decreased again when the growth of the rhizome started and then gradually increased. The difference in culms younger than 1 year was that the reserve starch granules appeared earlier after sprouting began and increased progressively even during the growing period of the rhizome (Fig. 2). In other words, the consumption of the reserve starch in 1-year-old culms was greater than storage of starch during the growing period of the rhizome, whereas this phenomenon was not always seen in the younger culms. A similar tendency was observed in different-sized culms; for example, the larger the culm, the higher the amount of reserve starch. The amount of reserve nutrients in the rhizome decreased during the growing period and increased during the interrupted period of elongation. A close relation was clearly demonstrated between the elongation of both culm and rhizome and the amount of reserve starch.

A study of the vertical distribution of reserve starch at the beginning of January disclosed that the amount of reserve starch was greater in the upper part of the culm than in the lower part. Seasonal changes in the vertical distribution of the reserve starch in the *P. bambusoides* culm were in nearly the same category as those in *Pleioblastus pubescens*, a species of *Sasa*.

Other findings were that there are fewer leaves on 1-year-old culms than on older ones; the lumber from 1-year-old culms is soft; and 1-year-old culms are a significant source of productive nutrients although not widely used as such. The quantity of leaves was greatest for 2-year-old culms, whereas bamboos older than 3 years had decreased leaves inversely proportional to their increases in age. In contrast, the vertical distribution of the leaf amount in bamboos did not differ markedly at different ages, but the vertical position of the maximum area of leaves in 1-year-old culms or 5-year-old culms was commonly less than that for culms of other ages.

The relationship between the diameter (D) of culms and the number of leaves (N_l) was examined for 3-year-old *P. bambusoides* culm; the resulting equation was:

$$N_l = 2422.8D - 4625.4.$$

The relationship between the weight of both branches and leaflets (W_{bl}) and the diameter (D) of culms was also expressed by an equation:

$$\log W_{bl} = 1.4103 \log D - 0.6871.$$

The leaves are responsible for metabolism; therefore seasonal changes in the amount of defoliation provide essential information on the growth and existing amount of bamboo. Use of a litter trap has demonstrated an equilibrium in the seasonal growth of bamboos; that is, 53% of the annual amount of defoliation was noted during May–July and 30% of the annual defoliation was seen between October and November, the seasons of maximum growth of the rhizomes. The average annual amount of defoliation was half the existing amount of leaves — evidence of the theory that defoliation occurs in even years.

Stand Density

The optimum number of bamboos in a stand can be determined by observations of existing bamboo forests. Another method is the use of an index that is based on the diameter of the culms. The index for *P. bambusoides* is expressed by the equation:

$$\log \rho = 5.0326 - 1.9705 \log D$$

where ρ represents the number of standing culms. Needless to say, the value also depends on the conditions of the soil, weather, topography, etc. (Fig. 3). The 35% density curve can be expressed by:

$$\log \rho = 4.5481 - 1.9705 \log D,$$

which provides the best density curve for *P. bambusoides*.

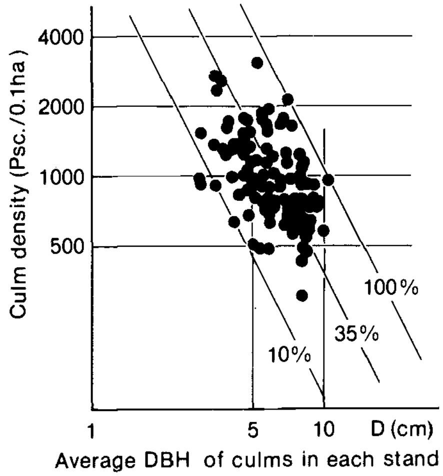

Fig. 3. *Full density curve and culm density index of P. bambusoides.*

Adequate stands promote productivity, but they can only be maintained by suitable selection of bamboo culm. Stands should be considered from viewpoints of ecology, physiology, and maintenance including, in order of priority, pest control in the bamboo forest; the use of fallen culms; the maintenance of random bamboo stands; and the value of 1–2-year-old culms, which are soft and not economically useful but are important in the forest for the continuation of bamboos. The majority of 2-year-old culms grow on the rhizomes, rich in reserve nutrients as well as reserve starch and nitrogen, and these culms, because of their plentiful leaves, play a functional role in the plant's metabolism. Thus, only culms older than 3 years should be cut.

The season recommended for cutting of bamboos is winter because the growth of bamboos is interrupted during this season. In addition, cutting should only be undertaken where the residual standing culms are sufficient to ensure continuation of the clump.

Biomass in Useful Bamboo Species

There are few reports available that elucidate the productivity or biomass of, and annual production of, bamboo forests in respect to forest ecology. For this reason, the actual condition of bamboo forests in Japan has never been indicated scientifically, even though the productivity of bamboo forests has been empirically believed to be high. In this paper, the biomass of bamboo forest was estimated by the allometric method (Table 1).

Viewing the results obtained by the present research activities, one must conclude that tending bamboo stands or forests is essential, especially for the large-diameter bamboo forests so that productivity can be maintained and increased. The most important thing in managing bamboo forests is to ensure that the bamboos of good quality are properly spaced (Table 2).

Fertilizer Application

A lot of inorganic nutrients are consumed by the bamboo during growth stages and propagation. The nutrients are supplied naturally through the soil or rain. If mineral salts are naturally abundant, fertilizer is not necessary, but sometimes fertilizer is needed for the improvement of soil conditions or the increase of yields.

Fertilizers should be applied about a month in advance of sprouting periods so that the effects appear at the time of sprouting and growth of rhizomes. The standard fertilizer used per hectare of bamboo forests is about 70 kg of nitrogen, 60 kg of phosphorus, and 80 kg of potassium; on shoot farms the amounts per hectare are 230 kg of nitrogen, 150 kg of phosphorus, and 200 kg of potassium. The application of silicic acid at 200 kg/ha improves results both in forests and in shoot farms. Much research has been done in this field (16–19, 287, 289, 405, 406, 409, 428, 438, 441, 444, 445, 446, 460).

Bamboo Flowering

Flowering of bamboo varies among the species; some flower periodically and others do not; some die after flowering and others do not even though the culm is defoliated and weakened temporarily. There are several theories concerning the causes of flowering; they include the:

- Pathological theory, which postulates that flowering is brought on by destruction of bamboo through causal organisms like nematodes, fungi, insects, and parasites (Koide and Shirai);
- Periodical theory, which is that the cycle of bamboo regeneration, through asexual methods by rhizome and culm elongation, reaches maturity and results in flowering (Kawamura, Masamura, and Katayama);
- Mutation theory, which considers that bamboo regeneration through any methods of asexual propagation is mutation and brings about flowering of bamboos (Kasahara et al.);
- Nutrition theory, which proposes that flowering and fruiting are usually the results of a physiologic disturbance arising chiefly from the poor growth of the vegetative cells brought about by an imbalance of carbon-nitrogen ratio (Muroi and Ueda); and
- Human activities theory, which states that human practices such as building fires induce bamboo flowering.

All these theories need to be researched further as do the possibilities that meteorologic factors or conditions induce flowering. Another possibility is that continuous asexual propagation of bamboos does not deplete nutrient supplies

Table 1. Biomass of some bamboo species estimated by the allometric method (per hectare).

	P. bambusoides			*P. pubescens*	*P. nigra* var. *henonis*
Site quality	Low	Middle	High	Middle	High
Stand density (pcs).	22000	10000	8900	5100	13800
Average DBH[a] (cm)	4.0	6.0	7.1	9.3	6.6
Height (m)	8.0	12.5	16.7	13.2	12.6
Culms (t dry weight)	25	28	61	49	73
Branches (t dry weight)	14	10	13	9	12
Leaves (t dry weight)	7	7	6	5	9
Roots (t dry weight)	30	30	80	38	63
Annual production of culms (t dry weight)	4	5	6	8	6
References	(428)	(428)	(460)	(405)	(409)

[a] Diameter at breast height.

Table 2. Standard culm density retained after harvest (per hectare).

	Site quality		
Species	High	Middle	Low
P. bambusoides	4000–5000	9000–11000	≥18000
P. pubescens	3000–4000	4000–6000	6000–8000
P. nigra var. *henonis*	5000–6000	10000–12000	15000–20000
P. nigra	10000–13000	15000–20000	25000–30000

and, thus, could result in the accumulation of certain substances that bring about the production of flower buds. This possibility also should be studied.

A period in the generation of *P. bambusoides* covers a relatively long time, and death of both culms and rhizomes is brought on by flowering. However, sprouting of regenerated bamboos is anticipated before the culms and rhizomes die completely, and efforts should be devoted to effective utilization of the regenerated bamboo. For this reason in Japan, the ecology and changes in productivity brought about by flowering were investigated in both partially and fully flowering bamboo forests. As a result, it was found that the decrease in productivity of partially flowering bamboo forests was offset by nonflowering bamboo and growth of rhizomes, which produced sprouts of healthy bamboo. It was also found that the productivity of the fully flowering bamboo forest was arrested completely, although recovery of the stand was rapid when new bamboos were sprouted from seeds. It was shown that cutting the bamboos enabled them to regenerate more effectively. During these studies, the classification of regenerated bamboo was also attempted.

Fertilizer application promoted recovery of the basal diameter and length of culm of regenerated bamboos, but it did not increase the number of sprouts. After 3 years of fertilization, the culms were heavier than those of unfertilized bamboos, but the productivity was not increased substantially because the type of bamboo was only of limited utility. Several more years of fertilization were needed to obtain useful bamboo.

The application of fertilizer directly on the ground may have resulted in a delay in the absorption of nutrients, so an alternative method — spraying the leaves — was tried. The results were that regenerated bamboo in the control area was still producing sprouts even after 2 years of the experiment, whereas in other areas no sprouting was observed. In the area where the leaves were sprayed with alpha-naphthalic acetic acid plus urea, the sprouts of regenerated bamboo were abundant in the first year but were absent in the second year. In contrast, sprouting from new bamboos was not influenced in the first and second years of treatment, although differences were apparent in the amount of bamboo produced from the third year on. The yield from plants sprayed with alpha-NAA plus urea was greater than that from plants supplied with three nutrient elements spread directly on the ground. The latter, however, was better than that from plants sprayed with three nutrient elements, a treatment that was better than no fertilizer at all.

The comparative-recovery promotion test was carried out in four plots where nitrogenous fertilizer was applied. The spray of alpha-NAA plus urea on the surface of leaves was a better treatment than spray of urea alone, which was better than scattered urea on the ground, which in turn was better than no fertilization at all. The flowering ratio of the regenerated bamboo was found to be the inverse order of the recovery results.

The scattering of fertilizer on the ground did not affect the amount of leaves produced, but spraying the leaves increased their area. These results indicate that the spray of nitrogenous fertilizer on the surface of leaves effectively promotes the recovery of flowering *P. bambusoides* forests and that fertilizer applied directly on the ground improves only the recovery of rhizomes (188, 189, 194, 237, 286, 375, 428, 433).

Genetics and Breeding

Studies on genetics and breeding in Japan have not yet progressed far enough to determine the causes of the factors involved in phenomena such as the flowering cycles and fruiting.

The pollen grains of some bamboo species show a wide variation (34.75–57.95 μm) in diameter, and those from regenerated bamboo that has developed subsidiarily from old rhizomes of *P. bambusoides* are generally smaller than those from flowering bamboo. The germination test of pollen grains of flowering or regenerated bamboo of *P. bambusoides* was undertaken on saccharose agar medium. The percentages of germination and the length of pollen tubes of *P. bambusoides* on agar medium soaked in solution were a little higher than on normal medium, although the reason is not completely clear.

Other studies on genetics include X-ray and colchicine treatment of seeds in attempts to make them polyploid but these have not been successful. The chromosome number of bamboo species propagated by monopodial type is $2n=48$, although most tropical species that propagate by sympodial type have $2n=72$.

Because electrophoresis techniques have been increasingly used in agriculture, forestry, medicine, and many other fields, studies of isozymes are increasing every year. In Japan, *P. pubescens* forests have been chosen as sample forests for variation experiments on isoenzymes. Results in this area are still at a preliminary stage (269, 270, 430, 447).