Table 1. Comparison of moment of resistance of bamboo-reinforced beams at first crack and ultimate load stages

		Working stress method			Limit state method		
Beam mark	% of bamboo	First crack load KN	Moment of first crack KNm experimental	Moment of resistance KNm theoretical	Ultimate load KN experimental	Ultimate moment KNm theoretical	Ultimate moment KNm
BTSC-1	1	1.87	0.47	0.42	5.68	1.42	2.06
	2	5.96	1.49	0.82	18.10	4.53	3.96
	3	8.84	2.21	1.22	26.80	6.70	5.70
	4	9.90	2.48	1.61	30.00	7.50	7.28
BTN	1	3.83	0.96	0.42	11.60	2.90	2.06
	2	6.50	1.63	0.82	25.80	6.45	3.96
	3	9.37	2.34	1.22	28.40	7.10	5.70
	4	11.09	2.77	1.61	33.60	8.40	7.28
BTCR	1	6.37	1.59	0.42	19.36	4.84	2.06
	2	7.40	1.85	0.82	29.60	7.40	3.96
	3	11.48	2.87	1.22	34.80	8.70	5.70
	4	12.67	3.17	1.61	38.40	9.60	7.28

increment of load under the load point. Load-deflection curves for beams in which three different techniques were used are given in Figure 3. The maximum deflections noticed were between l/150 and l/175 of span.

All the beams developed flexural cracks before they failed. Large deflections were noticed after the first crack, In no case did the beams fail in bond. The beams with one percent reinforcement broke at failure and showed a perfect bond between the bamboo reinforcement and concrete. Figure 4 shows the crack patterns for the three sets of beams with the three different techniques.

First crack loads and ultimate loads were recorded for all the beams (Table 1) and a comparison of strength was made in flexure by the working stress method and by the limit state method. This was done using a partial load factor of two for limit state approach and for the allowable stress, and a factor of safety of 10 for working stress approach for bamboo reinforcement.

Suggested Analysis

Working Stress Method

From the tests on bamboo-reinforced concrete beams, it was observed that the beams behaved similar to conventional reinforced concrete beams with respect to cracking, strain distribution across the cross-section and deflections.

Different types of bamboos available in most parts of the world possess ultimate tensile strength (UTS) ranging from 100 to 200 N/mm' and modulus of elasticity from 15 to 20 kN/mm^2. The UTS of the bamboo used in the present tests is 150 N/mm^2 (f_{by}). The concrete M15 grade was used.

To take into account the durability of bamboo, a low allowable stress is suggested for use in design. The following data are used in the analysis.

bt = allowable tensile stress in bamboo reinforcement
= (l/10 UTS) 15 N/mm'

Eb = Young's modulus of elasticity for bamboo
= 17.5 kN/mm2

E_C = 5700 f_{ck} = 22.08 kN/mm^2

σ_{cbc} = allowable stress in concrete
= **5** N/mm^2

m = 0.8

(i) For a balanced concrete section with bamboo reinforcement the strength constants are:

x/d = 0.21

z/d = 0.93

$\frac{Ml-}{bd^2}$ = 0.488 and

Abt = area of cross-section of bamboo reinforcement
= *0.035*
= 3.5% of effective concrete area.

A comparison of the experimental and theoretical moment of resistance as seen in Table 1 indi-

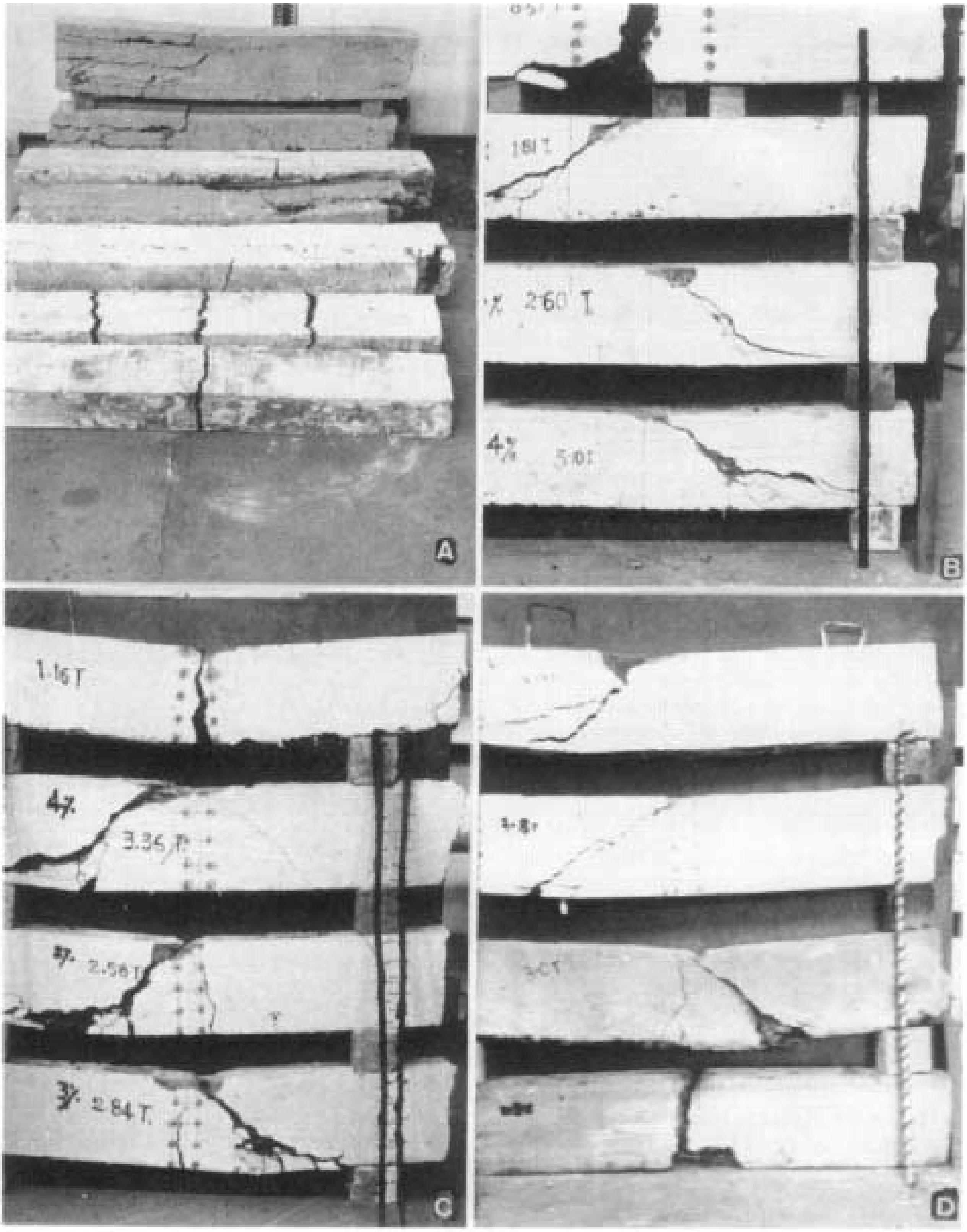
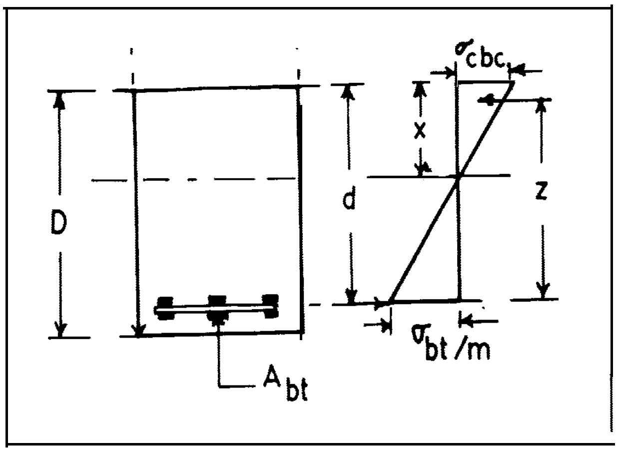


Fig. 4. Types of failure. A. Plain and untreated bamboo-reinforced concrete beams. B. Technique 1. C. Technique 2. D. Technique 3.



cates that the allowable stress adopted in the design is much on the conservative side with respect to techniques 2 and 3. If, however, untreated bamboo is used, the suggested allowable stress is justified.

(ii) For a balanced concrete section with steel reinforcement, using:
Steel Fe-250 grade σ_{st} = 140 N/mm2
Concrete M- 15 grade σ_{cbc} = 5 N/mm^2
m= 19,
the strength constants are:
x/d = 0.404, z/d = 0.87

$\frac{Mr}{bd2}$ = 0 87, A_{St} = 0 0072
= 0.72% of effective concrete area.

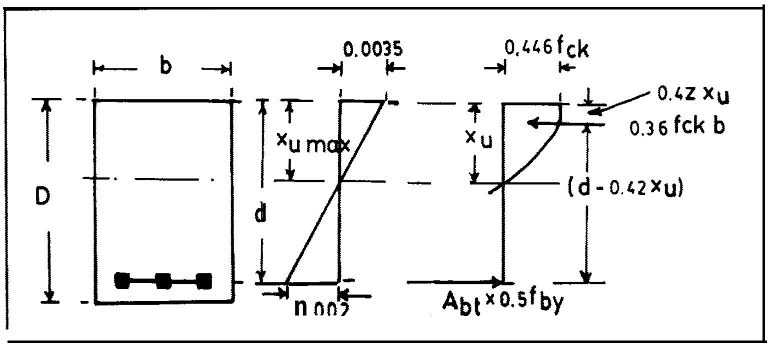
Limit State Method

From the test results, it has been found that the recorded strain at the level of bamboo reinforcement is in the order of 0.003 at the first crack. Based on this observation and to make the member free of visible cracking, a strain of 0.002 is suggested for design purposes.

Beams with bamboo as reinforcement-balanced section

Based on the experimental ultimate moments of the test beams, a partial factor of safety of two for strength of bamboo is suggested.

In the analysis the following data are used.
UTS of bamboo = f_{by} = 150 N/mm^2
Ml5 grade concrete f_{ck} = 15 N/mm^2
Partial factors of safety for concrete = 1.5



and for bamboo = 2

For these parameters, the limit state of collapse-flexure strength constants are

$\frac{Xumax}{d}$ = 0.636 d

$\frac{Mulim}{f_{ck}bd^2}$ = 0.168

Abt = 0.0458
= 4.58%

For a balanced conventional reinforced concrete section using M 15 grade concrete and Fe 250 grade mild steel, the strength constants are

$\frac{Xumax}{d}$ = 0.531

$\frac{Mulim}{f_{ck}bd^2}$ = 0.149

A_{st} = 0.132 bd
= 1.32% of effective cross-section.

Design of Precast Elements For Housing

Design of Slab Unit - Working Stress Method

Member reference	= S
Span	= 1m
Loading class	= 2000
Method	= W.S.D.

Materials and permissible stress

Concrete grade M 15 Bamboo reinforcement grade B- 150
σ_{cbc} = 5 N/mm'
σ_{bt} = 15 N/mm'
Ec = 22.08 kN/mm^2
Eb = 17.5 kN/mm^2
R = 0.488
m = 0.8
Z_1 =0.93

Design loads

Live load DL	= 2000 N/m'
Slab (75 mm) = 75 x 25	= 1875 N/m^2
Floor or roof finish	= 1000 N/m'
Ceiling plaster	= 500 N/m'
Total DL	= 3375 N/m'
Design or characteristic load	= 53,75 N/m'

Bending moment and shear force

$$M = \frac{5375 \times 12}{8} = 671.875 \text{ Nm}$$

$$S = \frac{5375 \times l}{2} = 2687.5 \text{ N}$$

Depth of slab

$$d = \sqrt{\frac{M}{Rb}} = \sqrt{\frac{671.875 \times 1000}{0.488 \times 1000}} = 37.11 \text{ mm}$$

Use D = 75 mm and d = 50 mm

Amount of bamboo reinforcement

$$A_{bt} = \frac{m}{bt \times z_1 d} = \frac{671.875 \times 1000}{15 \times 0.93 \times 50} = 963.26 \text{ mm}^2$$

$$P = \frac{Abt}{bd} \times 100 = \frac{963.26 \sim 100}{1000 \times 50} = 1.93\%$$

Bamboo reinforcement required for- the precast Unit of 500 mm width

$$= \frac{963.26}{2} = 481.63 \text{ mm}^2$$

Use 8 25 x 2.5 strips @ 75 mm c/c (500 mm2)

shear stress

$$\tau u = \frac{S}{bd} = \frac{2687.5}{1000 \times 5} = 0.054 \text{ N/mm}^2$$

which is negligible

Design of Beam Unit - Working Stress M&hod

Member reference	= B
Span	= 3m
Location	= interior
Loading from slab S	= 5375 N/m^2
Method	= W.S.D.

Materials and permissible stress

As in slab - S

Trial section

Try 200 x 300 mm, D = 300 mm, d=270mm,b=200mm

Design loads

Self weight of beam	= 0.2 x 0.3 x 25000 = 1500 N/m
Load from slab - S	=lx5375=5375N/m
Design load	= 6875 N/m

Bending moment and shear forces

$$M = \frac{6875 \times 32}{8} = 7743.38 \text{ Nm}$$

Depth of beam

$$d = \sqrt{\frac{M}{Rb}} = \sqrt{\frac{7734.38 \times 1000}{0.488 \times 200}} = 281.5 \text{ mm}$$

Use D = 300 mm and d = 270 mm

Amount of bamboo reinforement

$$A_{bt} = \frac{M}{\sigma_{bt} \times zld} = \frac{7734.38 \times 1000}{15 \times 0.93 \times 270} = 2053\ 5 \text{ mm}^2$$

$$P\% = \frac{Asrx\ 100}{bd} = \frac{2053.5 \sim 100}{200 \times 270} = 3.8\%$$

Use 16 - 25 x 5 mm strips in 4 layers (2000 mm')

Design of Slab Unit - Limit State Method

Member reference	= s
Span	=lm
Loading class	= 2000
Method	= L.S.D.

Materials, ulrimate stresses and design constants

Concrete grade M 15, bamboo reinforcement grade B-150

f_{ck} = 15 N/mm' f_{by} = 150 N/mm'

$$\frac{Xumax}{d} = 0.636$$

γm = partial load factor = 2

$$\frac{Mulim}{f_{ck}bd^2} = 0.168 \quad \text{Pt lim.} = 4.58$$

Trial section

Try D = 75 mm and d = 50 mm.

Characteristic load

LL	= 2000 N/m'
DL	
Self weight	= 75 x 25 = 1875 N/m'
Floor or roof finish	= 100N/m^2
Ceiling plaster	= 500 N/m^2
Total	= 3375 N/m^2

Design loud

Fd = 1.5 x DL + 1.5 LL = 8062.5 N/m^2

Ultimate moment

$$Mu = \frac{Fdl^2}{8} = 8062.5 \times 3^2 = 1007.81 \text{ Nm}$$

Limit state of collapse flexures

$$\frac{MU}{f_{ck}bd^2} = \frac{1007.81 \times 1000}{15 \times 1000 \times 502} = 0.027 \ (0.168)$$

Xumax = 0.636 x 50 = 3 1.8

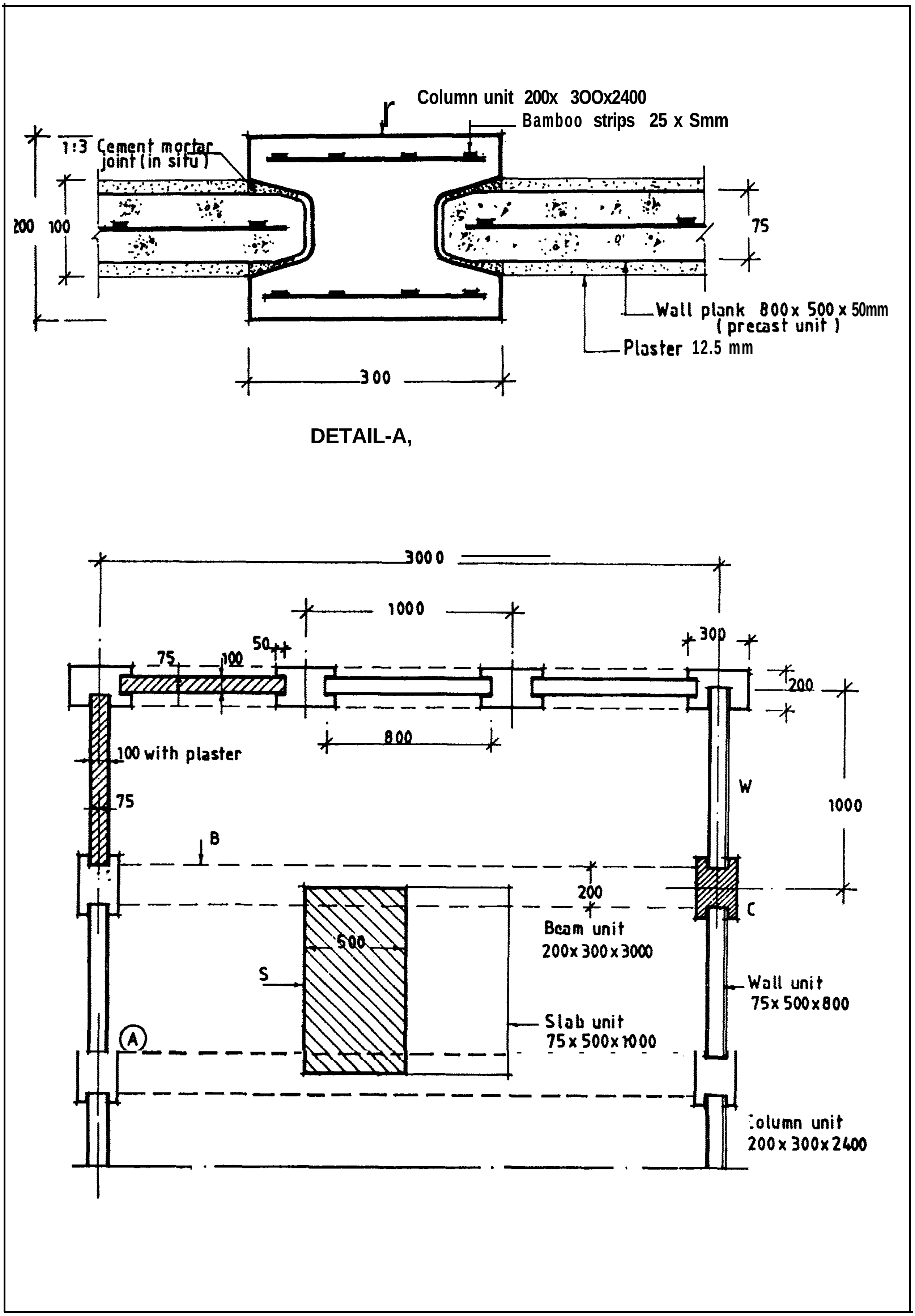


Fig. 5. Part plan of assembly of precast units.

Fig. 6. Floor assembly with precast units (used for load test and durability).

Z = (d - 0.42 xumax) = (50 - 0.42 x 31.8)
= 36.64 mm

$$Abt = \frac{Mu}{0.5 f_{by} z} = \frac{1007.81 \times 1000}{0.5 \times 150 \times 36.64}$$

= 366.74 mm^2

$$Pt\% = \frac{366.74 \times 100}{1000 \times 50} = 0.73$$

Use 4 - 25 x 2.5 strips for 500 mm wide slab (250 mm^2)

Ultimate moment of resistance

$$Xu = \frac{Pt}{100} \times \frac{0.5 f_{by} \times d}{0.36 f_{ck}} \times \frac{0.73 \times 0.5 \times 150 \times 50}{100 \times 0.36 \times 15}$$

= 5.07 mm

Mur = Abt x 0.5 f_{by} (d - 0.42 xu)
= 500 x 0.5 x 150 (50 - 0.42 x 5.07)
1795147 Nm = 1.8 kNm > 1.007 kNm

Design Of Beam Unit - Limit State Method

Member reference = B
Span = 3 m
Loading from slab S = 8062.5 N/m^2
Method = L.S.D
Materials - ultimate stresses and design constants as per slab S

Trial section
Try 200 x 300 mm, D = 300 mm, d = 270 and b = 200 mm.

Design loads
Self weight of beam = 1.5 x 0.2 x 0.3 x 25000
= N/m
From slab S = 8062.5 x 1 = 8062.5 N/m
Total load = Fd = 10312.5 N/m

Ultimate moment

$$Mu = \frac{10312.5 \times 3^2}{8} = 11601.56 \text{ Nm}$$

Limit state of collapse - flexure

$$\frac{Mu}{f_{ck} b d^2} = \frac{11601.56 \times 1000}{15 \times 200 \times 270^2} = 0.053 \ (0.168)$$

Xumax = 0.636 x 270 = 171.72
Z = (d - 0.42 Xumax) = (270 - 0.42 x 171.72)
= 197.88 mm

Bamboo reinforcement

$$Abt = \frac{MU}{0.5 f_{by} z} = \frac{11601.56 \times 10^3}{0.5 \times 150 \times 197.88}$$

= 781.22 mm^2
Use 8 - 25 x 5 strips (1000 mm^2)

$$Pt\% = \frac{1000 \times 100}{200 \times 270} = 1.85$$

Ultimate moment of resistance

$$xu = \frac{Pt \times 0.5 \times f_{by} \times d}{100 \times 0.36 \times f_{ck}} = \frac{1.85 \times 0.5 \times 150 \times 270}{100 \times 0.36 \times 16}$$

= 69.375 mm

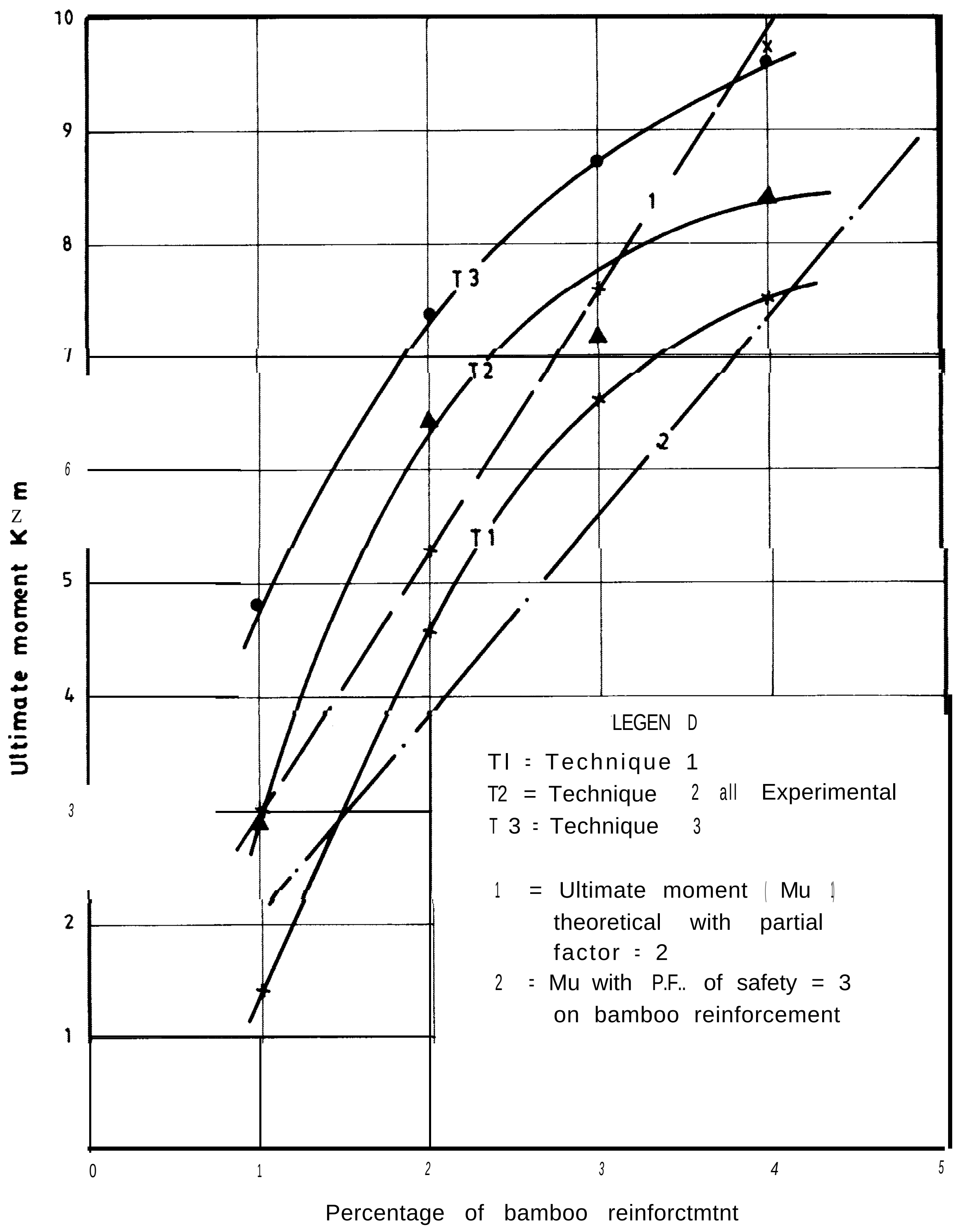


Fig. 7. Ultimate moment versus petcentage of bamboo reinforcement.

Mur = 1000 x 0.5 x 150 (270 - 0.42 x 69.38)
= 18064530 N mm
= 18.1 kNm > 11.6 kN

Figure 5 shows the part of the assembly of the precast units and Figure 6 shows the erected floor assembly.

Conclusions

Test results reveal that it is possible to replace steel reinforcement in conventional reinforced concrete with bamboo reinforcement completely.

The behaviour in flexure of bamboo-reinforced concrete beams tested with different percentages of bamboo-reinforcement is similar to the conventional reinforced concrete beams. Thus, the theory of reinforced concrete can be applied in the analysis and design of bamboo-reinforced concrete.

The magnitude of strain noted in the tests at the level of bamboo reinforcement is of the order of 0.003 at the first crack load and thus for design purposes this value may be limited to 0.002 for the limit state method of analysis and design.

The ultimate moment of resistance measured from tests and the theoretical values computed are found to be close with a partial factor of safety of two for bamboo reinforcement. This factor is, therefore, suggested for design.

For serviceability limit states of deflection and cracking, it is observed that the deflections noted are larger and cracking is wider than is found with conventional reinforced concrete. The deflections measured are in the order of l/150 to l/175 of the span. To control the larger deflections, larger depths may be used. The recommended span to depth ratio is around 10 to 15. It is also observed from Figure 3 that as the percentage of bamboo reinforcement increases, the deflections decreased under a given applied load.

It is seen from Figure 7 that in all the techniques used, the ultimate moment of resistance increased as the percentage of bamboo reinforcement was increased.

However, in the case of the working stress method with an allowable stress of one-tenth of UTS of bamboo, the carrying capacity as given in Table 1 is under-estimated and leads to an uneconomical design. This assumed value is on the conservative side, but the factor of safety of 10 is necessary to control cracking that takes place at first crack appearance.

As the ultimate tensile strength of bamboo is more reliable, a design based on limit state of collapse with a partial factor of safety of two on strength of bamboo and which also gives estimates close to the experimental values as in Table 1, is recommended for design of bamboo-reinforced concrete.

In the case of rectangular beams, about four to five percent of bamboo-reinforcement gives a similar ultimate strength as carried by conventional concrete-balanced beams with steel-reinforcement. Although the test results show that the load carrying capacity of bamboo-reinforced concrete members can be increased by increasing the percentage of reinforcement (Fig. 7), placement of this heavy reinforcement becomes rather difficult and, therefore, the maximum limit of reinforcement should be restricted to four percent of the cross-section.

The bitumen-coated bamboo strips wound around with coir rope as reinforcement develop a very good bond with the concrete. The coir rope forms a ribbed surface and behaves similar to ribbed steel and consequently improves the behaviour of the beams in flexure. These beams carried more ultimate load when compared to beams in which techniques 1 and 2 were used (Fig. 7.)

Further investigations are required on shear behaviour using technique 3 for drafting a set of suitable specifications for bamboo-reinforced concrete design.

References

Masani, N.J. & Dhamani, B.C. 1962. Research on timber concrete bamboo composite construction for standardization and the use of new and improved building material. FRI, Dehradun, India.

Geymeyer & Cox 1970. Bamboo reinforced concrete. Concrete Inst. 67 : 84 l-846.

Narayana & Rahman, Abdu11962. Bamboo concrete composite construction. J. Inst. Engineers **XLIl(9)** Part CI, Calcutta, India.

Gupchup, Jayaram & Sukhadwalla 1974. Suitability of strips as tensile reinforcement in concrete. CIB 6th Congr. Inter. Council Building Res. Studies & Documentation.

Application of Bamboo as a Low-cost Construction Material

K. Ghavami

Civil Engineering Department, Pontifcion Universidade Catolica, Rio De Janeiro 22453, Brazil.

Abstract

Some bamboos of Brazil have been classified according to their physical and mechanical properties. Their use as a substitute for steel in normal and lightweight concrete beams and slabs have been studied experimentally. Several curing methods and watet repellent materials have been considered for reducing their water absorption and improving their bonding ability with concrete. Some studies have also been carried out in developing new joints for the use of bamboos in space structures.

Introduction

The dimensional changes of bamboo due to moisture variation, low modulus of elasticity and the increase in industrial production of steel have reduced the interest in the use of bamboo in civil engineering construction, However, due to the recent energy and material shortages, many researchers have begun to explore new or low-cost substitute construction materials for steel (Ghavami, 1986; Ghavami & Fang, 1984).

Among the many low-cost substitute construction materials, the application of indigenous replenishable biological materials such as the bamboo have the greatest economic potential. This is especially so in the developing countries, since many of these are basically agricultural societies with serious housing problems at the present time. The improvement of the living standard in the less-developed regions in these countries requires a large quantity of construction materials.

Since 1979 several research programmes have been carried- out at the Civil Engineering Department of Pontificia Universidade Catolica of Rio de Janeiro (PUC/RJ) on the use of bamboo as a substitute for steel in civil construction. The purpose of this paper is to present the results of the investigations and outline variables studied for the solution of problems involved in the use of bamboo as structural elements such as bamboo reinforced concrete and bamboo space structures.

Physical and Mechanical Characteristics of Bamboos

In the State of Rio de Janeiro, seven species of bamboos which can be used in civil engineering have been classified according to their physical and mechanical characteristics (Martinesi, 1986).

Physical Characteristics

Bamboo culms are generally hollow cylinders with diameters and heights varying from 1 to 25 cm and 1 to 40 m, respectively. The diameter of the bamboo decreases along its length, from the basal end to the tip. The bamboos which are hollow, are totally separated at the nodes by transverse diaphragms (Ghavami & Martinesi, 1987). The exterior surface of the culm is covered by a hard

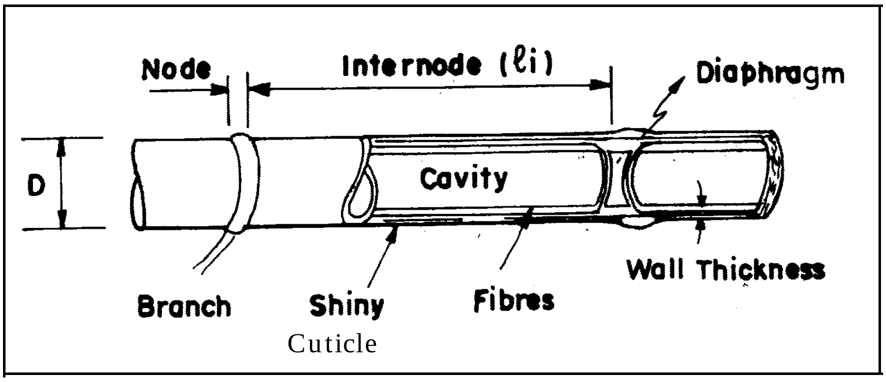


Fig. 1. Differentparts of a bamboo culm.

Table 1. Physical properties of classified bamboos of Rio de Janeiro

Bamboo species and color	Length, L(m)					Diameter, D(cm)			Thickness, T(mm)			Moisture content %	Specific weight kN/m³
	Over-all	Parts	Desig-nation	Size	Inter-node	Base	TOP	Average	Base	TOP	Average		
Bumhusa multiplex (green)	3.0	All	MR	3.0	0.45	2.5	1.5	2.0	4.0	3.0	3.5	15.4	8.8
Bamhusa multiplex (emerald green)	7.5	Upper	MDu	3.0	0.40	3.0	2.5	2.75	4.0	2.5	3.0	14.9	9.2
		Lower	MDl	3.5	0.55	4.0	3.0	3.5	5.0	4.0	4.0	15.5	9.2
Bamhusa tuldoidis (light green)	8.0	Upper	BTu	4.0	0.40	3.5	2.0	3.0	6.0	3.0	4.0	17.8	9.5
		Lower	BTl	3.0	0.40	4.0	3.0	4.0	8.0	6.0	7.0	13.5	9.7
Gundua super-ha (green)	9.0	Upper	GSu	4.0	0.40	10.0	4.3	7.0	7.0	6.0	6.0	19.2	7.3
		Lower	GSl	4.0	0.26	12.0	10.0	11.0	12.0	7.0	9.0	17.5	10.0
Bambusa vulgaris (yellow with Green stripe)	10.0	Upper	VIu	4.2	0.36	7.0	4.6	6.5	6.0	5.0	5.0	16.2	6.2
		Lower	VIl	5.0	0.3 1	8.0	7.0	7.4	14.0	6.0	10.0	15.9	6.8
Bambusa vulgat-is Schard (green)	13.0	Upper	VSu	4.3	0.39	6.0	5.0	5.5	9.0	6.0	7.0	15.6	7.0
		Middle	VSm	4.0	0.35	7.0	6.0	6.5	10.0	9.0	9.5	17.4	7.8
		Lower	VSl	4.0	0.29	11.0	7.0	10.0	10.0	10.0	10.0	17.6	6.6
Dendrocalamus giganteus (dark green)	21.0	Upper	DGu	4.0	0.40	8.0	6.0	7.0	8.0	6.0	7.0	13.9	8.2
		Upper middle	DGum	4.0	0.50	11.0	8.0	9.5	8.5	8.0	8.0	17.0	9.0
		Middle	DGTl	4.3	0.54	12.0	1 I.0	11.0	9.0	8.5	9.0	18.9	9.8
		Lower middle	DGm	4.0	0.54	13.0	12.0	12.5	11.0	9.0	10.0	18.5	8.7
		Lower	DGl	4.5	0.55	16.0	13.0	14.5	13.0	11.0	12.0	19.5	8.6

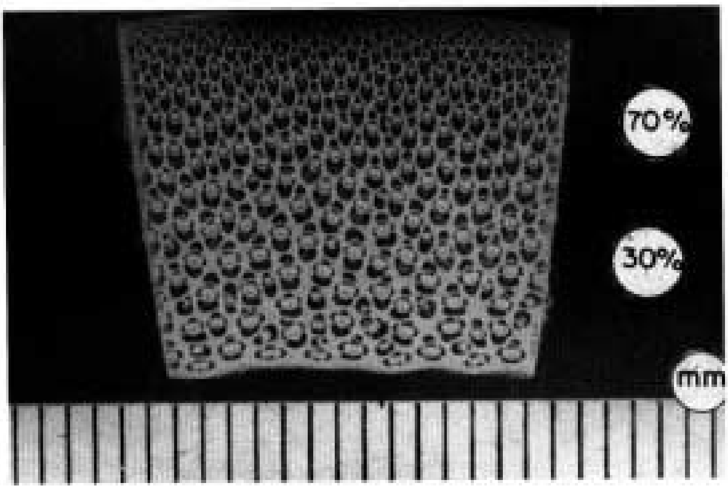


Fig. 2. T.S. of Bambusa tuldoides.

shiny cuticle which partly prevents water loss from the bamboo culm as shown in Figure 1.

The physical properties of the bamboo culm such as colour, overall length L, internode distance 11, diameter D and thickness t as related to the species studied are given in Table 1.

In the classification, the characteristics of the transverse cross-sections of each species of bamboo have been included. The fibres are principally responsible for the strength of the bamboos. They are distributed non-uniformly around the section. In general 40 to 70 percent of the fibres are concentrated in the outer and 15 to 30 percent in the inner part of the culm as can be seen in Figure 2.

The fibres are directed along the axis of the culm with a diameter from 0.08 to 0.7 mm depending on the species and their location in the cross-section. At the node, these are interconnected and partly enter into the diaphragm and branches. As a result of this discontinuity the nodes are generally the weakest point of the culm.

The durability and waterabsorption, etc. have also been studied. In Figure 3 the relation between water absorption and time for the different species is given.

Mechanical Properties

One of the main problems in establishing the mechanical properties of the species under study was to determine the type of the test specimens. In

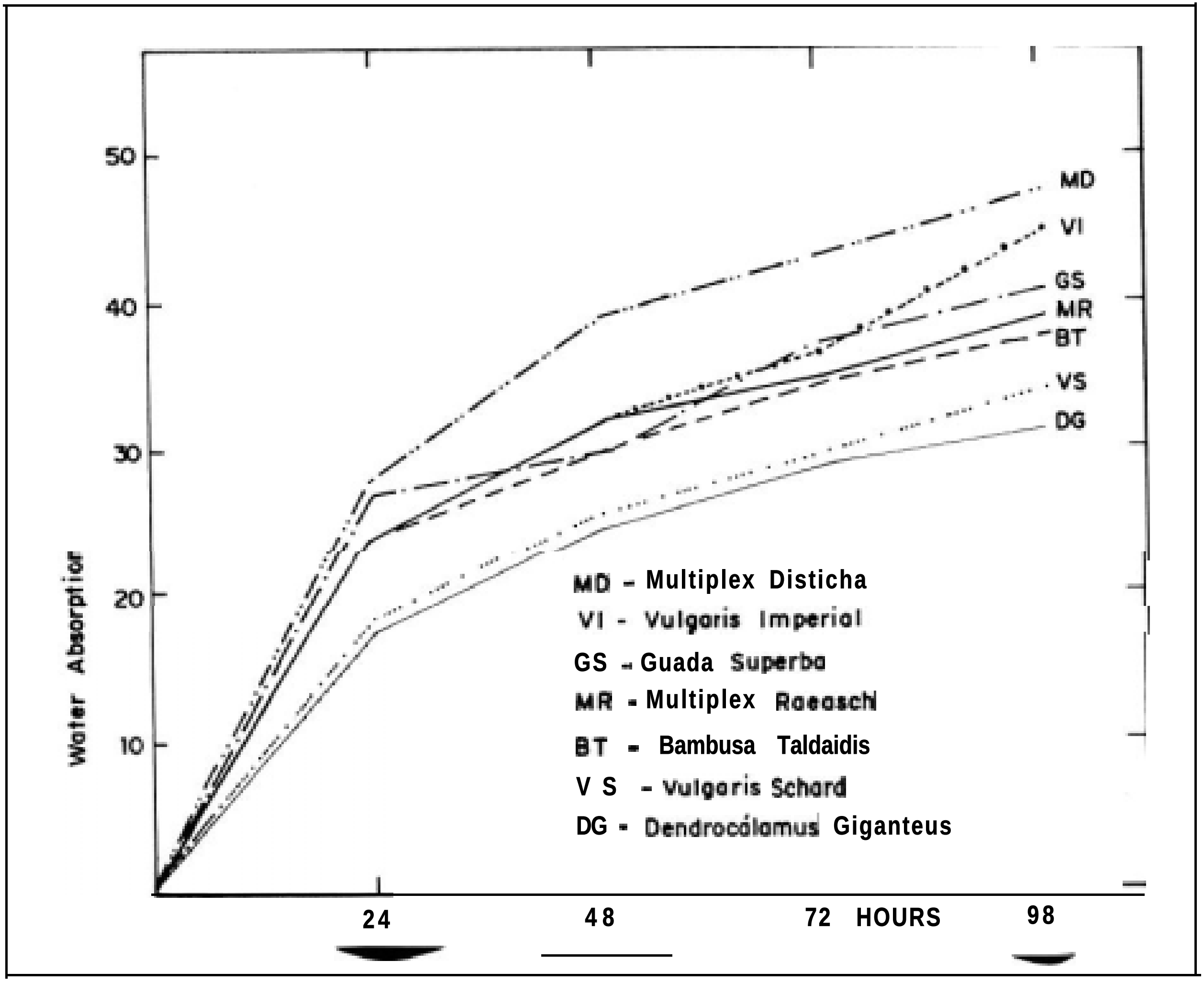


Fig. 3. Water absorption of bamboos

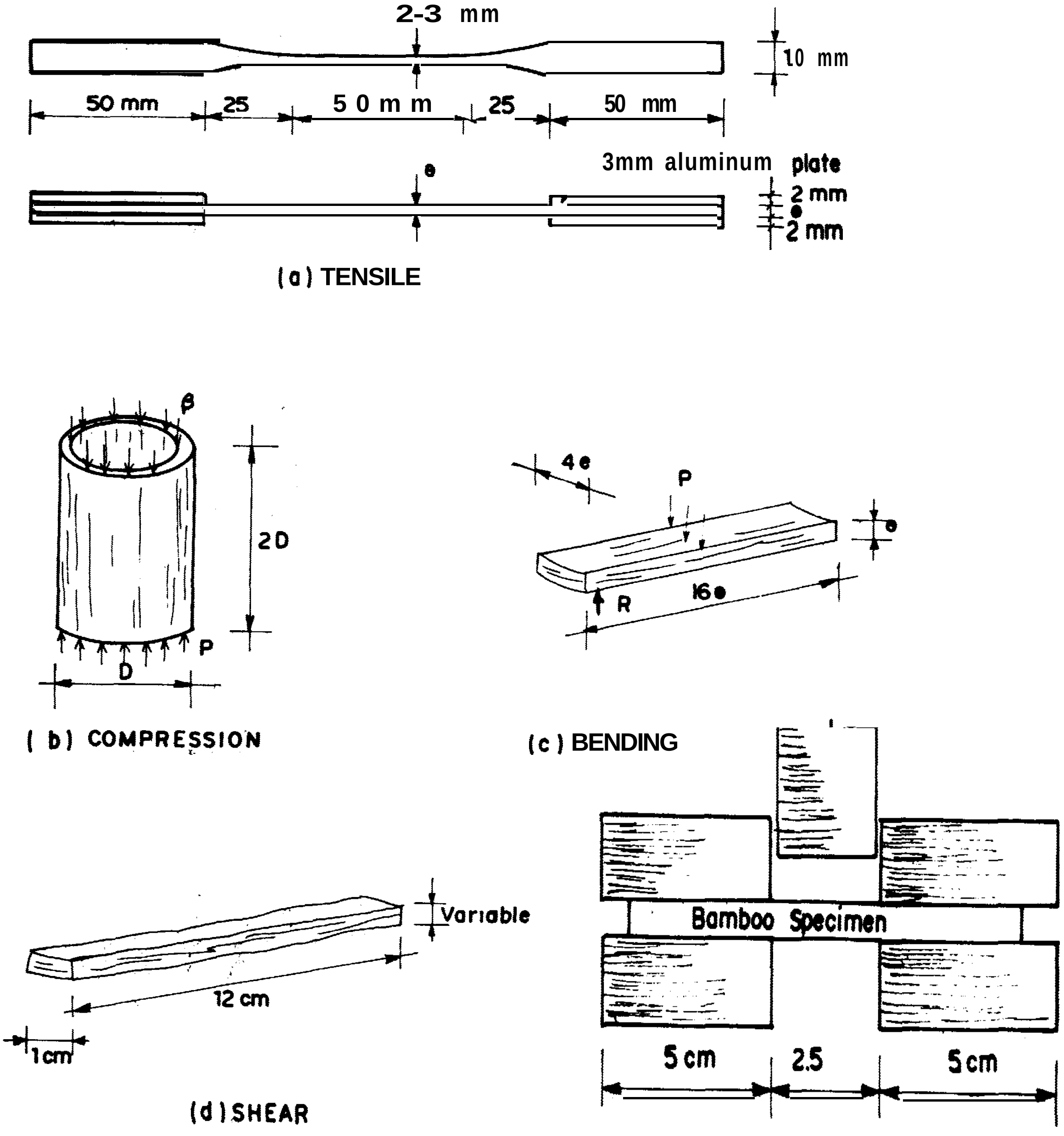


Fig. 4. Dimensions of test specimens.

Table 2. Mechanical properties of the classified bamboos of Rio de Janeiro

Species/ Parts of Culm	Tensile σt Node	Tensile σt No Node	Tensile MP, E_tx 10^4 Node	Tensile MP, E_tx 10^4 No Node	Compression σt Node	Compression σt No Node	Compression MPa E_c x 10⁴ Node	Compression MPa E_c x 10⁴ No Node	Bending σb Node	Bending σb No Node	Bending MPa E_bx 10^4 Node	Bending MPa E_bx 10^4 No Node	Shear MPa
MRu	95.3	124.7	I.005	1.210	27.2	35.7	0.280	0.33	71.0	98.3	0.803	0.968	62.0
MDu	79.8	140.5	I.196	1.267	20.0	26.5	0.355	0.427	63.0	83.6	0.760	1.264	57.0
MDI	68.8	108.4	1.111	1.491	20.6	30.0	0.305	0.415	57.0	78.0	0.966	1.109	49.0
BTu	95.8	98.0	0.855	I.1 19	30.0	38.3	0.283	0.278	79.0	84.0	0.635	0.974	59.0
BTI	112.0	140.5	0.999	1.267	30.2	37.8	0.297	0.324	94.0	115.2	0.816	0.894	50.0
GSu	115.8	151.0	0.942	1.183	35.0	45.0	0.283	0.355	94.1	105.0	0.620	0.960	50.0
GSI	108.8	142.6	0.833	I.048	36.4	50.6	0.246	0.312	85.4	122	0.725	0.887	46.0
VIu	41.5	101.6	0.575	0.716	Il.6	32.0	0.203	0.246	36.0	86.0	0.487	0.630	42.6
VII	54.6	167.2	0.634	0.83	13.0	50.2	0.217	0.249	47.5	144.0	0.549	0.694	39.0
VSu	145.6	182.0	0.945	I.267	42.0	59.0	0.280	0.367	118.8	150.0	0.79 l	1.096	42.0
VSm	106.1	153.5	0.85	1.023	39.5	46.0	0.236	0.319	89.7	33.2	0.736	0.91-7	42.5
VS1	131.6	176.4	0.846	I.002	37.5	53.0	0.260	0.286	112.3	40.5	0.676	0.791	39.0
DGu	109.3	156.0	0.857	I.072	32.6	49.0	0.245	0.308	86.0	36.7	0.724	0.896	49.0
DGum	119.2	148.3	I.274	I.548	37.5	50.0	0.410	0.458	t 02.0	l 32.5	1.05 1	⌋ 336	44.5
DGm	114.6	139.7	l .269	I.593	32.9	47.5	0.401	0.446	97.0	223	1.109	l .298	45.6
DGim	109.3	129.8	I.250	l .522	33.0	41.5	0.375	0.456	94.6	18.3	I.032	I.262	44.7
DGI	99.3	101.6	l .222	I.498	58.8	39.7	0.357	0.34 I	85.6	I I2	I.057	1.296	47.0

addition, the exact age of the bamboo specimen was not known. However, for the determination of tensile, compression, bending and shear strength of the bamboo species under study, the test specimen shown in Figure 4 was used. After trying different methods of fixing the specimen in the universal testing machine, satisfactory results were obtained by fixing 3 mm aluminium plates at the grips for the tensile test.

To establish the average values of the strength for the mature cured bamboos and the standard deviation for each test group, 4 to 12 specimens were tested. The average values, for each species at different points on the bamboo are given in Table 2. It can be noted that *Bambusa vulgaris* Schard (VS) and *Bambusa vulgaris* Imperial (VI) have got the highest and lowest strengths, respectively.

Water-repellent Treatment

One of the major handicaps of bamboo for application in civil construction is its water absorption. The water absorption for untreated species of bamboos under study was found to be between 27 and 33 percent after 96 h immersion in water. In order to overcome this weakness of bamboo culms 20 different water repellent treatments were studied (Ghavami & Hombeeck, 198 1; Martinesi, 1986). It was found that the application of bitumen and Negrolin both of which are relatively cheap gave the best result.

Bond between Bamboo and Concrete

In order to examine the bond between bamboo and concrete, pull-out tests were carried out on concrete cylinders depicted in Figure 5. The preliminary bond tests were carried out using the type A pull-out test (Ghavami & Hombeeck, 1981) which was modified to type B at a later stage of research (Martinesi, 1986).

The bond strength of treated bamboo culm showed an average of 50 to 90 percent improvement over the untreated material for Negrolin-sand and Negrolin-sand-wiring, respectively. The tests were carried out on segments of bamboo with and without nodes. In all cases the bond strength for specimens with nodes was higher by over SO percent.

Development of Joints for Bamboo Space Structures

To cover a large space without using many columns, steel truss space structures are usually used. The resistance and form of bamboo are very

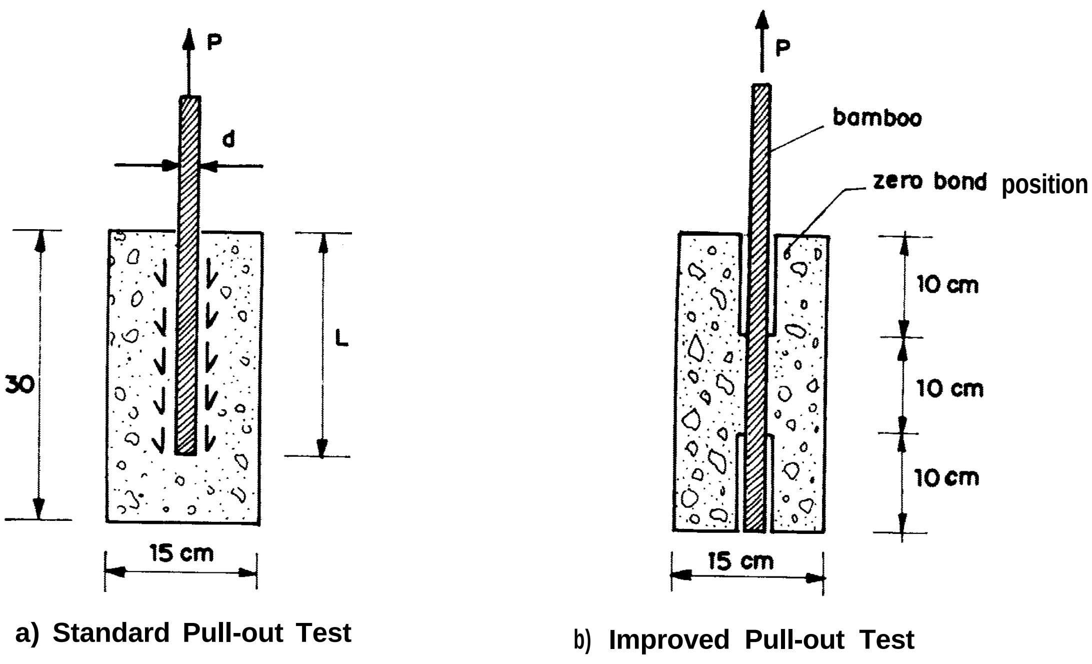
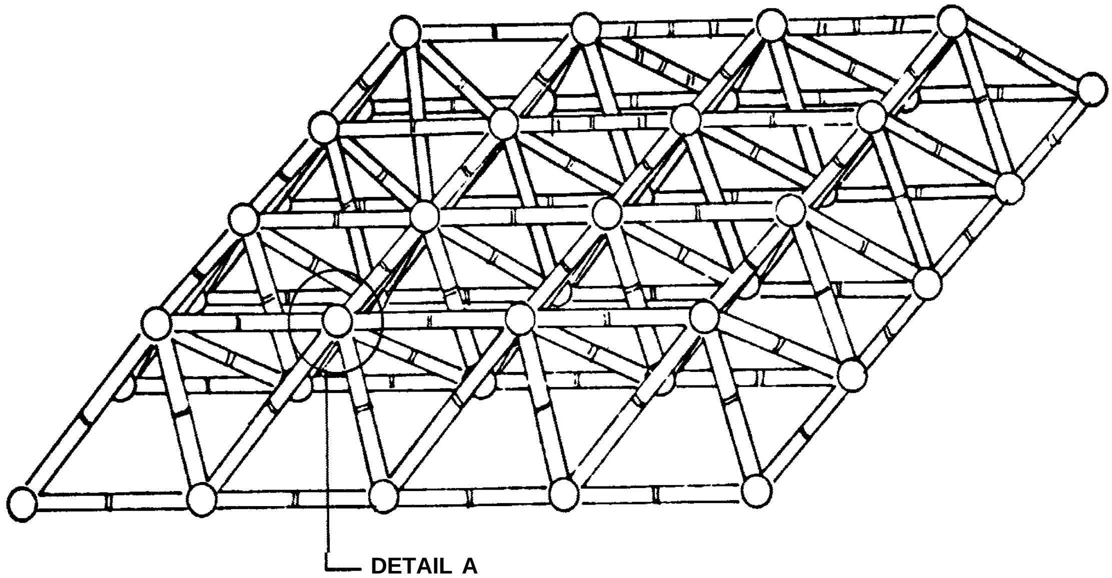
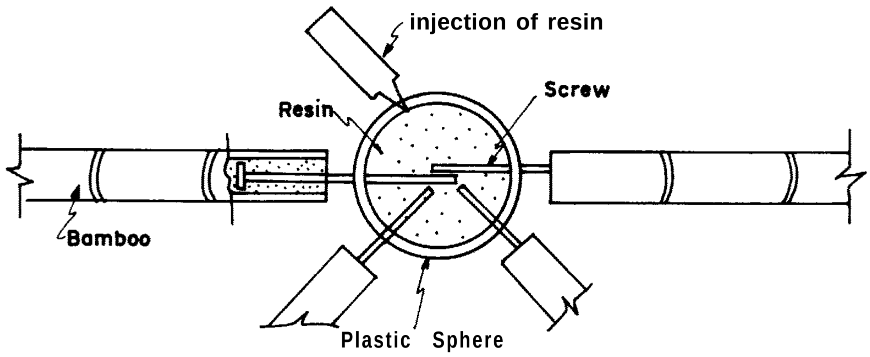


Fig. 5. Bond test specimens.



(a) SPACE STRUCTURE



(b) CROSS - SECTION OF DETAIL A

Fig. 6. Bamboo space structure.

suitable for such structures. In the construction of structures such as shown in Figure 6, the most difficult part is the formation of joints. Several types of joints besides the conventional method of using rope or wire were developed (Ghavami *et al.*, 1984). The best joint type is shown in Figure 6.

Bamboo-reinforced Concrete Elements

To verify the performance of bamboos as reinforcement in concrete beams and slabs, 11 tests with normal concrete and three beam tests with lightweight concrete were carried out.

Bamboo Reinforcement in Normal Concrete Beam

Two simply-supported bamboo-reinforced concrete beams with overall dimensions of 20 cm width, 30 cm depth and total length of 200 cm were tested. The beams were subjected to two point loads at the third of the span. The bamboo segments of 3 cm width were treated with IGOl-T which is a resin-based product.

In one of the specimens the bamboo segments were positioned vertically along the depth of the beam, It was found that the beam with the bamboo segment in horizontal position had a better performance and higher ultimate load carrying capacity as compared to bamboo reinforcement in the vertical position. In the former case the behaviour of the beams before cracking was close to the predicted result. Normal concrete of 1: 1.4:24 with a water to cement ratio of 0.45 was used.

However, upon appearance of the first cracks in the tension side, the beam developed higher crack width and deflection in relation to the normal steel-reinforced concrete beams. Close to the ultimate load the cracks were not numerous but were wide showing that the bonding is yet poor (Ghavarni & Hombeeck, 198 1).

Permanent Shutter Slabs

To establish the behaviour of one way simply supported permanent shutter slabs, two series of tests as shown in Figure 7 were carried out.

In the first series a total of six medium-sized specimens with untreated bamboo, bamboo soaked in water for 48 h and bamboo treated with primer paint-sand were used. Additional variables were the type of bamboo cross-section, (half or quarter splits of the 8 cm diameter culm). In each case the effect of a gap of 3 cm between the bamboos was also studied (Ghavami & Zielinski, 1988).

It was found that the slabs made of half-treated bamboo without gap performed better than the others under bending stresses. Based on this finding the second series of full-sized tests are being prepared. In this series the specimens are being made with half-section bamboo treated with paint-sand and epoxy. In one of the slabs with paint-sand treated bamboo, some shear connectors are being included.

Light Weight Concrete Bamboo Beam

To reduce the self-weight of the beam three full-sized specimens using light weight concrete were tested. Expanded lightweight clay aggregate has been used for producing the concrete. As a reference the first test in this series was executed with normal steel reinforcing bar with a reinforcement (p) (i.e. area of reinforcement to total beam cross-sectional area) of 0.78 percent. The other two tests were prepared identical to the first but used DG, and DG,, bamboo with p = 3.33 and p = 5.00 respectively. In all beams only steel strips were used (Martinesi, 1986).

In Figure 8 the dimensions and position of the reinforcement and pattern of the cracks before final failure are given. It was observed that by increasing the reinforcement from 3.33 to 5 percent, the load-bearing capacity of the beam decreases. Therefore, based on this limited study it is possible to state that the optimum value for the reinforcement for this type of beam is around three percent.

The behaviour of this series of tests is in general similar to beams with normal concrete; before cracking of the concrete the experimental results were close to the predicted values. However, the test with p = 3.33 percent showed a low neutral line as can be seen in Figure 8b.

Conclusions

The improvement of housing in the less-developed regions of Brazil requires a large amount of construction materials currently not available to the people. In addition, housing is an important part of the control plan of triatominoe vectors of Chagas disease as one of the measures of indirect control.

The problems which deter the use of industrialized materials such as steel is not only the cost of the materials but also the cost of transportation. In most of these regions, proper roads do not exist and besides, these are often quite far from the industries which are located around or in the big cities. Hence the utilization of locally available indigenous biological materials such as bamboo have a greater practical value in relation to possibilities such as industrial and mining wastes, etc. It can be expected that the collection of all available data and a thorough understanding of the major variables

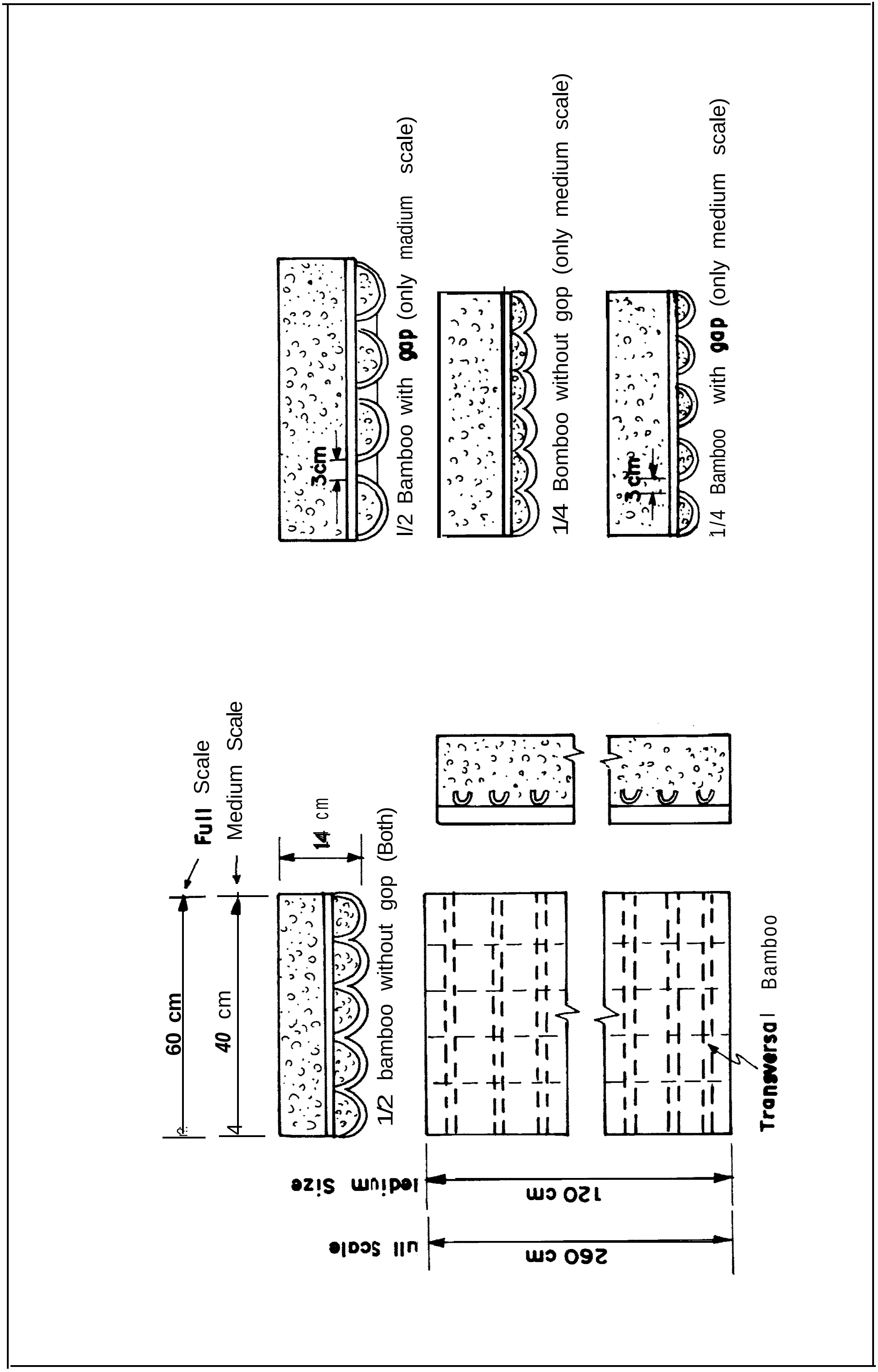


Fig. 7. Bamboo permanent shutter slab.

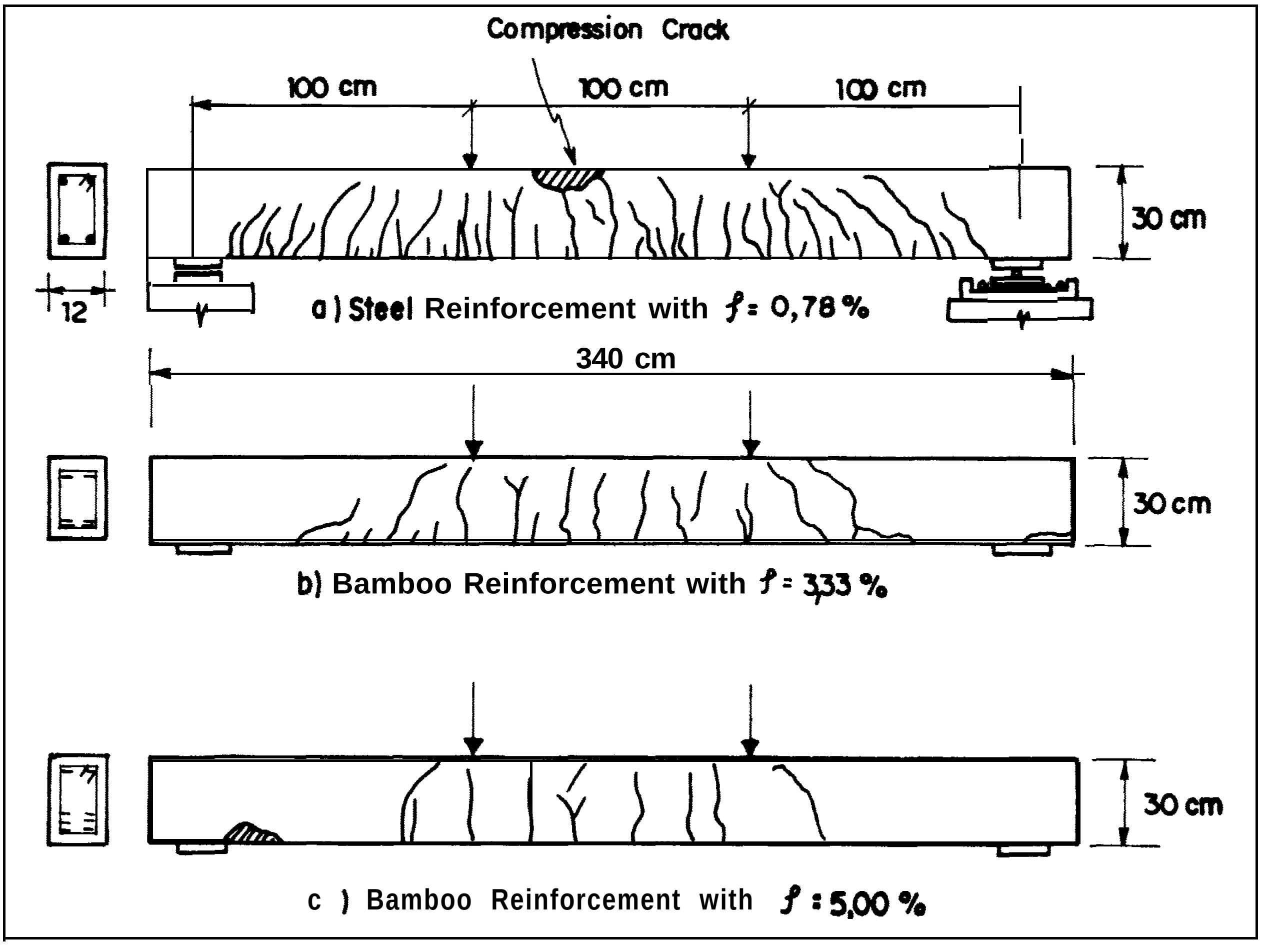


Fig. 8. Reinforced light weight concrete beams.

which govern the engineering properties of bamboo will make it possible to develop a basic set of design and construction criteria.

Acknowledgements

The author would like to acknowledge the contribution and cooperation of Mss Martinesi, Andrade, Antunes and Mr Hombeeck in the execution of the research programme. Further, he would like to thank Profs Zielinski and Douglass and Mr Nouraeyan from Concordia University foi their contribution in the execution of tests on bamboo slabs. Thanks are also due to Gloria for reproducing the drawings and to Eni and Magali for typing.

References

Ghavami, K. & Hombeeck, R.V. 1981. Application of bamboo as a construction material. Part I. Mechanical properties and water-repellent treatment of bamboo. Part II. Bamboo reinforced concrete beams. : 49-66. In Proc. Latin Amer. Symp. Rational Organization Building Appl. to Low Cost Housing. IPT, Sao CIB. Paulo, Brazil.

Ghavami, K. & Fang, H.Y. 1984. Low Cost and Energy Saving Construction Materials. Vol. I. Envo Publ. Co. Inc. Lehigh, U.S.A. pp 624.

Ghavami, K. 1986 Low-Cost and Energy Saving Construction Materials. Vol. 2. EXPED-Expressao e Cultura. Rio de Janeiro, Brazil. pp 300.

Ghavami, K. & Martinesi, R.A. Culzoni 1987. Utilizao do bambu como Material em Habitacao de Baixo Gusto.: 18 1- 188. **In** Proc. Inter. Symp. Transfer and Production Housing Technology Research and Practice HABITEC. IPT, CIB. Sao Paulo Brazil (Portuguese).

Ghavami, K.; Hombeeck, R.V.; Andrade, H.N. de & Antunes, C.C. 1984. Viabilidade de uma Trelica Espcial de Bambu.: 32. Internal Report, RI10/84, Civil Engineering Department Catholic Univ. Rio de Janeiro, Brazil. (Portuguese}.

Ghavami, K. & Zielinski, Z.A. 1988. Permanent shutter bamboo reinforced concrete slab. Report BRCSI, Dept. Civil Engn. Concordia Univ. Montreal, Canada. pp 34.

Martinesi, R.A. Culzoni 1986. Caracteristicas dos bambus e sua Utilizacao corn Material Alternativo no Concrete 134. Master Thesis, Civil Engen. Dept. Catholic Univ. Rio de Janeiro, Brazil. (Portuguese).

CIB-WI8B Activities Towards a Structural Design Code for Bamboo

G.N. Boughton

Curtin University of Technology, Perth, Australia.

Abstract

Bamboo has been used successfully as a structural building material for centuries and doubtless there are design guidelines or rules in existence. This paper points out the benefits to be accrued by publicising an internationally recognized bamboo design code and provides a broad outline for the form of the code.

Introduction

The Conseil International du Batiment pour la Recherche 1' Etude et la Documentation (CIB) is an international organisation specifically established to document building research activities in various parts of the world. It has a particular interest in translating research into a form that can be used directly by industry in a practical way. CIB does not specifically fund research, but relies on voluntary participation that will enable the appropriate documentation of research. In many cases, the output of the CIB activities are draft standards that have been adopted by the International Standards Organisation (ISO) or incorporated into specific national standards or regional standards such as the Eurocodes.

CIB operates by establishing a number of task-related working commissions that have well-defined themes. In 1987 a subgroup of Working Commission W 18, Timber Engineering was formed to address the needs of tropical timber-producing countries. The new group, CIB-W18B, a working commission on tropical and hardwood timber, met for the first time in September 1987 at Singapore and has since met again in September 1988 at Seattle, USA.

The membership of CIB-W 18B is drawn from West Africa, Asia, Australia, North America and Central America, and attempts have been made to have active participation from the Andean Pact nations as well. A number of specific documentation proposals have been drawn up by the working commission, and chairmen for each proposal have been assigned.

1. Comm on International Timber Engineering Standards
2. Trade in Hardwoods
3. Structural Utilization of Mixed Species
4. Design with Bamboo
5. Manuals on Hardwood Engineering Practice
6. Simplified Timber Engineering Design Codes
7. Pole Buildings
8. Engineering Design Criteria
9. Plantation Hardwoods

Of these, project 4 involves assembling known documentation on bamboo design and producing a design standard that is at least compatible with the simplified timber design standard also being prepared. The reasons for the preparation of such a standard are detailed in this paper.

Bamboo

Bamboo is an excellent structural material, being light-weight, circular and moderately strong. It has been used throughout the tropics as a building material for centuries. The use of bamboo over a long period of time had built up confidence in its performance, treatment and construction techniques. The rapid growth of the bamboo plant meant that it had a short production cycle, and the resilience of the plant meant that its commercial production could be achieved with minimum effort or control.

Construction techniques which have survived the test of time vary from country to country, and even from region (or language group) to region. In some cases the construction techniques may have been documented as design rules, but would require interpretation within the social and local technological context in which they were originally written.

Current world housing shortages have forced a number of countries to seriously consider the use of bamboo for providing shelter as part of a national strategy. However, in many cases, the social stigma of being "poor man's lumber" has prejudiced its use. A further complication is that bamboo, is not a recognized modern building material and has no code of practice. This makes it hard to formalize its use in any kind of contractual sense. The most conspicuous use of bamboo is in short-term scaffolding and owner-constructed rural or urban fringe housing. Neither of these uses has enhanced the social image of bamboo.

In locations where bamboo has seen popular use, a number of manuals have been written to provide guidance as to the traditional methods of construction. Some examples include the work of McClure (1970), Munandar (1985) and Siopongco (1986). Unfortunately, many of the manuals that have been produced are not able to provide the technical information on strength and behaviour of bamboo that will enable a practising structural engineer to design in bamboo with confidence.

Bamboo - an Engineering Material

The potential of bamboo as a structural material has not gone unnoticed, and a number of research projects have identified base-line engineering properties that enable the commencement of documentation of the material. This includes work by Janssen (1987), Abdullah and Abdul-Rahim (1987), and no doubt, many others. A number of research projects have amassed information on the various species of bamboo commonly used in construction throughout the world, and have enabled classification schemes to be formulated.

This work has demonstrated that for work with bamboo, repeatability in tests can be obtained, properties can be classified, and the species can be grouped to simplify strength and behavioural grading. If design in bamboo were codified, engineers would be able to use it with the same confidence that they display in the use of recognized engineering materials such as steel or timber.

Advantages of Codified Design with Bamboo

The codification of design with bamboo would have a number of social and practical advantages that could see an increase in the effectiveness of its use.

Engineering Recognition

Structural engineers are given the responsibility for the safe and cost-effective design of many types of structures. In order to exercise that responsibility properly, engineers make use of codes. Codes bring a much broader experience base to bear on any problem than could be provided by an engineer in isolation. They establish the limits of "normal practice". They also implicitly provide checklists to ensure that all possible combinations of loads and failure modes have been checked. All of these factors lead to confidence in application by practising engineers.

Contractual Advantages

In many cases engineering works are subjects of contractual arrangements. Codified design and construction methods have considerable advantage in these cases. In Government-funded projects, the use of building regulations and codes of practice is often specified in the contract. Codification of design and construction techniques for bamboo will enable it to be specified in contractual arrangements without uncertainty as to the safety or effectiveness of the finished product.

Trade Advantages

The existence of a single unified bamboo code will have obvious trade implications. Not only will quality control over bamboo products become easier to manage, but designers with experience in bamboo would be able to market their skills internationally.

Increased Use of Bamboo

The combination of the above three effects will increase the use of bamboo in three ways.

1. The improved "respectability" of bamboo may make it more socially acceptable in the wider sense. Where bamboo was not being used because of current social stigmas, the fact that it can be classified, stamped and used as a reputable engineering material may enable its widespread and deliberate re-introduction to building.
2. The codification of bamboo design may lead to innovation on the part of designers. Its use may, therefore, be diversified and adopted in non-traditional areas.
3. As more designers gain experience and confidence in the use of the material, it will be specified more regularly. The low production and transport cost of bamboo will make it a highly competitive structural material, particularly in the developing countries where other

structural materials such as steel are very expensive. Increases in the use of bamboo will improve the economy of many tropical countries that rely heavily on the use of imported building materials.

International Focus for Research and Documentation on Bamboo

The development of any code provides impetus for co-operative research and investigation. It also provides a focus for that work, as the discussions with respect to codification highlight current deficiencies in knowledge. An international code development programme would bring together and give direction to the expertise of research workers on every continent.

Philosophy of the Bamboo Code

Similarity with the format and rationale of the timber codes is an obvious advantage to the new bamboo code. This will reduce the time that designers will have to spend on learning to come to grips with a new code. As the countries that would be expected to make the largest use of bamboo are developing countries, they would use a simplified version of the timber code (Boughton, 1988) with which the bamboo code should be closely aligned.

The use of similar nomenclature, symbols and terminology would also save confusion. It could well be that the same chapter headings could be used, although for the present, if the code is restricted to the use of round bamboo, its design code should be simpler than the timber design code. (For example: as bamboo is round, with excellent torsional properties, there would be no need to include anything under lateral buckling of single member beams.) In general, its shape will make the structural design clauses simpler, but the connection and structural properties section may be more complex.

A Suggestion for the Code Format

1. Introduction
   includes scope, notation and definition.
2. Basis of Design
   includes the fundamental requirements and general design concepts.
3. Materials
   includes fundamental properties of various bamboo species and the materials commonly used in joints-rattan, twine, natural fibres, nylon line and polypropylene.
4. Structural Design - Members
   includes behavioural aspects of beams, struts and tension members.
5. Structural Design - Connections
   includes behavioural and geometric aspects of many common types of connections.
6. Structural Detailing
   may include some standard structural forms.

Recommendations

In view of the advantages expected from the production of a bamboo code, bamboo producing countries should be canvassed to ascertain their willingness to participate in the code formulation process.

Collection of available engineering information can be commenced immediately so that it can be assembled and used as a basis for code discussions and the planning of future research work.

References

Abduilah, A.A.A. & Abdul-Rahim, A.A.A. 1987. Bamboo as a low cost material of construction. Proc. CIB-W 18B, Singapore.

Boughton, G.N. 1988. The use of simplified design codes in developing countries. Proc. CIB-W 18B, Seattle.

Janssen, J.J.A. 1987. Banboo as a building material. Proc. CIB-W 18B, Singapore.

McClure, EA. 1970. Bamboo as a building material. USDA.

Munandar, M. 1985. The technology manual on bamboo as a building material. Inst. Human Settlements. Ministry Public Works, Bandung, Indonesia.

Siopongco, J.O. 1986. Typhoon resistant bamboo house construction systems. UNIDO/UNDP Seminar/ Workshop on Typhoon Resistant Construction Methods, Manila.

PROCEEDINGS OF
THE INTERNATIONAL
BAMBOO WORKSHOP,
NOVEMBER 14-18, 1988

BAMBOO FOR PULP, PAPER AND BOARD

Development of a Bamboo Base and its use as a Raw Material in the Paper Industry

Shen Zhen-xing, He Tian-jian, Zeng Guang-zhi, Chen Shao-nan

Changjiang Paper Mill, Sichuan, China.

Abstract

The importance of replacing wood with bamboo for paper-making is emphasized. A case history of raising bamboo plantation as a joint effort between a big paper industry and government is illustrated.

Introduction

The modemizatiqn of the paper industry in China has seen a change in the main raw material from an agricultural product (straw) to a forest material. The forest resources, however, are rather poor and the yield is low. At present, it is not possible to expect a large amount of wood from the forest for supply to the paper industries. In 1985, the proportion of wood pulp used in China was only 22 percent as against the world level of 94 percent. In comparison, in the Sichuan province, the proportion of wood pulp dropped from 40 percent in the 1950s to 13 percent in the 1980s.

According to data gathered by the Sichuan Paper-making Association, there are 98 paper mills located in eight provinces which together produce 42 different kinds of paper. The maximum are in Sichuan province and hence there is a large requirement of pulp. Based on experiments and experiences in paper-making, it has been recognised that bamboo fibre is by far better than that of deciduous wood and straw in terms of quality, and as good as coniferous wood. In 1983, the production of bamboo pulp was about 27 000 tonnes. At present, wood supply being low in Sichuan, it is important to carry out research on the use of bamboo instead of wood in the paper industry and develop a good bamboo base in the country.

History and Present State of Paper-making with Bamboo at the Changjiang Paper Mill

The Changjiang Paper Mill is about 50 years old. At present, it consumes 150 000 m^3 of wood and 20 000 tonnes of bamboo, and produces 30 000 tonnes of industrial packing paper annually. The species of bamboo used are *Bambusa multiplex, B. rigida, Neosinocalamus affinis, Phyllosrachys heteroclada, P. nidulalria,* and others. All of these are available in the Yibin area. In the past, bamboo used to be stored in the open as a result of which it was attacked by fungi resulting in low pulp yield and low strength of paper. Lately, new storage techniques have been adopted in order to decrease the decay of bamboo. Since 198.5, fresh bamboos are being put to use as soon as they arrive. Thus, the extent of decay has dropped and the quality of the product has improved.

Mixing bamboo pulp with wood pulp as a raw material increases the variety of paper products that can be produced. At present, the Changjiang Paper Mill can produce some ten different kinds of paper using the bamboo-wood pulp mixture. The bamboo content is raised up to 30 percent for some varieties of paper. The bamboo consumption has increased from 2000 tonnes in 1979 to 2 1 000 tonnes in 1986. During the eighth Five Year Plan, it is envisaged that the bamboo content in paper would increase to 50 percent. Thus, in the past several years, much wood has been saved in this way and the cost of production brought down considerably.

Establishment of a Bamboo Base for Paper-making

China is poor in forestry resource; and the supply of wood is declining. In the near future, it would become very difficult to obtain adequate wood for the paper industry. It is, therefore, imperative that the raw material problem is solved.

In Yibin and its surrounding areas, 15 species of bamboo are found and the area under bamboo forest is about 435 000 mu. The annual bamboo production is about 150 000 tonnes. There are still some 400 000 mu of uncultivated land, including hills, suitable for bamboo cultivation. Since the amount of bamboo consumed is bound to increase every year, the bamboo resources will face destruction through indiscriminate cutting, unless properly managed. It is, therefore, important that a dependable, stable bamboo plantation is established.

In 1983, with the support of the forest department of Yibin, the Changjiang Paper Mill surveyed several counties for the availability of bamboo resources. On completion, a proposal for the establishment of a bamboo plantation was made. In March 1984, proposal was approved and the forest-cultural fee was fixed at 12 yuan for every tonne of bamboo consumed. From 1984 to 1987, the mill has paid 810 000 yuan as fee.

In October 1983, the Changjiang Paper Mill signed a contract with the Forestry Bureau of Yibin county which stipulated that from 1983 to 1987, 50 000 mu of bamboo plantations were to be established in eight districts, 19 villages and one forestry area. The mill was to pay 18 yuan for every mu as investment. This investment was to be paid in instalments within four years. The contract also stipulated that five years from the time when the bamboo plantation was accepted as mature, the plantation would supply the suitable material to the paper mill. During the contract period of 20 years, the county on its part warranted to sell seven tonnes/mu of dry bamboo at the market price to the mill. The duties, rights and economic responsibilities of both parties were also stipulated.

Research Work on Selecting Bamboo Species for Paper-making

During the past three years, research work on pulp and paper-making with different kinds of bamboo growing both in and out of Sichuan province has been going on. Based on the data derived from these experiments, it was concluded that many species of bamboo such as *Bambusa sinospinosa, Dendrocalamus giganteus, Sinocalamus laliforus,* are good for paper-making. Paper made from these were better than those produced from other species of bamboo in strength and came close to fir wood in quality.

Forecast of Profit from Raising Bamboo Plantations

According to the master plan of the Changjiang Paper Mill, its output is to reach 50 000 tonnes during the seventh Five year plan and 80 000 tonnes at the end of the Eighth Five year plan. An area of 250 000 mu of pine and 200 000 mu of bamboo plantations will need to be established. At the end of the Eighth Five Year Plan, the 200 000 mu of bamboo plantations is expected to produce about 80 000 tonnes of bamboo (about 35 000 tonnes of pulp) every year and 190 000 m^3 of wood material can be saved. Bamboo also consumes less alkali and power than wood to produce pulp and its cost is also lower. If the cost of production of a tonne of bamboo pulp is lower than that of wood by 400 yuan, by the end of the Eighth-Five Year Plan, the savings will be of the order of 14 million yuan every year.

In order to establish 200 000 mu of bamboo plantations, the mill will need to invest four million yuan. During the period of afforestation, the average investment every year will amount to 300 000 yuan.

When the plantations become productive, seven tonnes of dry bamboo chips per mu will be sold to the mill. Since the price is 100 yuan per tonne, the average annual income of the farmers will be seven million yuan. After the bamboo plantation is raised and put into production, the county government can get 16.8 million yuan (12 yuan/tonne) every year. An advantage of raising plantations is that a steady supply of fibre raw-material will be available in the vicinity of the paper mill. The cost of transportation will, therefore, be lower.

Problems in Raising Bamboo Plantations

At the time of developing the bamboo base, the local governments at different levels did not have a unanimous point of view. Much attention was not paid to this work, and little publicity was given. During the early stages of raising of the forests, the plan and design were not carried out in earnest. Some farmers did not carry out the work as per plan. Also instead of paying attention to the development of a new base, much time was spent in trying to reform the old one with poor results. In the past, much bamboo has been destroyed to plant corn on the banks of the streams and it is now difficult to switch back to bamboo planting again.

During the early stages of the plantation, poor management resulted in indiscriminate cutting of bamboo. Some small paper mills also use the bamboo without ever resorting to planting. This results in competition between big and small paper mills in buying bamboo.

Another problem has been the lack of adequate funds for experiments on selection and cultivation of new species of bamboo.

Suggestions for Raising Bamboo Plantations

The raising of bamboo plantations should be included as an important part of the development plans of forest production. There should be new bamboo cultivation plans. The existing resources should be protected and productivity increased. In ten years, 400 000 mu of land (which is suitable for planting bamboo) in the Yibin district should be converted to a bamboo forest by making use of the paper mill's investment or other afforestation funds.

Bamboo supply to paper mills must be guaranteed and its sale to units outside Yibin must be controlled. The price of bamboo must be relatively stable. Small mills which cause pollution and are not viable must be closed down. New paper mills should not be set up indiscriminately.

In the new bamboo plantations, the species of bamboo selected must be suitable for paper-making, should be fast-growing and should give a good yield. Research work on raw material storage and processing must be carried out. Research projects must be well-defined and funds assured. Wide publicity must be given about the social significance, economic utility and the benefits of raising plantations. The government must also provide low interest loans to the paper industry for raising forests. If full use is made of the bamboo resources and progressive teachinques are employed, the paper industry will have a bright future,

The Efficient Utilization of Bamboo for Pulp and Paper-making

Subhash Maheshwari[1] and K.C. Satpathy[2]

Pulp and Paper Research Institute, Jaykaypur 765 017,[1]; [2]Department of Chemistry, Sambalpur University, Jyoti Vihar, Buria, Orissa, India.

Abstract

The pulping characteristics of (a) bamboo of different ages, (b) diflerent portions of the culm and (c) a few common varieties of bamboo were studied and the results are discussed. Efective methods of proper handling and storage of bamboo are also been suggested.

Introduction

Bamboo is termed as 'green gold' of the forest due to its varied uses. During the last few decades, it has become a major source of raw material for the Indian pulp and paper industry. The paper industry has an installed capacity of 2.7 million tonnes covering 288 small, medium and big paper mills, and produced about 1.65 million tonnes of paper and paper-board during the year 1987.

The industry is presently facing problems of non-availability of suitable fibrous raw material in adequate quantity to meet its requirements. The supply of bamboo, so far the main raw material for the industry, has been dwindling in the recent years. Still, bamboo accounts for 60 percent of the fibrous raw material requirement of the industry. In order to meet the present and future requirements of the paper industry, efforts are needed not only to improve productivity but also to use the existing bamboo resources judiciously and efficiently.

Forestry

The extraction and management of bamboo needs to be reviewed in the light of its great demand. The following rules for the working of bamboo areas are suggested to allow for the healthy growth of bamboo forests and obtain maximum bamboo yield per unit area (Maheshwari, 1982):

- Immature culms should not be cut.
- In a clump containing 12 or more mature culms, at least six should be retained. Where there are less than three mature culms, all culms above one to two years of age should be retained.
- The height above the ground level at which the culms are cut should not be below the second node and in any case not higher than 30 cm from ground level.
- Bamboos should not be cut in the year of their flowering but should be clear-felled after they have shed their seeds. The cutting of such clumps need not be combined to the working 'coupe' of the year.

The above mentioned guidelines can be adopted in principle. However, certain modifications may need to be carried out depending on the locality.

Effect of Age of Bamboo on Pulp and Paper-making

Bamboo culms, in general, attain their maximum height at the end of one growing season but are not suitable for utilization because they lack strength and are prone to biological attack. The pulp and paper-making characteristics of one to four-year-old *Dendrocalamus strictus* were studied (Maheshwari & Satpathy, 1984b). The results are summarised in Table 1, the salient points of which are given below :

1. One and two-year-old culms produce more slivers during chipping, causing additional load on rechippers.
2. With increase in age, holocellulose, lignin and ash contents also increase.
3. It is observed that with increasing age, active alkali requirement to get a fixed kappa number increases. Total pulp yield also increases with

Table 1. Effect of age on pulping characteristics

Characteristic	Years			
	1	2	3	4
Proximate chemical analysis				
Holocellulose (%)	63.9	65.9	68.9	70.9
Klason lignin (%)	24.9	26.9	27.2	27.6
Ash (%)	2.9	3.1	3.3	4.6
Pulping data				
Active alkali on chips as Na_2O (%)	16.0	17.0	17.0	17.5
'H' factor	1120	1120	1120	1120
Total pulp yield (%)	41.3	45.4	46.5	46.8
Kappa no.	23.8	25.1	26.3	26.5
Bleaching with CEHH sequence				
Total Cl_2 consumed (%)	8.17	89.6	9.27	9.43
Brightness (El) (%)	79.8	80.5	78.8	80.0
Viscosity (CED) (Cp).	8.3	9.1	10.4	10.6
Physical strength pronerties at 30° SR				
Burst factor	38	40	40	45
Tear factor	80	84	90	98
Breaking length (km)	6.40	6.50	6.90	7.30
Double folds	85	100	130	160

increase in the age of the culm.

4. 'Pulp obtained from clums of different ages behave similarly during bleaching. However, bleached pulp viscosity increases with age indicating improvement in pulp properties.
5. The physical and strength properties of bleached pulp increase with increase in age of bamboo.

Effect of Position of Culm on Paper-making

Although there are set rules for the cutting of bamboo, it is observed that at times the bottom and/or top portions of the bamboo culm are left unutilized in the forest. A study on the paper-making characteristics of the top, middle and bottom portions (about 7m long bamboos were divided into three. portions) of bamboo *(D. strictus)* was carried out and the results are summarized below (Table 2; Maheshwari & Satpathy, 1984a).

1. Top portions give thinner and uniform chips compared to the other two portions.
2. The holocellulose and lignin contents decrease from bottom to top while ash content increases.
3. With increasing height of the culm, the requirement of active alkali to obtain pulp of the desired Kappa number decreases. The pulp yield also follows a similar trend.
4. There was no difference in pulp obtained from different positions of the culm with respect to bleaching.
5. Pulp from the bottom portion of the culm has better properties than that from the middle and top portions.

The present study reveals that all the portions of the culm can be equally used. The forest operation should be performed in such a way that neither top nor bottom portions of the culm are left unutilized.

Evaluation of Different Bamboos

With the growing demand for bamboo it has become imperative to go in for large-scale plantations. The following species of bamboos occur widely in India and they are used for paper-making: *Dendrocalamus strictus, Bamhusa arundinacea* and *B. tulda*. Out of these, *D. strictus* is the most commonly used. A study was conducted (Maheshwari, 1982) on the pulp and paper-making characteristics of *D. strictus (S-l), B. arundinacea (S-2). B. tulda (S-3)* and *Melocanna bambusoides (S-4)*. The results (Table 3) of the study are summarized below.

1. Depending on the physical characteristics these species give chips of varying dimensions. S-2 gives thicker chips while S-4 gives quite

Table 2. Effect of position of culm on pulping characteristics

Characteristic	TOP	Middle	Bottom
Proximate chemical analysi			
Holocellulose (%)	63.4	65.6	67.1
Klason lignin (%)	26.7	27.7	28.1
Ash (%)	4.60	3.72	3.60
Puluinp data			
Active alkali on chips as Na20 (%)	17.0	18.0	19.25
'H' factor	1120	1120	1120
Total pulp yield (%)	47.1	48.5	49.5
Kappa no.	26.7	27.1	27.3
Bleaching with CEHH sequence			
Total Cl_2 consumed (%)	8.91	9.05	9.38
Brightness, (El) (%)	79.3	80.1	79.3
Viscosity (CED) (Cp)	8.8	9.2	10.1
Physical strength moper-ties (at 30" SR)			
Burst factor	35	45	48
Tear factor	102	115	120
Breaking length (km)	6.20	6.70	7.00
Double folds	175	200	215

Table 3. Paper-making characteristics of different bamboo species

Characteristic	*S-l* *D. strictus*	5-2 *B. awndinacea*	s-3 *B. tulda*	s-4 *M. hamhusoides*
Proximate chemical analysis				
Holocellulose (%)	70.9	66.6	63.6	64.0
Klason lignin (%)	27.6	24.6	25.2	27.2
Ash (%)	4.6	3.0	3.2	5.4
Pulning data				
Active alkali on chips as Na_2O (%)	17.5	17.0	16.0	17.0
'H' factor	1120	1120	1120	1120
Total pulp yield (%)	46.8	47.4	47.1	45.3
Kappa no.	26.5	24.8	25.3	26.3
Bleaching with CEHH sequence				
Total Cl_2 consumed (%)	9.43	8.88	8.98	8.68
Brightness (El) (%)	80.6	79.1	79.0	80.1
Viscosity (CED) (%}	10.6	10.2	9.0	9.1
Physical strength properties (at 30° SR)				
Burst factor	45.0	45.0	45.0	46.0
Tear factor	98	110	88	101
Breaking length (km)	7.30	6.80	7.10	7.00
Double folds	160	175	100	190

thin chips. The cell wall is quite thin in the case of S-4.
2. S-3 and S-4 have lower holocellulose content while the lignin content is lowest in S-2. Ash content is highest in S-4 while it is lowest in s-2.
3. Active alkali requirement to obtain the desired Kappa number is more or less the same in all the-samples. However, pulp yield is lowest in s-4.
4. Bleaching behaviour of all the pulps is the same. However, the bleached pulp viscosity of S-3 and S-4 are comparatively low.
5. The physical and strength properties of pulp from S-2 are highest while these are lowest for S-3.

This study showed that depending on the pulping characteristics, selection of useful species can be done for raising plantations.

Handling and Storage

Due to the tropical climatic conditions a continuous, supply of bamboo from the forest to the mills is not possible throughout the year. Hence, efficient handling, transportation and storage is called for to incur minimum loss in terms of quantity and quality. The following remedial measures are suggested (Maheshwari & Satpathy, 1988) which would improve overall productivity of pulp from bamboo.

1. Since immature bamboos are quite prone to biological attack they should not be cut. In case they are harvested, they should not be stored with mature bamboo.
2. Infested bamboo should not be collected from the forest to avoid infestation of other bamboo stock.
3. Measures for soil and water conservation, and protection around the clump should be undertaken to facilitate the healthy growth of bamboo.
4. Forest fires should be prevented.
5. One side felling of bamboo should be avoided.
6. The planning of transportation of bamboos should be done in such a manner that bamboo bundles get at least two months for drying in the forest. This is faster as stacks are small at the felling site.
7. Periodical inspection of infestation should be done and corrective measures taken.
8. The storage yard should have a proper drainage system. Stacking on raised foundations or parapet walls should be done to facilitate water drainage and aeration. The soil should be poisoned to prevent termite attack. The bamboo stacks should be given prophylactic treatment periodically.
9. Good yard management practice should be formulated and executed to use bamboo on a first-come-first-used basis.

In order to achieve the above objectives. the following variables need to be studied and optimised:

1. ***Quality of bamboo***: Bamboo should be neither green nor stored for long periods nor infested. This guarantees betterpulp and paper quality.
2. ***Chipping and*** chips: Chipping should be done in a manner such that minimum dust is produced with uniform chipsize. Chip washing (Kar, 1987) is also suggested to get optimum moisture in the chips and for removal of dirt.
3. ***Chemical addition:*** White liquor used should be of known strength. The optimum sulfidity of liquor should be about 20 percent for bamboo pulping.
4. ***Concentration of chemicals:*** Homogenity of pulping depends upon chips to liquor ratio which also affects the overall pulp yield and quality. Hence, this aspect also needs careful attention.
5. ***'H' factor-:*** The pulping of bamboo can be regulated by the 'H' factor which singly represents time and temperature. This concept is useful and should be applied to get more or less the same pulp quality in spite of variations due to unforeseen reasons in temperature and/ or duration of cooking.

Other Factors

1. ***Use of additives:*** In order to improve overall pulping performance and productivity, a number of additives have been tested. Use of anthraquinone has given quite promising results and may be used regularly during reduction.
2. ***Silica problem:*** Bamboo contains a high percentage of ash when compared to hard and softwood. The main constituent of ash is silica which ultimately causes a problem of scaling in preheaters of digester and evaporator pipes. Efforts are being made to solve the problem effectively.
3. ***Fracrionation:*** Bamboo pulp consists of long as well as short fibres. The use of long fibres has a distinct advantage and hence studies have been conducted to separate short fibres and fines which constitute more than 30 percent and use both long and short fibres separately and efficiently.
4. Bamboo, though woody in nature, belongs to

Table 4. **Paper-making characteristics of nodes, internodes and culm *(D strictus)***

Characteristic	Nodes	Internodes	Whole culm
Proximate chemical analysis			
Holocellulose (%)	63.2	71.5	70.9
Klason lignin (%)	29.5	25.9	27.6
Ash (%)	4.8	4.0	4.6
Pulning data			
Active alkali on chips as Na_2O (%)	18.5	17.0	17.5
'H' factor	1120	1120	1120
Total pulp yield (%)	44.0	47.4	46.8
Kappa no.	28.5	27.4	26.5
Bleaching with CEHH sequence			
Total Cl_2 consumed (%)	9.37	9.48	9.43
Brightness (EL) (%)	79.5	80.2	80.2
Viscosity (CED) (Cp.)	7.8	10.7	10.6
Physical strength pronerties (at 30" SR)			
Burst factor	28	48	45
Tear factor	60	105	98
Breaking length (km)	4.85	7.36	7.30
Double folds	42	175	160

the family Graminae and consists of nodes and internodes. A study (Maheshwari & Satpathy, 1988) has been made of the pulp and paper-making characteristics of nodes, internodes and culm of *D. strictus* and the results are summarized in Table 4. This shows that the internode portion is better than the node, though it is not practical on a commercial scale.

Conclusion

We need to take steps to manage our existing bamboo resources efficiently besides raising plantations of suitable species. *Dendrocalamus strictus* which occurs abundantly in India was also found to have good pulping characteristics.

References

Kar, S.K. 1987. Ippta 25 :49.

Maheshwari, S. 1982. Studies on Some Aspects of Pulp and Papetmaking Characteristics of Orissa Bamboo. Ph.D. Thesis. Sambalpur Univ. India.

Maheshwari, S. & Satpathy, K.C. 1984a. Paper-making characteristics of top, middle and bottom portions of bamboo. Indian Pulp and Paper 38: 5-9.

Maheshwari, S. & Satpathy, K.C. 1984b. Studies on pulp and paper-making characteristics of bamboos of different ages. Indian Pulp and Paper 38: 15-2 1.

Maheshwari, S. & Satpathy, K.C. 1988. Ippta 25: 15.

Recent Developments in Bamboo Board Manufacture and Future Research Needs

S.S. Zoolagud

*Indian Plywood Industries Research Institute,
P.B. No. 2273, Turnkur Road, Bangalore 560 022, India.*

Abstract

This paper reviews the developments that have taken place in India alld other countries in the manufacfure of bamboo board. Future research needs are also highlighted.

Introduction

Bamboos possess excellent mechanical properties, especially with regard to tensile strength. Very few species have been intensively evaluated for their physical and mechanical properties in India (Sekhar & Bhartari, 1960). The wide distribution, low cost, easy workability and high strength characteristics of bamboo have been responsible for its use like any other wood.

Bamboo Boards

The range of forest-based panel products in the country has increased during the last two decades. Panel products possessing various end uses are being introduced. The common panel products available in India are plywood, particle-board and fibre-board. The current shortfall of wood raw material identified for the panel industry is about 527 000 m^3. The various strategies identified for meeting the raw material shortfall are short-term ones like wood imports, improvement in conversion techniques, worker training, utilization of non-wood raw material and long-term ones like plantation of fast-growing timber species, etc. (Anonymous 1987).

In the context of the increasing shortfall of industrial wood, importance is being given to the development of non-wood materials. Bamboos have a widespread distribution and rapid rate of growth. Due to their inherent, unique physico-mechanical properties, they can be utilized in more exacting applications by transforming the raw material into high quality products by modern processing techniques. Bamboo board is one such product. Viewed in the above context, the development of bamboo board is of immediate interest as pressure on wood can, to some extent, be reduced; also, raw material can be made available at a faster rate as bamboo is harvested in a four to five year cycle as against 30-40 years for medium density hardwood species used for plywood.

Developmental Work in other Countries

China is reported to have developed ply bamboo during the Second World War for making aeroplane accessories. As a result of later technological improvements, various types of bamboo boards are now being manufactured (Hsiung, 1987). Processes for the manufacture of composite panels using bamboo and wood veneers bonded with urea-formaldehyde resin (Zhao, 1987; Zhao & Cheng,1982) have been developed. These panels are said to be a substitute for plywood and the cost is l0-20 percent lower than plywood. Recently developed bamboo panels have been found to be suitable for concrete form work (Dong, 1987). A preliminary study on bamboo plywood as a packing material has also been conducted. A study on the technology of oriented bamboo particle board has been conducted by Suzhou (1987). It is reported that more than 100 small-scale factories produce about 10 000 tonnes of bamboo plywood or bamboo particle boards.

A factory in Thailand is reported to be manufacturing bamboo mat boards bonded with urea-formaldehyde adhesive of thickness ranging from 110 mm for export to European countries for use in panelling, wardrobes, ceiling, etc. (Sharma, 1980, 1983).

Developmental Work in India

Attempts to make bamboo boards in India were made in the 1960s. A process was developed at the Forest Research Institute, Dehradun (Narayanamurti & Bist, 1963). This involved soaking woven mats in phenol-formaldehyde (PF) resol resin solution, conditioning them in a drying kiln and then hot pressing them at a temperature of 140-145 C under a pressure of 2.8 MPa for about 25 minutes for a 2.5 mm thick board. About 15 percent of PF resin solids of the weight of bamboo mats was found to be required to get adequate bond strength. Bamboo boards in combination with wood veneers and other speciality products were also developed. Although the boards thus developed were attractive and possessed high strength values, the process was not commercially exploited because of the sophistication required in the production process and the high cost of production.

Work at IPIRI

The Indian Plywood Industries Research Institute (IPIRI) took up de novo studies on development of bamboo boards in 1979 under a project sponsored by the All India Handicrafts Board and developed a more economical process for making boards out of woven mats of *Ochlandra trartancorica* (Anonymous 1982). The adhesive used for bonding the mats was Cardanol-Phenol-Formaldehyde (CPF) resin developed in the Institute using cardanol (obtained from cashewnut shell liquid) to partially replace phenol in PF resin and thereby reduce the cost of resin to some extent. The manufacturing process developed in the Institute involved the spreading of conventional PF resin or CPF resin on bamboo mats dried to a moisture content (MC) of around 6 10 percent and later hot pressing the resin-coated assembly at a temperature of 140- 145 C and a pressure of 1.6 MPa for a period of six minutes for 3 to 4 mm thick boards. An open assembly time (OAT) of 16 to 24 h was given to reduce the MC of glued mats to about 15 percent. Between the PF resin and CPF, the latter was found to be better not only from the point of cost considerations but also for bonding slivers with a glazed surface,

Room temperature setting UF resin adhesive was also used to bond bamboo boards. A pressure of 1.2- 1.6 MPa and pressing time of 16-24 h were found to be adequate to get satisfactory bond -strength.

Testing of Bamboo Boards

At the request of the Kamataka Forest Industries Corporation, the process developed in IPIRI was tested employing mats woven out of the most common bamboo species available in Karnataka, *Bambusa arundinacea* and *Dendrocalamus strictus*. The results were comparable to those obtained for *Ochlandra travancorica.* Because of its criss-cross sliver construction and thin size, it could not be tested using the existing method for determining its glue shear strength as in the case of plywood. New methods were, therefore, evolved for evaluating their bond strength. Two methods currently used to evaluate the bond strength of bamboo boards are:

1. Tensile strength perpendicular to the panel surface - Internal Bond (IB) strength
2. Glue shear strength by torque wrench method.

Strength values were evaluated both in dry and wet conditions. PF resin adhesive bonded boards were subjected to boiling water resistance test and UF resin adhesive bonded boards were tested for cold water resistance test.

Preservative Treatment of Bamboo Boards

It is reported that water soluble fixed types of preservatives like Copper-Chrome-Boric (CCB), Acid-Copper-Chrome (ACC) and Copper-Chrome- Arsenic (CCA) are suitable for protecting bamboo from biodegradation. Bamboos treated with preservatives last over 20 years (Tewari & Singh, 1979). Detailed treatment schedules have been worked out by using CCB preservative composition which is recommended for exterior grade wood-based panels.

Applications of Bamboo Boards

The developmental work includes a detailed study on possible end uses of bamboo boards. Some of the uses that have been found to be technically feasible are: (1) roofing panels, (2) door and window shutters, (3) structural components as 'I' beams having bamboo board web, box beams and bamboo board gussets, (4) grain storage bins and (5) tea-chest boxes.

Future Research Needs

Based on the process developed at IPIRI, the Kerala State Bamboo Corporation is manufacturing boards utilizing mats mostly of *Ochlandra travancorica* woven by village communities (Sharma, 1983).

Interest in bamboo boards has been shown by several entrepreneurs. It is, however, extremely important to take note of the following points before encouraging entrepreneurs to take up manufacture of this product.

1. Requirement of a comparatively larger quantity of resin per unit area of bamboo board as compared to plywood. In the present process, resin is applied on all surfaces to be bonded. Reduction in quantity of resin or attainment of higher coverage of resin will significantly reduce cost of the product.
2. Non-uniformity in bonding especially in places where slivers overlap. It is natural that high variability is exhibited by the material because it contains criss-cross sliver construction. Uniformity in bonding is essential to sustain "bond integrity".
3. Spreading of resin to board surface through inter-sliver spaces causing unwanted colouration and wastage of resin.
4. Requirement of releasing agents to be applied to metal cauls while hot pressing. Elimination of releasing agents or use of low cost releasing agents will reduce cost of production.
5. High resin cost despite partial replacement of phenol by cardanol. Replacement of phenol by suitable economic organic materials will lead to cost reduction.
6. Low durability of untreated bamboo boards. Presence of phenolic resin adhesive in the board did not prevent it from biological degradation. The use of a fixed type of preservative was found to be essential to make the panels durable. This enhances the cost of panels due to cost of chemical treatments and other related processes. Apart from this, grain rise on the panel surface, specially on overlapped area is quite possible. Incorporation of the economical preservatives during board manufacture would reduce the cost of panels.
7. Traditional methods of bamboo preservation have to be reviewed in order to simplify the process.
8. High total cost as a result of cost of resin adhesive and production cost. Significant cost reduction will help the product to penetrate the rural market for building houses and for making storage bins, packing cases for fruits, etc.

Acknowledement

The author is grateful to Dr P.M. Ganapathy, Director, IPIRI, Bangalore for his valuable advice and guidance in the preparation of this paper.

References

Anonymous 1982. Project report on development of improved and new products from bamboo mats: I- 100. Indian Plywood Industries Res. Inst. Bangalore, India.

Anonymous 1987. Report of the raw material sub-committee: Development panel for wood based industries. l-59. Delhi, India.

Dong, Weizheng 1987. Bamboo glued panels- a study on structure and application of concrete formworks. J. Bamboo Res. 6:49-56.

Narayanamurti, D. & Bist, B.S. 1963. Building boards from bamboos. Composite Wood. **1 : 9-54.**

Sekhar, A.C. & Bhartari, R.K. 1960. Studies on strength properties of bamboos: a note on its mechanical behaviour. Indian For. 86 : 296-30 1.

Sharma, Y.M.L. 1980. Bamboos in the Asia-Pacific region. : 99-120. **In** Lessard, G. & Chouinard, A. (eds) Bamboo Research in Asia. IDRC, Canada.

Sharma, Y.M.L. 1983. Regional resources of bamboo and its utilization in Asia Pacific region. : l-4. **In** Asia Pacific Forest Industries Development Group. FAO United Nations, Kuala Lumpur.

Tewari, M.C. & Singh, Bidhi 1979. Bamboos-their utilization and protection against biodegradation. J. Tim. Dev. Assoc. 25 : 12-23.

Hsiung, W.Y. 1987. Bamboos in China: new prospects for an ancient resource. Unisylva. (2) :42-49.

Suzhou, Yin 1987. A study on technology and properties of oriented particle board. J. Nanjing For. Univ. (3):65-72.

Zhao, Li & Cheng, Benzhao 1982. Technology of bamboo-wood composite board production. J. For. Products (2) : 14-15.

Zhao, Li 1987. New way of substituting bamboo for wood and intermediate test of bamboo-wood composite board. J. Newsletter Wood Application Technol. (1) : 12.

PROCEEDINGS OF
THE INTERNATIONAL
BAMBOO WORKSHOP,
NOVEMBER 14-18, 1988

OTHER APPLICATIONS OF BAMBOOS

catastrophically. Geosynthetic inclusions are generally specified to fulfil one or many of the following purposes, namely, separation, filtration, moisture barrier, reinforcement and drainage.

The applications of interest here are separation (where the geosynthetic acts as a barrier to the mixing of two different soil masses), reinforcement (where it augments the strength of a soil mass usually by providing the tensile resistance the soils lack) and filtration (where it is required to stop the movement of soil particles while still allowing the free passage of water).

Because no single geosynthetic will be capable of fulfilling all possible purposes, manufacturers have developed a wide variety of fabric forms. The forms that have been developed can be differentiated by their strengths and weaknesses in various characteristics, a few of which are listed here:

- tensile strength
- tear resistance
- burst strength
- friction against soil
- interlock with soil
- permittivity (permeability *across* the fabric plane)
- transmissivity (permeability *within* the fabric plane)
- equivalent opening size (i.e. average "hole size")
- percent open area.

Geotechnical designers identify the role played by the geosynthetic in a particular application, determine which properties are important to that role and finally determine what values of those properties are appropriate. For reinforcement, separation and filtration roles, all of the above properties, with the exception of transmissivity, are important.

Inclusions in Soil Structures

Three example applications where geosynthetics could be replaced by bamboo can be delineated. In the first, an embankment is built on the geosynthetic placed on soft, weak ground (Fig. 2). The geosynthetic prevents the mixing of the embankment fill with the soft subgrade soils. In addition, the geosynthetic resists the tensile stresses which would otherwise be generated across the bottom of the embankment. Given a properly designed and selected geosynthetic inclusion, the fill material is prevented from strength degradation due to mixing, and is reinforced by the fabric. Settlements are still large, but the embankment is prevented from breaking up as it settles (Fig. 3).

In the second application, a geosynthetic is used to prevent a steep embankment slope from failing (Fig. 4). The correct placement of the geosynthetic across the potential failure surface keeps the soil mass coherent and a slope failure is avoided.

The third application uses the geosynthetic to tie back the face elements of a retaining wall (Fig.5). In a manner similar to the reinforced slope design, the geosynthetic spans the potential failure surface, keeping the soil mass behind the wall from failing.

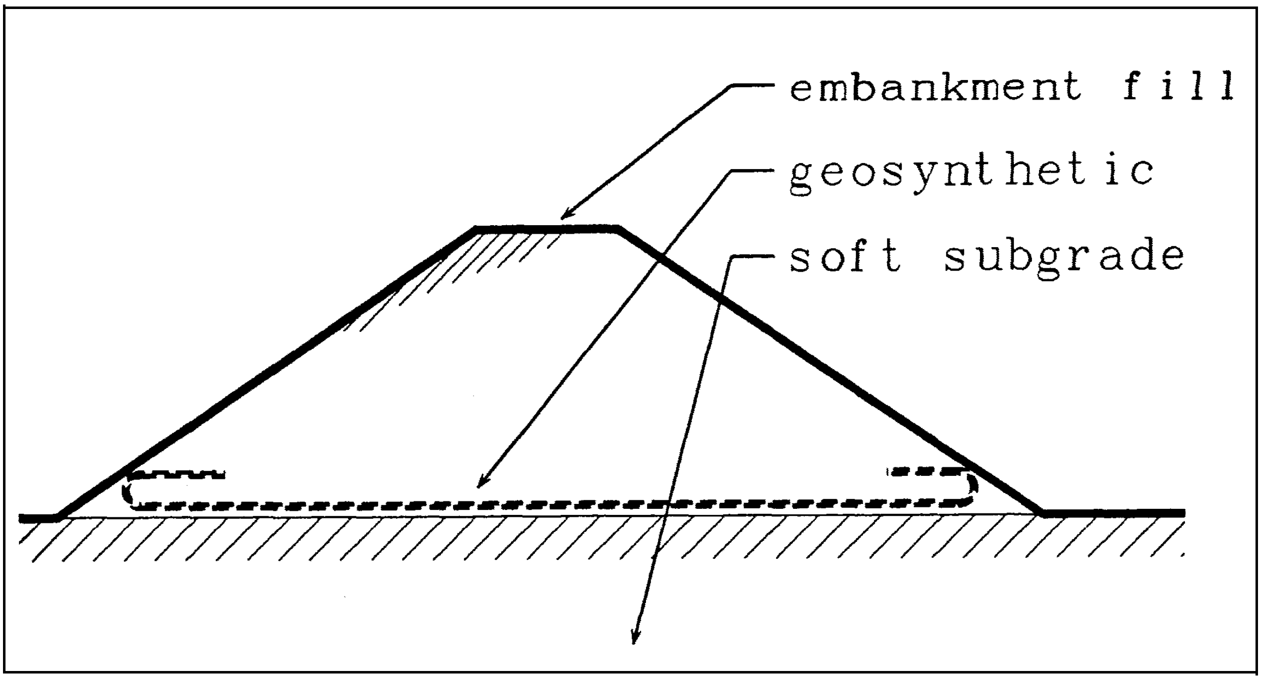


Fig. 2. Cross-section of reinforced embankment on soft ground.

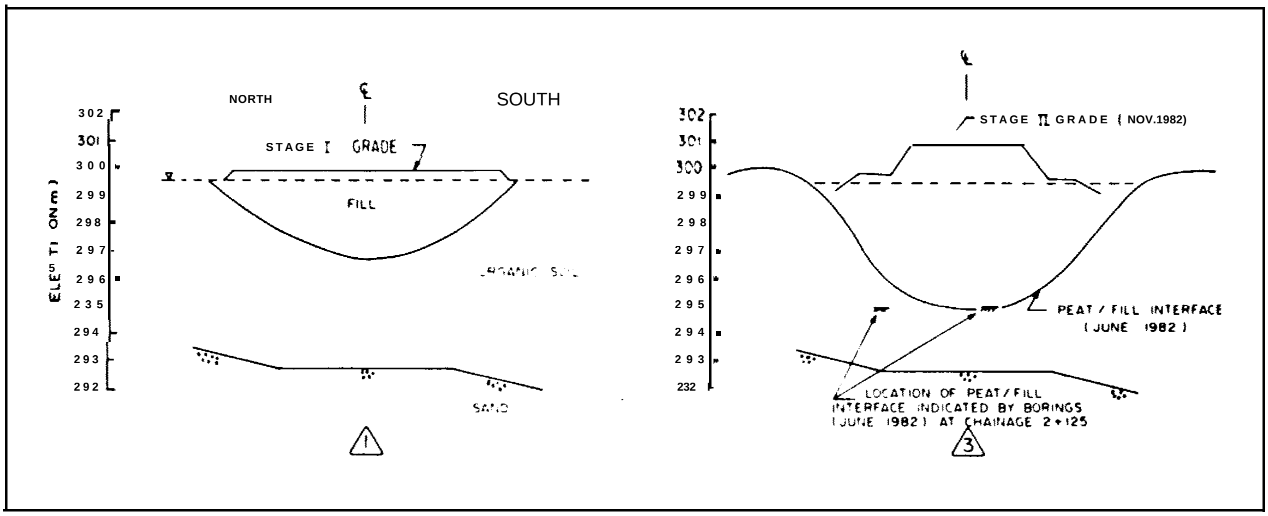


Fig. 3. Large subgrade settlements beneath reinforced embankment on soft ground (Rowe et al., 1984).

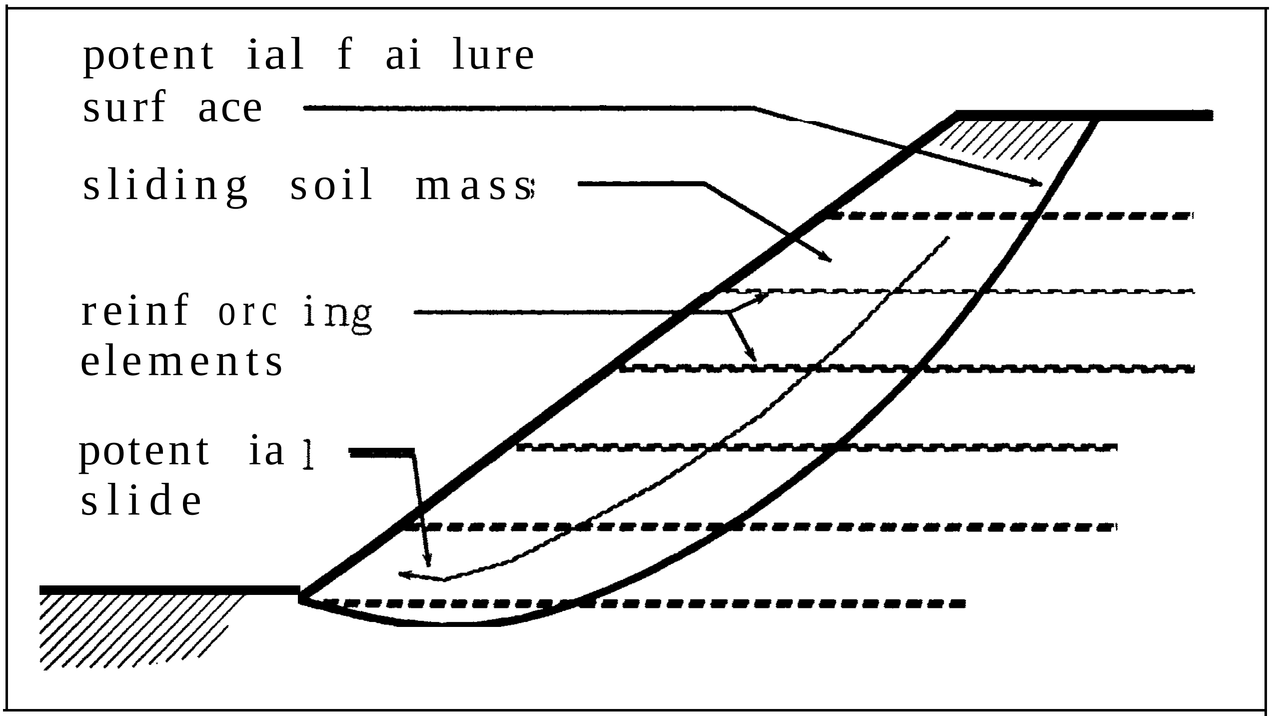


Fig. 4. Reinforced slope.

In each of these three cases, the tensile strength of the geosynthetic is paramount, since the geosynthetic is placed in a tensile mode. Secondary properties of importance are the fabric's ability to survive construction operations (tear resistance, burst strength); the ability of the geosynthetic to develop high friction and pull out resistance within the surrounding soil; and when used as reinforcement at the bottom of the embankment, the geosynthetic's ability to keep soil types separate (percent open area, effective opening size).

Bamboo has these attributes. It also has desirable properties which geosynthetics do not possess, making it a prime candidate to replace geosynthetics in these applications.

Bamboo Compared to Geosynthetics

As a construction material, bamboo possesses many attractive features. It has a high strength to weight ratio, surpassing that of structural steel (Table 1). As a circular tube with periodic nodes, it represents the most efficient form for structural columns. It is not the most efficient form for beam elements but is nearly so. Its tensile strength is high, it is light, and it is easily split into strips which can be woven into mats.

Bamboo can thus compete on an equal footing with geosynthetics, as demonstrated for a typical geogrid in Table 1. It has similar tensile strength and can be used as a woven mat. Beyond this, it is

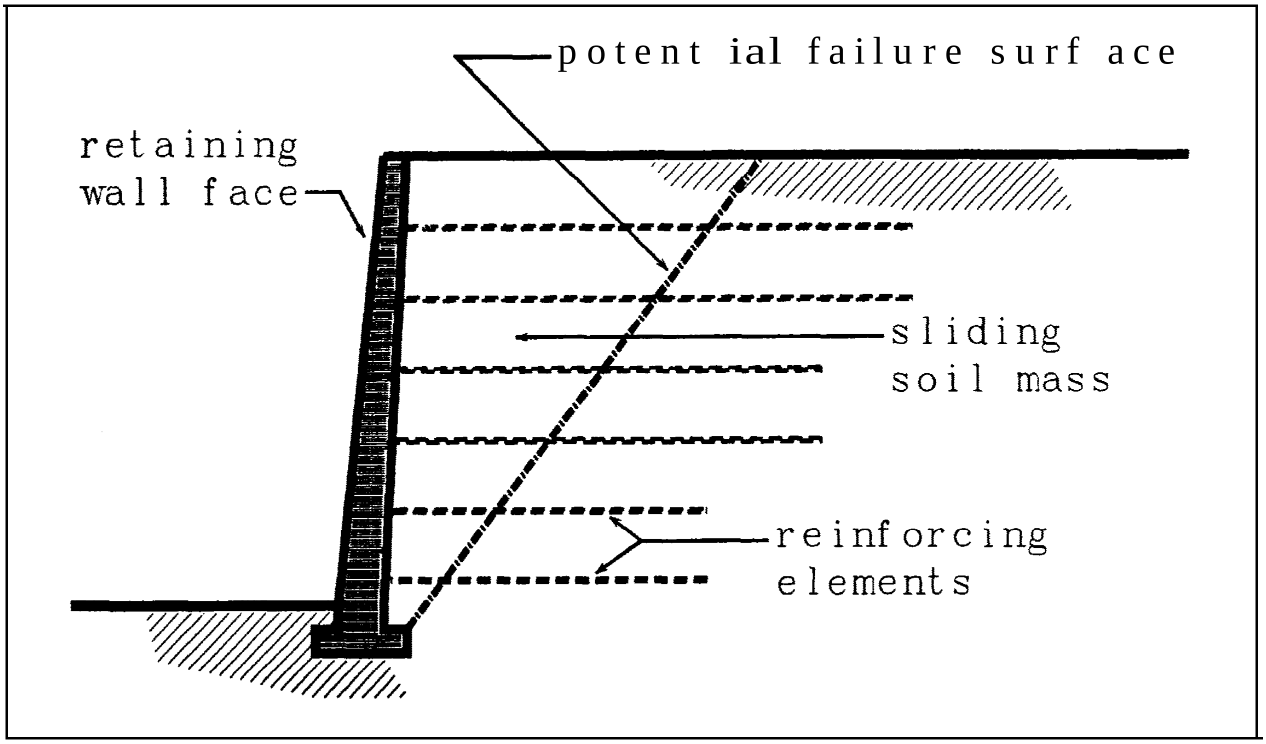


Fig. 5. Retaining wall constructed with tie back elements.

Table 1. Comparison of typical material strengths (after Fang, 1979)

Material	Thick-ness mm	Strength kN/m	Strength kN/m²	Mass kg/m’	Mass kg/m³	Sp.gr. G.	/G kN/m²	/G rel to steel
Steel	--	--	280000	--	--	7.9	35000	1.0
Polypropylene	--	--	470000	--	--	0.9 1	520000	15.0
Bamboo	--	--	73000	--	--	0.72	100000	2.5
Polypropylene-grid	4.0	32.0	--	0.32	80	0.08	98000	2.8

possible to make use of bamboo’s bending resistance, a property geosynthetics do not possess. Possible geotechnical applications can thus be envisaged.

Round bamboo could be placed transversely across road subgrades, in much the same way that corduroy roads are constructed. The culms would act as beams, spreading the applied vehicular loads over a wide area on the subgrade, thus decreasing the applied pressure and reducing the anticipated settlements. Woven mats of split bamboo could be used to separate road embankment fill and soft, weak subgrades. Whole culms could be used with the mats to increase roadbed strength. Grids of small diameter bamboo culms can be lashed together at centreline spacings of the order of 0.3 m. These grids have already been used to reinforce the shoulders of steep slopes (Fang, 1979) as in Figure 4 and could also be used to tie back retaining walls, as in Figure 5. Vertical soil “nails” made of whole culms placed in augured holes in the shoulders of potentially unstable slopes have already been designed (Fang, 1979). Through high shear resistance, the row(s) of culms prevent the potentially failing soil mass from sliding (Fig.6.

These applications of bamboo inclusions in soil structures make use of the mechanical properties bamboo has in common with geosynthetics, as well as the high shear strength and bending resistance that bamboo culms possess and geosynthetics do not. However, if bamboo is to be put to these uses successfully, a number of research areas must be investigated.

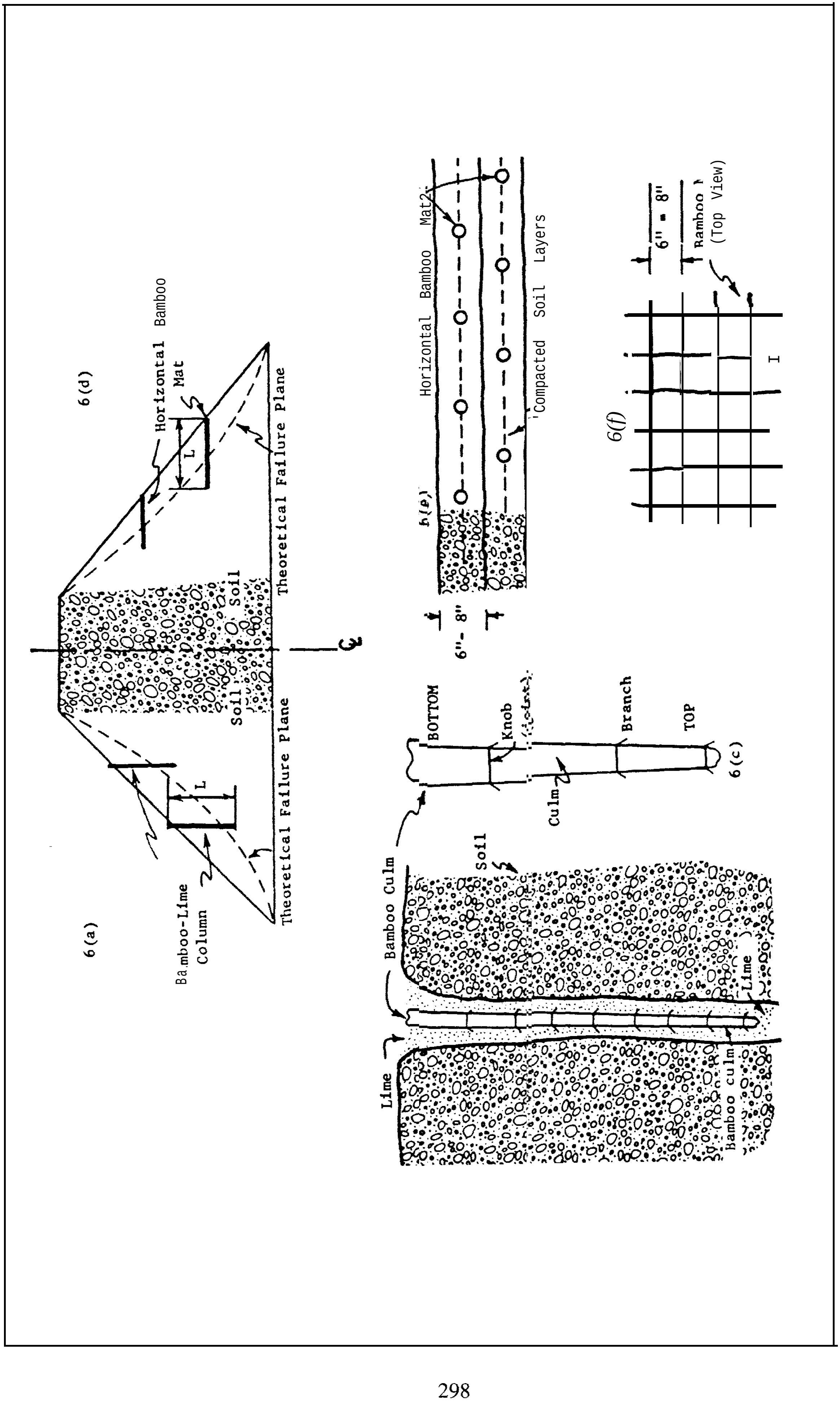


Fig. 6. Slope reinforced with soil "nails" (Fang, 1979).

Recommendations for Research

Work has already been performed on the treatment of bamboo to make it resistant to insect and fungal attack, and to weathering. This should be continued with vigour, because any soil structure relying on bamboo for support is implicitly unstable without that support. If the bamboo deteriorates during its service life, collapse of the soil structure will ensue.

An adequate knowledge of the mechanical properties of bamboo must be established, if workable engineering designs are to be developed. The fact that bamboo is a "new" material to formal engineering design, is complicated by the fact that it has biological origins. Given that there are an estimated 75 genera and 1250 species of bamboo, and that it is grown in habitats ranging from the temperate to the tropical (Sharma, 1980), it is understandable that the mechanical properties of bamboos will be extremely variable. Work carried out by Janssen (1980) on bamboo obtained from just one location indicates a wide variation in mechanical properties and a multiplicity of controlling factors. How wide the variation might be, and what values of the mechanical properties are typical for different species of bamboo must be determined if reasonable engineering design codes are to be assembled.

Research should be carried out on the frictional resistance that can be developed between bamboo and the surrounding soil, and the amount of interlock that can be developed between bamboo elements and soil, as it is upon these properties that the bamboo-based geotechnical structures will rely for anchorage. Unless properly anchored, the bamboo structural elements will not be able to develop the tension they are required to resist in these structures.

Beyond an understanding of the properties of the fresh material, the variation of the properties over time, caused by treatment, aging and service conditions must be understood. If the mechanical properties of the bamboo deteriorate below threshold values over time in service, the structures will eventually collapse.

Trial designs should be built, instrumented and tested, in order to check the validity of design assumptions, and to work out such details as connection methods for the bamboo structural elements. Small models can indicate trends in an economical way. Large models, designed on the basis of small model results, can then be tested on a field scale. What is sought is a battery of safe, economical, workable designs for reinforced road structures, embankments, slopes and retaining walls. Some applications of bamboo which may just not prove to be feasible can be identified through model studies.

If bamboo is to become widely used as a geotechnical engineering material, reasonable design methodologies and common terminologies should be worked out. The steps developed for geosynthetic design could serve as a model, but modifications will be required to take into account the peculiarities of bamboo.

Socio-economic Context

If bamboo-based geotechnical designs are to be widely adopted, recognition must be given to the conditions under which the material will be processed and used - a low capital, high labour context. Fortunately, the material itself is light. lending itself to labour intensive methods. and technology for its processing has been long established.

Using bamboo mats in road construction will build upon skills already developed for the manufacture of walls and partitions with woven bamboo (McClure, 1966). Mat size must be selected so that the mats are easily made in a cottage industry setting, are easily transported, and yet are large enough for efficient road building. Standard design for the mats is suggested, so that the end product is consistent while manufacturing activity can be carried out in scattered locations. A parallel to the modular design and construction of Bailey bridges is appropriate.

It is recommended that a common system of grading whole bamboo culms be adopted, so that their engineering properties can be reliably predicted in the field despite processing at numerous widely scattered small scale facilities. Precedents are already available in conventional timber engineering.

Conclusions

The future looks bright for the use of bamboo in geotechnical structures. Taking a broad view of the developments in geosynthetics can indicate the paths that bamboo-based geotechnical research should take, leading to designs which make use of this economical, indigenous and efficient engineering material while simultaneously satisfying socio-economic needs. The research effort should be channelled toward:

- further research on treatment methods to extend bamboo life in geotechnical structures
- an understanding of the conventional mechanical properties of bamboo: how variable those

properties are and what parameters control the properties
- a determination of hitherto unexplored properties such as the friction developed at the bamboo/soil interface, and the amount of interlock bamboo can develop with soils
  an understanding of how rapidly the mechanical properties of bamboo deteriorate with time when placed in soil
- the testing of carefully designed model and prototype bamboo-built pavements, embankments, slopes and retaining walls
- the development of rational design methodologies and terminologies for bamboo construction
- the development of a design code and grading system for the use of bamboo as a construction material.

Acknowledgements

The author wishes to express his gratitude to the International Development Research Centre (IDRC) and particularly to Dr Cherla B. Sastry of IDRC, Singapore, for the opportunity to participate in the Bamboo Workshop and related research taking place at the Forest Research Institute of Malaysia.

References

Fang, H.Y. 1979, Utilization of sulphur-treated bamboo for low-volume road construction, **In** Proc. 2nd Inter. Conf. Low-Volume Roads, Washington. D.C., U.S.A.: Transportation Research Board, National Academy of Sciences. Transportation Research Record. 702 : 147-154.

Janssen, J. 1980. The mechanical properties of bamboo used in construction.:173-188. In Lessard, G. & Chouinard, A. (eds) Bamboo Research in Asia. IDRC, Canada.

Koerner, R.M. 1986. Designing with Geosynthetics. Englewood Cliffs, N.J., U.S.A., Prentice-Hall. pp 424.

McClure, F.A. 1966. The Bamboos: A Fresh Perspective. Harvard Univ. Press. Cambridge, Mass, U.S.A.

Rowe, R.K.; Maclean, M.D. & Barsvary, A.K. 1984. The observed behaviour of a geotextile-reinforced embankment constructed on peat. Can. Geotech. J. 21: 289-304.

Sharma, Y.M.L. 1980. Bamboos in the Asia-Pacific region.: 99-100. In Lessard, G. & Chouinard. A. (eds) Bamboo Research in Asia. IDRC, Canada.

Utilization of Bamboos for Engineering Purposes

K.S. Low

Forest Research Institute of Malaysia (FRIM),
52109 Kuala Lumpur . Malaysia.

Abstract

The stiffness and relatively high tensile strength make bamboo suited for- use as an earth-reinforcing material. With the support of the International Development Research Centre (IDRC), the Forest Research Institute of Malaysia (FRIM) has initiated a research programme for the utilization of bamboo in reinforced earth structures such as highway/road embankments, vertical retaining walls, etc. This paper- highlights the work being carried out at FRIM on this aspect.

introduction

Being an ancient material, bamboo bears a close relationship with the development of civilization in some parts of the world notably Asia, where it occurs in abundance. Bamboo has been put to a wide range of new applications in numerous fields including engineering (Janssen, 1981, 1985, 1988; Siopongco & Munandar, 1987). One of these is the use of bamboo in reinforced earth structures.

A major problem facing the use of bamboo in earth structures is its long-term durability. This is of prime importance because any failure caused by low durability could mean disaster. This problem can be expected to be more critical than with geotextiles because bamboos are prone to greater deterioration than geotextiles. Other disadvantages associated with the use of bamboo include variability, non-homogeneity and the anisotropic nature of the material. In practice, these have resulted in difficulties in using the material because property values required for design cannot be determined with sufficient accuracy.

Traditionally, bamboos have been commonly used in the construction of houses, scaffoldings, bridges, etc. However, it has also other interesting engineering applications such as in control of soil erosion (Noda, 1986), reinforced concrete slabs (Kankam, 1986) and reinforced concrete roads (Grisay, personal communication).

Bamboo-reinforced Earth Structures

It is very difficult to build a steep earth slope on a ground with a low bearing capacity. Even on soil with high bearing capacity, there is a limit to the gradient of the slope. As shown in Figures 1A and lB, a steep slope may result in the shear resistance of the fill being unable to withstand the potential sliding moment caused by the weight of the soil on the slope. Subsequently, any external disturbances such as traffic vibrations may trigger a slide along any plane within the fill.

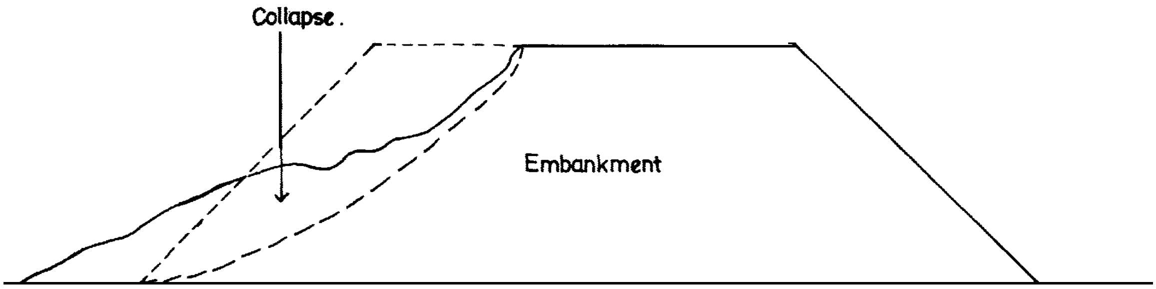
By incorporating horizontal layers of bamboo reinforcement (Fig. lC), the shear resistance of the fill is increased to provide additional resisting moment to counteract the sliding moment (Ingold, 1982). Furthermore, the slide is also avoided partly by the high strength/low strain characteristic of the bamboo. In addition for steep but non-vertical slopes, natural vegetation must be planted on the slope to prevent soil erosion.

The construction of a bamboo-reinforced earth slope has a distinct advantage in that this technique does not require any special skill or expensive equipment. The bamboos are simply laid on the horizontal ground before they are covered with a layer of fill and compacted.

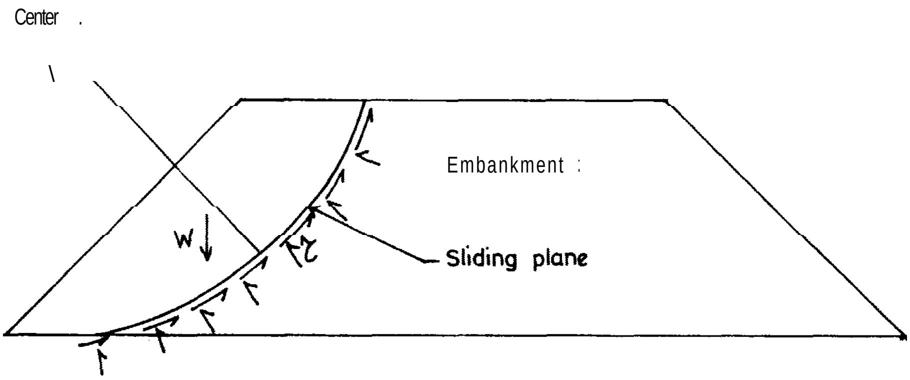
The research on bamboo-reinforced earth structures ('geobam') being carried out at FIRM is in two parts: (i) full-scale trial at Bukit Gambir and (ii) laboratory investigation.

Full-scale Bamboo-reinforced Embankment Trial

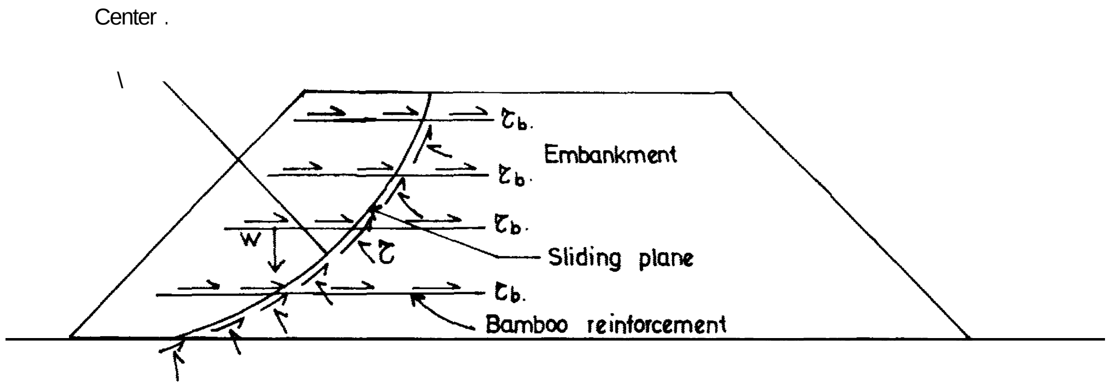
Towards the end of 1987 the Malaysian Highway Authority (MHA) agreed to provide to FRIM a section of its lay-by embankment of the Seremban to Ayer Hitam'kighway project under construction to carry out research on the use of bamboo as slope reinforcement in highway embankment construction.



(a) Failure mechanism of an embankment .



lb) System of forces in an embankment.



(c) System of forces in an embankment when horizontal bamboo reinforcements are incar porated

Fig. I. Embankment stabilization.

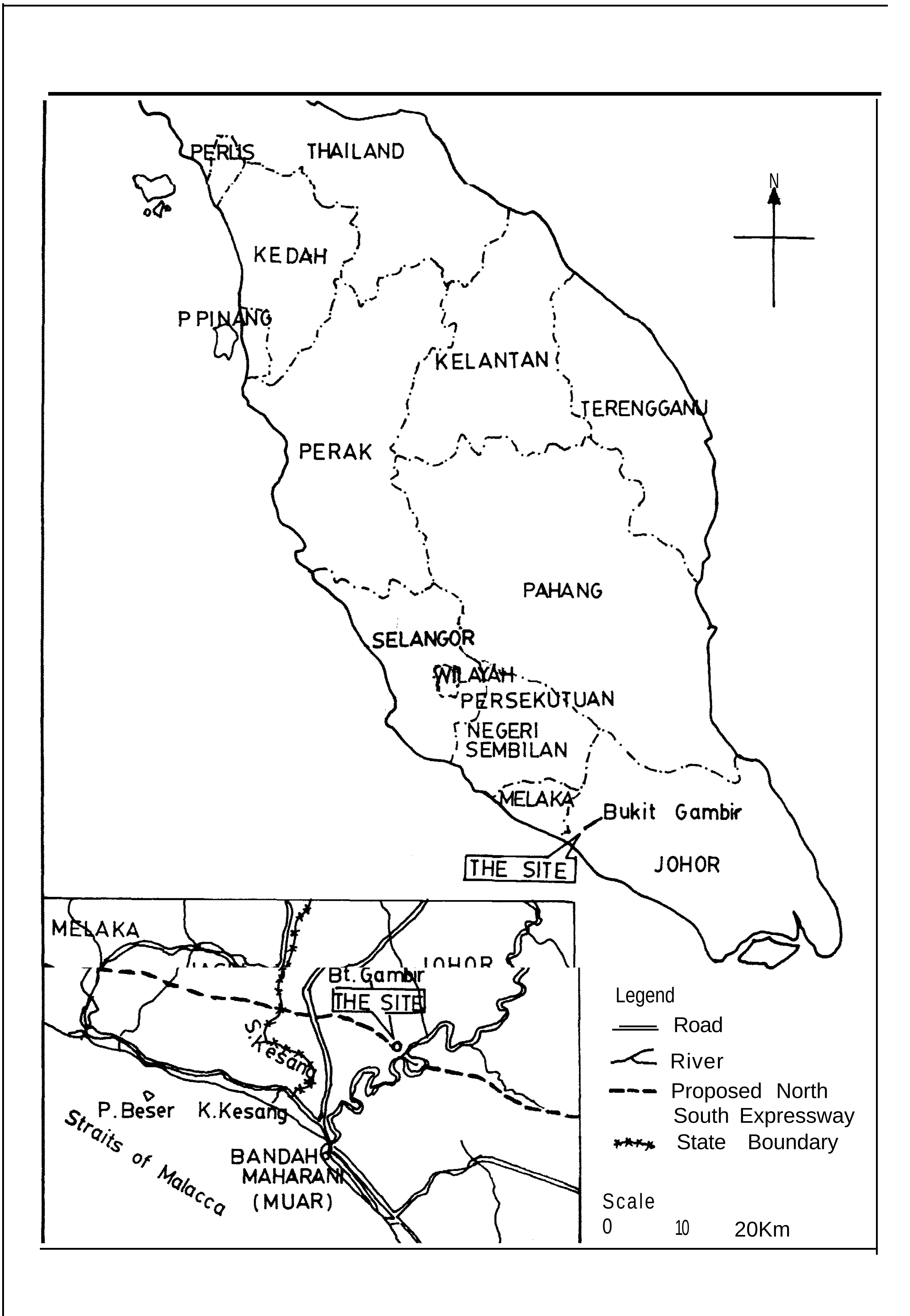


Fig. 2. Location plan for full-scale trial at Bukit Gambir:

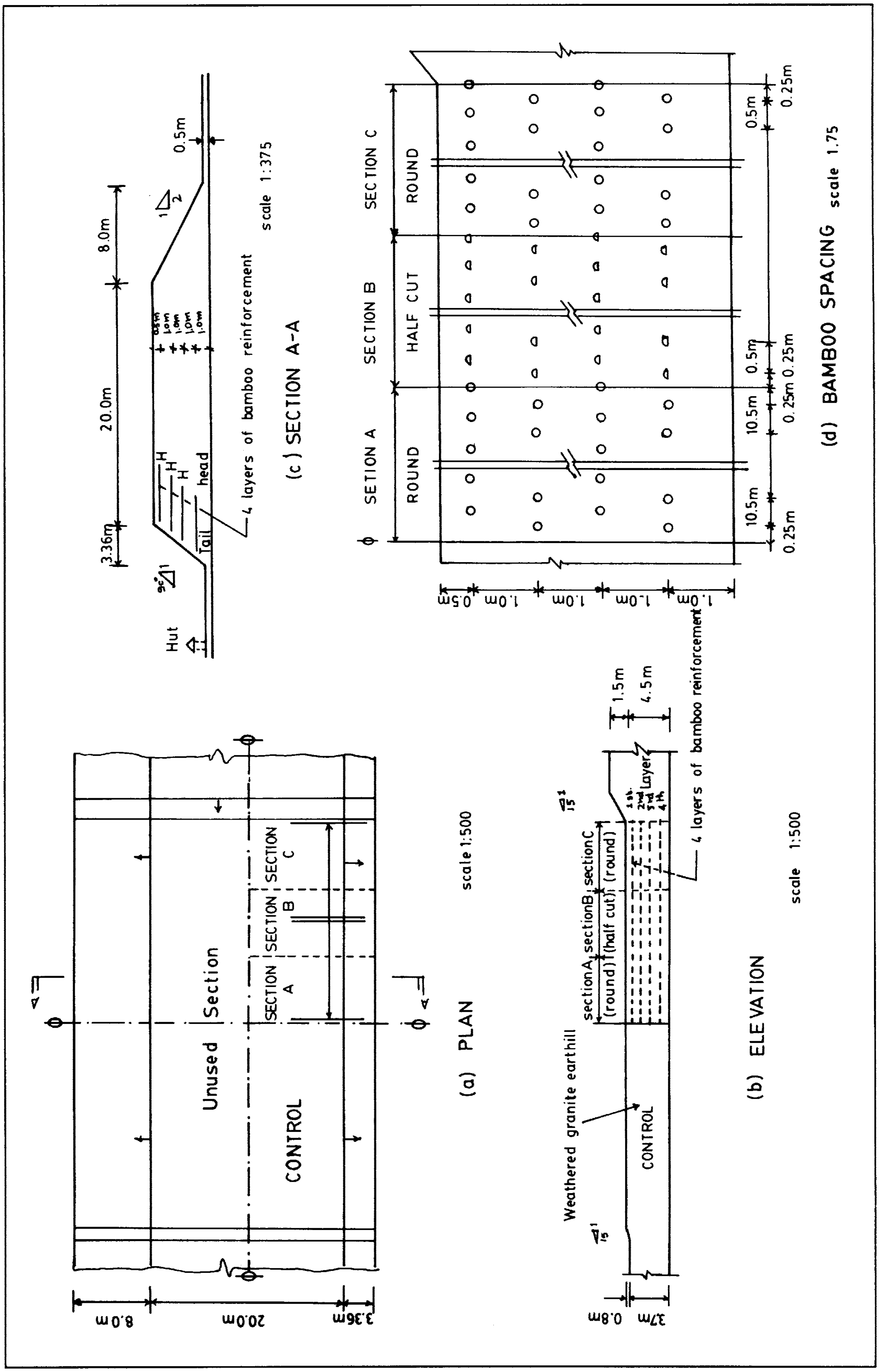


Fig. 3. The general layout and arrangment of the full-scale trial.

As shown in Figure 2, the full-scale trial test site is located near a small town called Bukit Gambit- which is approximately 200 km south of Kuala Lumpur. The trial commenced in mid-June 1988 when construction work began on the embankment. As shown in Figure 3A the base of the embankment is 31.36 m wide and the height is 4.5 m. However, only one-half of the embankment was used for the experiment. For the test portion, the slope designed was 1:2 whereas for the used section it was 1:0.84 (Fig. 3B). In addition, the used portion of the embankment was divided into two parts such that one part (25 m) acted as a control section with no reinforcement and the other part (25 m) was reinforced with bamboo (Figs. 3A, B).

Two species of bamboo, namely, *Gigantochloa levis* and G. *scortechinii* were chosen based on easy availability and suitable sizes. In addition, two cross-sectional shapes, round and half-round were selected for the test. In order to increase the durability of bamboos against termite attack, these were treated with the copper/chrome/arsenic (CCA) preservative before embedding in the soil.

As shown in Figure 3B, 15 culms of round bamboo (each 5 m in length) of G. *levis* were laid in section A; 15 half-cut bamboo of both G. *Levis* and G. *scortechinii* in section B and 15 culms of round bamboo' of *G. scortechinii* in section C, respectively, in each layer. The embankment consisted of four such layers with a spacing of 1 m between them. In this way, the uppermost bamboo layer is 0.5 m from the finished surface. The horizontal spacing between two bamboo culms was fixed at 0.5 m.

For this type of construction, the inter-layer spacing, the horizontal spacing between bamboo culms, and length of bamboo culms are normally determined from soil data, and the height and slope angle of the structure. However, for this preliminary investigation, the optimum design data required for these parameters were not yet known and here all parametric values used in the current investigation were arbitrarily chosen.

Strain gauges were attached to the centre culm in each section. In section A, for example, a total of 12 strain gauges, or six pairs, were placed at the internode positions along the culm (Fig. 3C). However, only six gauges, all on the top, were placed along the half-cut bamboo culm in section B, and for section C all six gauges were placed at nodal positions of the round bamboo (Fig. 3D) , In order to prevent undesirable effects that might be caused by water seepage, a water-proofing agent was applied to these gauges.

These strain gauges allowed strain changes on the bamboo culms to be measured using a strain meter. The detection is achieved via a set of wire leads that emerged from the sloping surface of the embankment. However, a number of these gauges were lost, usually by detachment from their wire leads, during their embedment.

p

Stresses induced in the bamboo culm were obtained from the measured strain value by multiplying with the appropriate Young's modulus value already determined in the laboratory. Test results obtained indicated that considerable stresses, both tensile and compressive, were developed at different locations along the bamboo culms. The magnitude of the stresses induced was dependent on the position of the layer (i.e., embedment depth) of the bamboo reinforcement. The greatest stresses were recorded near the base of the embankment. The structural behaviour of this newly constructed bamboo-reinforced embankment slope will be monitored over a period of at least three years.

Laboratory Investigation

Basically, the laboratory investigation have been on (a) the bamboo material, (b) the soil material and (c) soil-reinforcement interactive systems.

The bamboo material: In view of the importance of the durability of bamboo in earth structures, the natural durability of two bamboo species used, namely, G. *levis* and G. *scortechinii* was studied. A total of 396 culms of untreated bamboos, each 2.3 m length, were embedded 0.46 m deep into a test ground at FRIM. After a six month period, it was found that nearly 50 percent of all bamboos had been attacked and destroyed mainly by termites. The variability of bamboo warrants a comprehensive study on the variation of engineering properties along the bamboo culm. In addition, the drying characteristics of these bamboos were also investigated. Furthermore, microslides of sections taken from along the culm were prepared in order to correlate the anatomical structure of bamboo with its various properties as obtained during the tests.

The soil material: The earth fill of the full-scale test consisted mainly of weathered granite material. Standard shear box tests were carried out to determine the shear friction angle for remoulded and undisturbed soil samples.

Soillreinforcement interactive systems: The standard shear box tests were conducted on (i) soil and bamboo, (ii) soil and steel, and (iii) soil and a geotextile material. For the soil/bamboo system, however, in addition to the outer surface, tests involving the middle and inside sections of the bamboo were also carried out. These tests were designed to determine the maximum friction angle developed at the interfaces of these systems.

A steel rectangular test container measuring 3.6 x 1.8 x 1.5 m was fabricated to hold a bed of soil for reinforced-earth investigation. With one movable side wall, this test container will permit pull-out tests on bamboo reinforcement to be performed. A number of results have already been obtained and are being analysed.

Conclusion

The full-scale test results obtained indicate the suitability of bamboo as reinforcements in the construction of reinforced-earth structures. In addition, the tests show that strain gauges can be employed for strain measurements in large-scale work.

Engineering applications of bamboo have at present a lower socio-economic importance than other applications. However, the fact that engineering applications such as geobam normally involve a substantial quantity of material may suggest a more prominent socio-economic role for bamboo in the future.

References

Ingold, T.S. 1982. Reinforced Earth. Redwood Burn Ltd., Great Britain.

Janssen, J.J.A. 1981. Bamboo in building structures. Ph.D. Thesis. Univ. Technol, Eindhoven, The Netherlands.

Janssen, J.J.A. 1985. A series of articles on the use of bamboo in building construction. Univ. Technol. Eindhoven. The Netherlands.

Janssen, J.J.A. 1988. Building with Bamboo - a hand book. Intermediate Technol. Publ. England.

Kankam, J.A. 1986. Bamboo-reinforced concrete two-way slabs subjected to concentrated loading. The Structural Engineer (December) 64B.

Noda, N. 1986. Community forest development in Nepal. Farming Japan. Agriculture Forestry & Fisheries **20:** 58-61.

Siopongco, J.O. & Munandar, M. 1987. Technology on bamboo as building material. Forest Products Research. & Development Institute, Philippines.

Maintenance and Operation of a Bamboo Pipe Water Supply System

T.N. Lipangile

Wood/Bamboo Division, P.O. Box 570, Iringa, Tanzania.

Abstract

For the past few years, Tanzania has successfully set up rural water supply schemes by using pipes made out of bamboo conduits. Must of the scientific and technical prohlems have been resolved to a satisfactory extent. This paper briefly describes the management, handling, maintenance and operation ofa bamboo pipe water supply system.

Introduction

The bamboo pipe water supply system developed in Tanzania, is receiving wide global recognition from several scientific and technical research-oriented organizations which are basically interested in developing and propagating useful bamboo products (Bronkonsult, 1983; Gokcesu, 1980; Liese, 1986; Lipangile, 1984, 1985a,b, 1986a-d, 1988; Lipangile et *al.*, 1978; Purushothama, 1954). Through experience it has been observed that bamboo pipes can be effectively used in meeting the rural needs of villages with a population of 2500 to 10 000. In some areas, bamboo pipes can be supplemented by conventional materials, for example, steel and plastic, where higher pressure and larger diameter pipes are desirable.

The problems encountered earlier and those resolved in using bamboo as a water supply system are given below.

- Selection and identification of suitable species of bamboos for water supply purposes.
- Hydraulic behaviour of the bamboo culm when exposed to water pressure impact, friction of water in the bamboo tube, velocity of water in relation to the flow with transmitting gradient.
- General techniques involving system design and construction
- Safe bamboo preservation techniques that do not cause health hazards and environmental pollution.
- The economic advantage of using bamboo pipes when compared with conventional materials like steel and plastics.
- Socio-economic benefit through village participation during project implementation.

Recent Experience - Preservation

Although the design and construction of pipe systems made of bamboo had been standardised earlier, there were technical difficulties in adopting a suitable and safe preservation technique. This problem has been resolved recently as given below:

Prevention of decay fungi

Constant saturation with water prevents interior decay and exterior decay is prevented by coating tar on the outside.

Coating the inside and outside of the bamboo pipe with bitumenous paint approved for drinking water contact surfaces. This is achieved by the dipping method.

The impregnation of less toxic fungicides, for example borax, AAC (alkyl ammonium compounds) and lining with polythene film inside the pipe as a water contact prevention barrier.

Prevention of Termite Attack (Smith et al., 1972)

- Admixture of pyrethroids insecticide with tar and coating the bamboo on the outer surface. The tar fixes pyrethroids and prevents degradation. Water quality tests conducted by Wellcome Research Laboratories, U.K. showed that the tested water was within the World Health Organization approved standard.
- In non-termite infested areas, tar coating alone is sufficient to prevent minor incidental termite attack.

If a life span of over 10 years is achieved by these methods, the preservation methods will be economical.

Table 1. Cost of running and operation of village bamboo water supply scheme

Particulars of expenditure	Rate	Cost/annum (US $)
Annual salary payable to two men employed in the village	US $ 15.00 per person per month	360.00
Wire reinforcement (1/2 of a roll per annum)	US $70.00/ro11	35.00
Spare bamboo pipes including transportation from forest to site	Lump sum	35.60
Preservatives e.g. chlorine, insecticides, tar, etc.	Lump sum	21.20
Taps, fittings and joints	Lump sum	100.00
Inspection including transport and allowance	Lump sum	22.44
Miscellaneous	5% of the total cost	28.71
	Total cost /annum	602.95

Maintenance and Operation of Bamboo Water Supply System

Organization

During construction of the bamboo water system in the village, two people from among the village community are selected by the village government as prospective workers for training future village maintenance technicians.

Training Procedure

As the construction work progresses, for example, construction of intake, pipeline building, etc., the villagers are made to interact with other workers in the construction activities so that they can learn all aspects. Strong emphasis is placed on the proper maintenance of water intake pipelines by replacement of burst bamboo pipes, repair of leaking pipe joints, repair to insect attacked spots; sterilization of the whole water system by chlorine, flushing of the bamboo water main and cleaning of water tanks; upkeep of spares like joints, wire for bamboo pipe reinforcement, keeping of spare bamboo pipes in the water pond, spare water taps, insecticides, chlorine, etc.; upkeep of daily operational incidents, for example, burst pipes, leaky joints, insect attack, availability of water at the source and spares in stock, etc.; monthly reporting to the headquarters by means of a proper station logsheet; attending village government council meetings.

Water Quality Control

Bamboo is prone to bacteriological decay and can become accidentally chemically polluted. Samples of water are collected by a qualified senior laboratory official and submitted to the central laboratory for analytical purposes.

cost

The cost of the bamboo water supply scheme is low (Table 1).

References

Bronkonsult, A.B. 1983. Evaluation of Tanzania Wood-Bamboo Technology, Final Report (June) (Engineers-Economists-Planners c/o Sundberg Vag 1-3, S 18363 Taby-Sweden).

Gokcesu, Suhan 1980. Laboratory investigation for determining hydraulic design for bamboo and woodstave pipes. Univ. Dar es Salaam, Tanzania.

Liese, W. 1986. Bamboo. Hamburg Univ., West Germany.

Lipangile, T.N. 1984. Wood-Bamboo. Presented at Rural Hydraulic Development A.P.V. Countries & Mediterranean Basin {June), Marseilles, France.

Lipangile, T.N. 1985a. Role and development of wood bamboo division and experience of one decade. Regional Water Engineer's Conf. Arusha.

Lipangile, T.N. 1985b. Use of bamboo as water pipes. :315-320. **In** Rao, A.N.; Dhanarajan, G & Sastry, C.B.

(eds) Recent Research on Bamboos. CAF, China and IDRC, Canada.

Lipangile, T.N. 1986a. Wood and Bamboo as Water Conveyance. Seminar on Rural Technology in Tanzania, Univ. Dar es Salaam. Tanzania.

Lipangile, T.N. 1986b. Wood-Bamboo in Water Conveyance, International Water and Sanitation Conference, Calcutta, India.

Lipangile, T.N. 1986c. Use of Bamboo Pipe in Water Supply Systems. Proc. Use of Vegetable Plants and Their Fibres, Baghdad, Iraq.

Lipangile, T.N. 1986d. Development of Bamboo Water Piping Technology in Tanzania. Proc. Bamboo Production and Utilization. IUFRO World Congress, Ljubljana, Yugoslavia, September.

Lipangile, T.N. 1988. Manufacture and Construction of Bamboo Water Supply Systems. Presented at ABC. Prafrance, France.

Lipangile, T.N.; Jacobs & Kundborge, N. 1978. Main Final Report, Wood-Bamboo Project 1978. SIDA, Stockholm, Sweden.

Purushothama, A. 1954. Preservative treatment of green bamboo under low pneumatic pressures. Indian Forest Bull. No. 178.

Smith,V.K.; Beal, R.H. & Johnston, H-R. 1972. Twenty-seven years of termite control.40: 28, 42, 44 U.S. Department of Agriculture's Forest Service Laboratory at Gulfport, Mississippi.

Waste-water Treatment by Low Cost Bamboo Trickling Filter and Pond Systems

Wolfgang Kirchhof

Research Institute for Water- Technology, Technical University of Aachen, Mies-van-der-Robe-StraBe I7, D-5100 Aachen, Federal Republic of Germany.

Abstract

Two low cost bamboo trickling filters and a waste water pond system have been constructed in Java and operated for two years for the secondary treatment of municipal wastewater. For running these systems, health hazards, caused by noxious organisms and ingredients of the waste-water, should be reduced to a non-critical level for a subsequent recycling of the waste-water for irrigation in paddy fields. The project combined traditional building skills with sophisticated methods of calculation and design of water treatment facilities. Bamboo filter systems were compared with a stabilization pond system, which is already ulell-known. Emphasis Was placed on the assessment of the efficiency of removal of pathogenic germs and on the estimation of the requirements of land, energy andfinancial inputs. The cost-benefit analysis showed a low specific capital cost for. each waste-water treatment system. A level of less than 20 US dollars per capita has been achieved at a small design population of about 20 persons. The data of these probe studies indicate that both the pond and the bamboo filter systems can be used as a small scale waste-water treatment plant. The preference of these systems depends on local settings. In densely populated or mountainous regions the advatltages of the bamboo filter- systems outweigh those of the pond system. In regions abundant in water resources, the pond system should be prefer-red.

Introduction

Waste-water reuse in agriculture is becoming an attractive method of increasing water resource utilization (Anonymous 1972). In addition to the value of the reclaimed water, the nutrients contributed to the crops by use of such water which are rich in organic matter cannot be overlooked, particularly in a period of increasing cost of chemical fertilizers and increasing demand for settlement area.

The use of domestic waste-water for crop fertilization has been widely practised for years in many regions of Java. While the improvement in soil productivity is of vital importance, the public health risks caused by disease transmission to agricultural workers or to the consumers of crops eaten raw must be carefully considered. Human excreta and raw domestic micro-water have been shown to carry the full spectrum of pathogenic micro-organisms endemic in the community.

Stabilization ponds are still the simplest form of waste-water treatment (Arthur, 1982: Gloyna. 1971; Li, 1978). Although these are land-intensive, these are the most effective way of removing pathogens. This is particularly important when the effluent is to be reused in aquaculture and irrigation. If land is not available or is too costly to justify pond treatment, alternative waste-water treatment processes, such as trickling filter operations will have to be considered.

In trickling filters, aerobic attached-growth biological-treatment processes are applied to remove organic matter found in waste-water. Trickling filters are classified according to hydraulic or organic loading rates as low-rate, intermediate-rate, high-rate and super-rate. Hydraulic loadings vary from 1 to 200 m^3/d per m^3 and the organic loadings from 0.08 to 6.0 kg BOD_5/d per m^3. BOD_5 refers to the biological demand in five days at 20 C. Assuming a population equivalent (PE) from 40 to 50 mg/d, a trickling filter could be charged with loading rates from 1 PE/m^3 filter media to 1000 PE/m^3.

Setting

In West Java, the Ministry of Public Works has initiated a programme to develop low cost waste water treatment plants with minimum land requirements. The Institute of Hydraulic Engineering (IHE), Bandung and the "Forschungsinstitut fur Wassertechnologie" (FIW) of the Federal Republic of Germany, have chosen two different types of trickling filters as waste water treatment plants as these systems are commonly used and require only simple construction skills and low energy.

As bamboos are widespread throughout Indonesia and its utilization is ethnologically well known to the local population (Widjaja, 1988), the project had focused on the construction and operation of filter systems, with many parts made from bamboo material. The filter media consisted of open bamboo rings, varying in size from 30 to 60 mm in diameter and length. The depth of the bamboo media was about two m.

For the trial the IHE rented a 0.25 ha paddy field in the lowlands south of Bandung. Here, the fields were irrigated with water from the river passing through the main population area of Bandung, where it got highly loaded with domestic wastes.

Performance Data

The waste water treatment facilities were built in 1985. From 1986 to 1987 research activities were carried out in four periods, the duration of which were adapted to the local rice growth periods. The flowsheet in Figure 1 describes the plant arrangement of the third sample run in which four different processes were tested. The capacity of each treatment plant was for 20 persons.

Grid removal facilities, especially for separating plastics, were installed ahead of each process line so that they were fed with waste-water free from coarse solids. The first main process unit was a low-rate bamboo trickling filter, assessed for a volumetric BOD_5-loading rate of 0.1 kg BOD_5/m^3 per day. The feed-water was first pumped into an elevated supply tank for primary settling. This type of filter was designed for operation in mountainous regions where a gravity-flow inlet could be installed. The second main process unit was a high-rate bottom filter, with an assumed volumetric BOD_5-loading rate of 0.3 kg BOD_5/m^3 per day, and a sedimentation basin installed beneath. Because of its low inlet weir, the filter was directly charged from the irrigation channel. The third main process unit was a pond system which consisted of a first step water hyacinth pond, a second step aerobic pond, a third step aquaculture pond and a fourth step maturation pond. Beneath each of the waste water treatment processes described above, a paddy field as a third treatment process unit was attached. As a reference point a directly irrigated paddy field was also operated.

Filter Construction

The construction of the filter systems is illustrated in Figures 2 and 3. The bottom filter (Fig. 2) was discharged in free-head and high-loaded at a designed loading rate of 20-30 PE/m^3. The low-rate trickling filter (Fig. 3) was discharged by a hand pump or an electrical pump. A service reservoir was installed ahead of the discharge facility (Fig. 4) to equalize' the inflow rate. The discharge facility was made from zinc sheets, but split bamboo poles could be used as well.

The main parts of the filters were made from "bamboo gombong" *(Cigantochloa verticudata).* As filter media and as roof laths "bamboo tali" (G. apus) was used. Both bamboo species were common local building materials, prices of which varied from 150 Rp (10 US cents) for one pole of bamboo tali to 1500 Rp (1 US $) for one pole of bamboo gombong.

The performance data of the bamboo filters and of the stabilization pond system are summarised in Table 1.

Results and Discussion

The evaluation of the reduction of total coliforms, degradation of nutrients, evaluation of rice yields, observation of users' acceptance of the systems and a cost-benefit analysis were done. Sample runs lasted from November, 1985 until January, 1986 (1), June. 1986 until October, 1986 (2), February, 1987 until June, 1987 (3), and September, 1987 until December, 1987 (4). Twice weekly, at about 11 a.m. to 1 p.m., samples were taken and analysed. Family members of an agriculture worker living nearby were instructed by the IHE-engineers to daily maintain the treatment plant, to observe the filters, ponds, paddy fields and dikes, and to measure simple physical parameters. Meteorological parameters were obtained from the Geofisika Station of Bandung. For sample run 3. the environmental conditions of the pond and filter systems have been characterized by the parameters. means of which are summarized in Table 2.

Microbiological Water Quality

In sample run 1, the total coliforms (TC) was measured in raw water influent and effluent of the bottom filter, the pond system and the paddy fields.

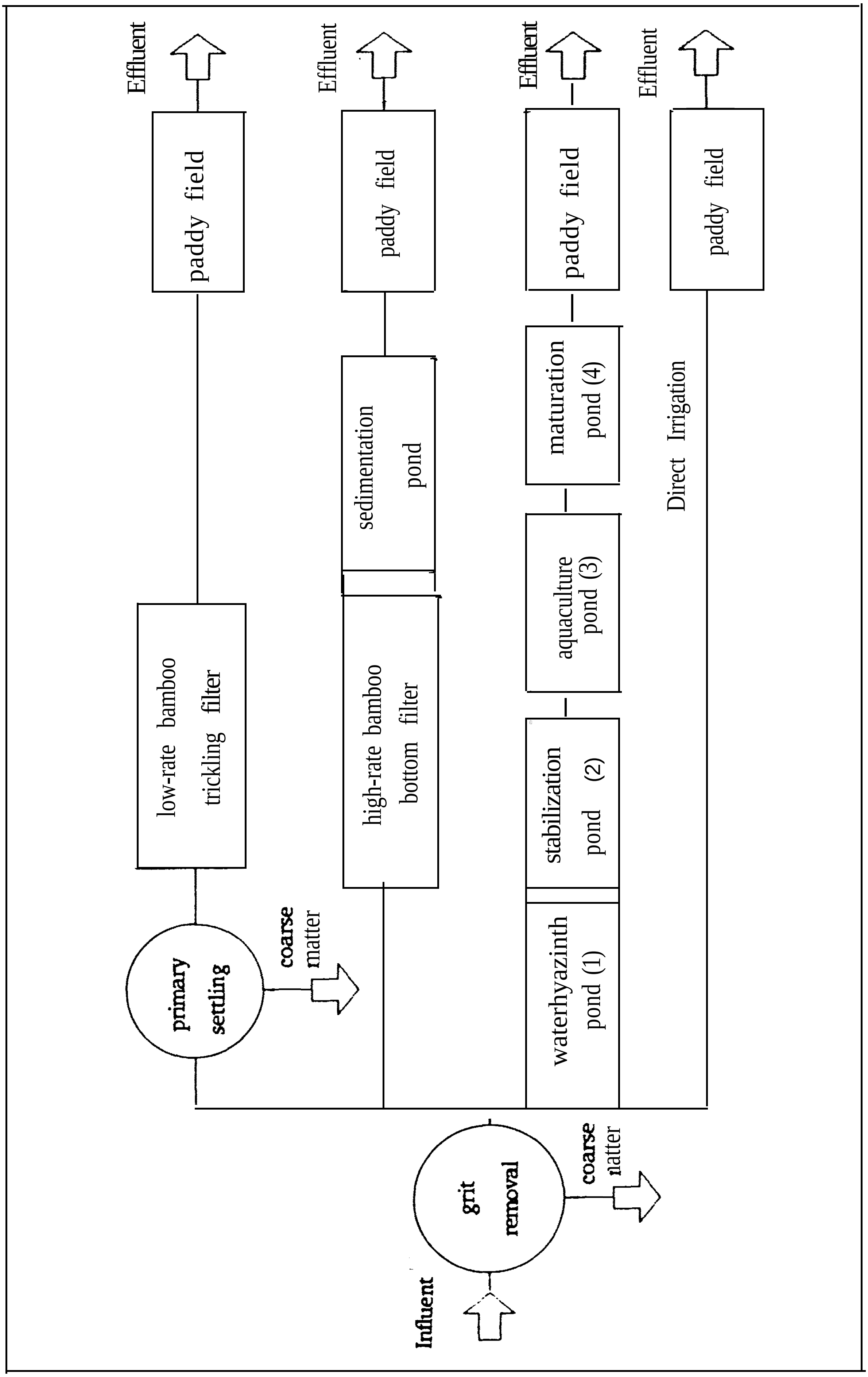


Fig. I. Flowsheet of the waste-water treatment systems (sample run 3).

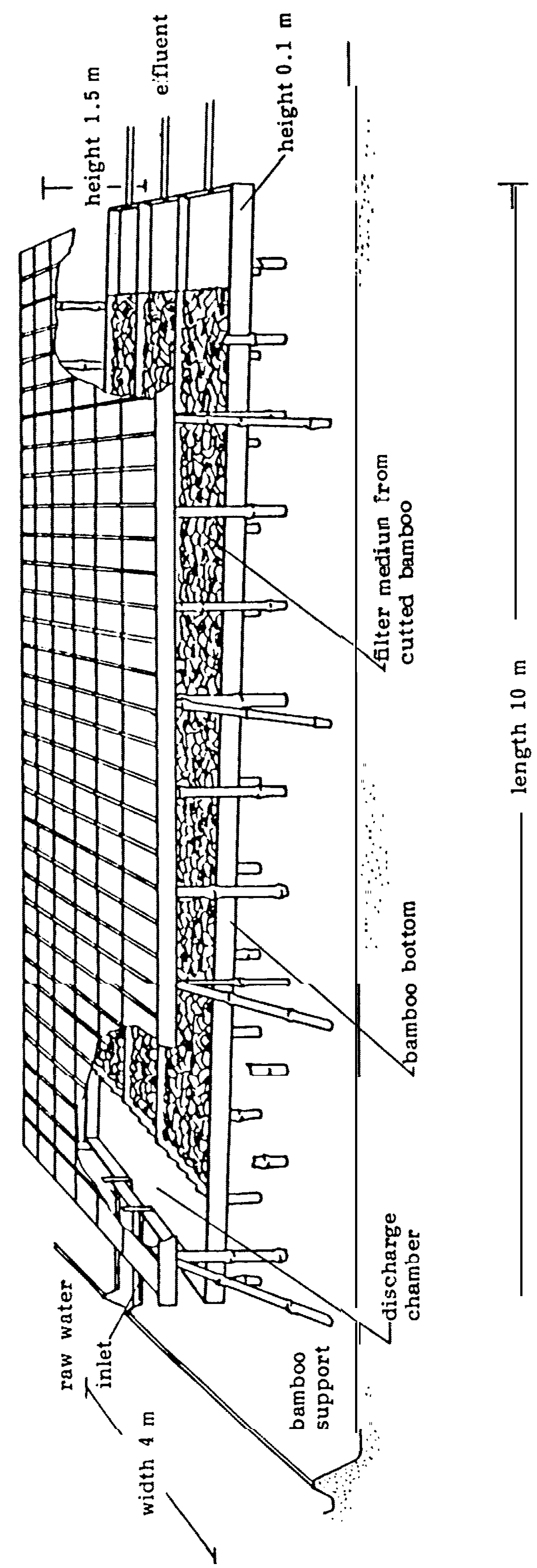


Fig. 2. Illustration of the bamboo bottom filter.

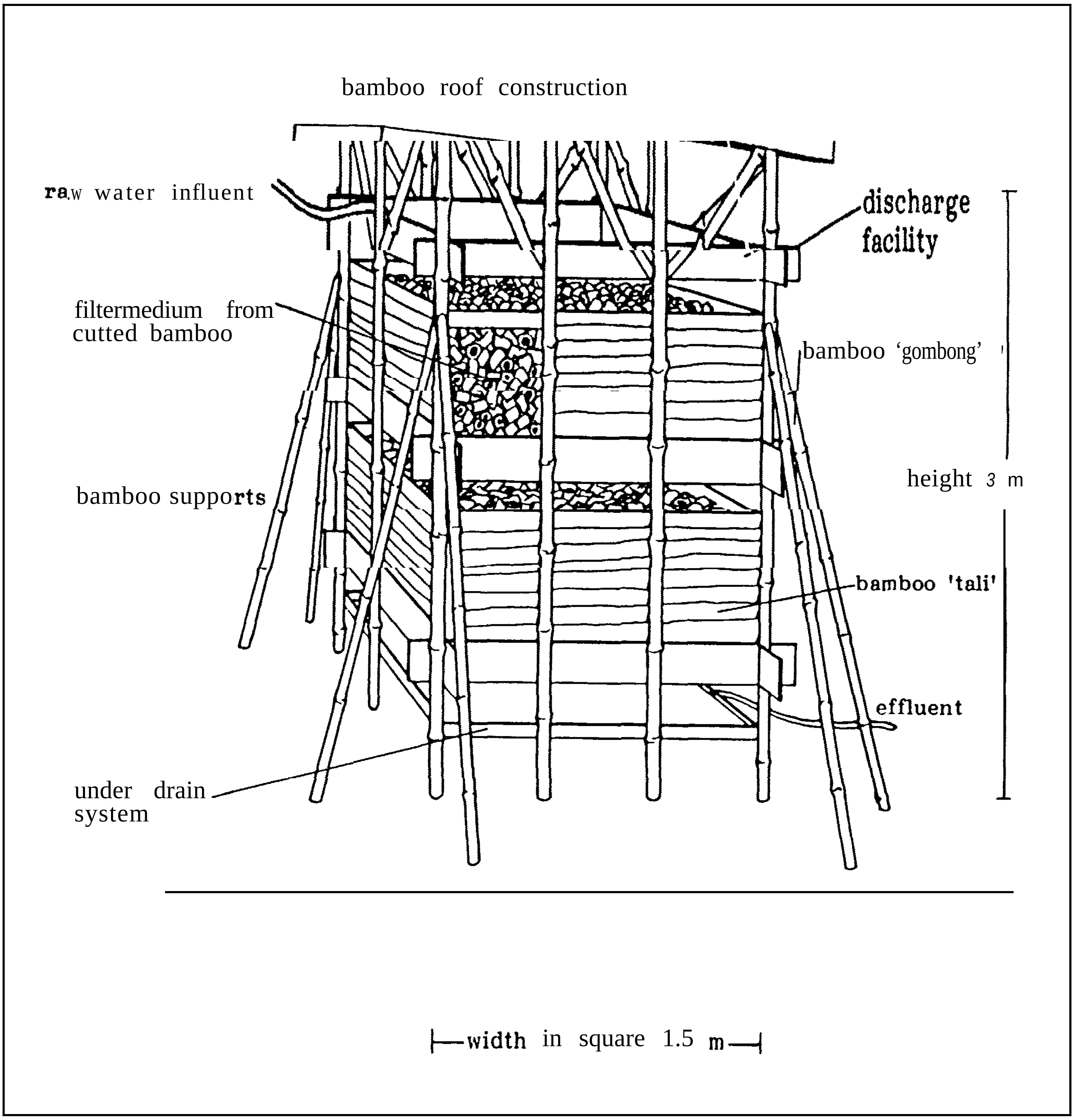


Fig. 3. Illustration of the bamboo trickling filter.

Figure 5 shows the minimum, maximum and median values obtained. In the bottom filter the TC level is reduced by an order of 1.1 and corresponds to values stated by Feachem *et al* (1977). The disinfection by the pond systems was more effective, reducing the feed TC level to about 2.0 log units.

Physical and Chemical Quality of Water

The objective of the waste-water treatment was to reduce the levels of noxious organisms and harmful substances in the raw water as effectively as possible and not affect nutrient constituents such as nitrogenous or phosphorous components. The concentrations of orthophosphate and ammonium measured during sample run 3 are summarized in Tables 2 and 3. The treatment systems caused a non-intended reduction of the P and N concentrations in the water applied to the paddy fields. As the degradation in the filter systems is based on bacterial activities, the reduction of phosphate from 3.82 to 3.2 1 mg/l was lower than the degradation in the pond system from 3.82 to 1.23 mg/l caused by algal growth. The highest P and N degradation rate in the paddy fields was observed when the raw water was directly used for irrigation. Thus, the nutrients in raw water were more effectively degraded in pond systems than in filter systems and

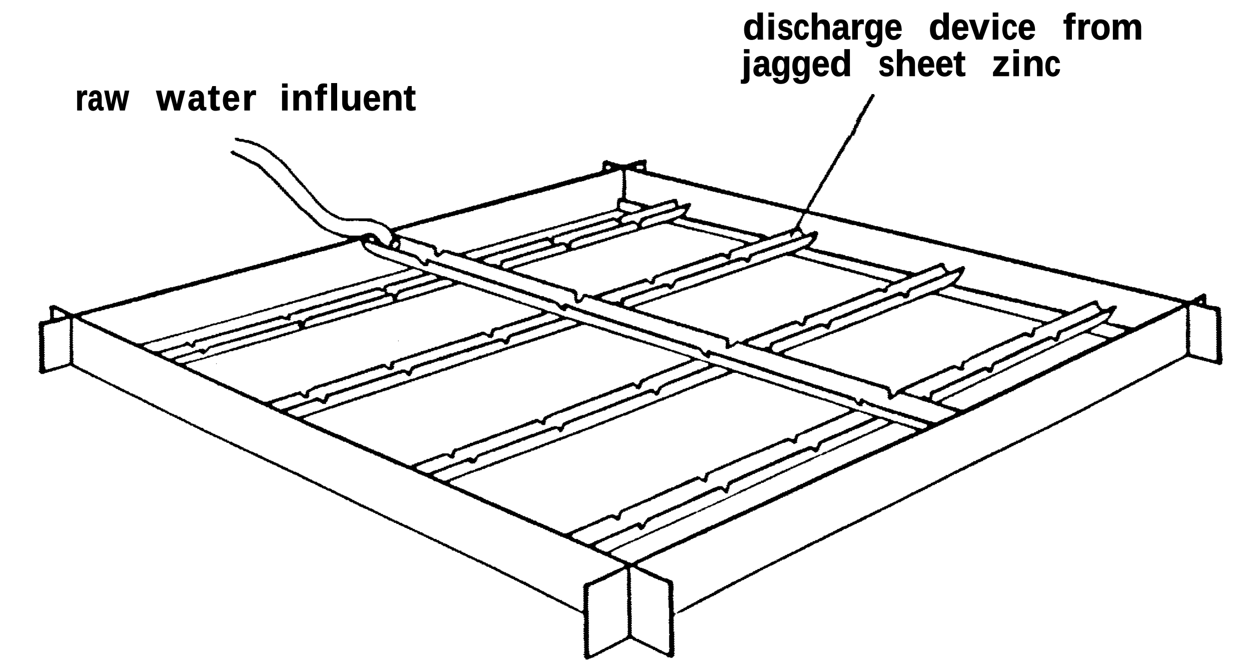


Fig. 4. Discharge facility of the trickling filter.

Table 1. Performance data of the bamboo filters and the pond system

Item	Bottom filter	Trickling filter	Pond system			
			Water hyacinth	Pond 2	Aquaculture	Pond 4
Area (m^2)	3.0	1.5*1.5	15.0	75.0	50.0	50.0
Depth (m)	0.08	2*0.9m	0.25	0.25	0.5	0.3
Volume influent (m^3)	0.5-2.3	4.0	4.0	20.0	25.0	15.0
Flow rate influent (m^3/day)	1.0-3.4	1.0-3.4	3.4	3.3	3.1	3.0
BOD conc (kg BOD/m^3)	0.03-0.05	0.03-0.05	0.034	0.014	0.021	0.016
Detention time (h,d)	0.5-2.5h	2.5-5 h	1.2 d	6d	8d	5d
Vol. BOD-loading (kg BOD/m^3/d)	0.2-0.4	0.1-0.2				
Loading rate (kg BOD/ha/d)			77.0	6.2	13.0	9.6

BOD refers to the BOD in five days at 20 C unless otherwise mentioned

a negative effect on the rice yield can be expected.

Rice Culture Results

The rice yields of the harvests are summarized in Table 4. In sample run 2, the results were low because of improper handling of seedlings and a long drought at the beginning of the growth period. The results of sample runs 1,3 and 4 show that the yield on the paddy that was directly irrigated was normal, varying between 7.1 and 9.9 tonnes/ha. The yield of the pond paddy, which ranged from 6.2 to 8.1 tonnes/ha, was about 18 percent below the reference yield, In sample run 1, the low yield of the bottom filter system was not only because of lack of nutrients but mainly caused by rodents damaging the roots of the rice plants. Normal operation was achieved in sample run 4, with no significant difference between the pond and filter systems.

Assessment of the Reception of the Waste-water Treatment System

As the systems have been designed for operation at village level, emphasis was placed on the acceptance of these systems by the users. In rural areas, the acceptance of waste-water treatment

Table 2. Data of influent and effluent of the filter and pond systems

Parameter	Influent	Bottom filter		Trickling filter		Pond system		Pond 4
		Filter	Sedim. pond	Primary settling	Filter	Water hyacinth	Aqua-culture	
Temp. (C)	26.40	24.90	28.80	28.60	24.60	27.50	3 1.30	30.20
pH-level	7.21	7.63	8.23	8.36	8.19	7.25	9.17	8.86
Org. matter (mg/l)	21.60	13.40	14.60	19.60	25.70	12.80	19.00	14.90
NH4-N(mg/l)	17.00	12.29	8.42	3.90	2.50	6.23	2.26	1.40
PO_4-P (mg/l)	3.82	3.21	2.21	1.98	2.60	1.56	1.73	1.23

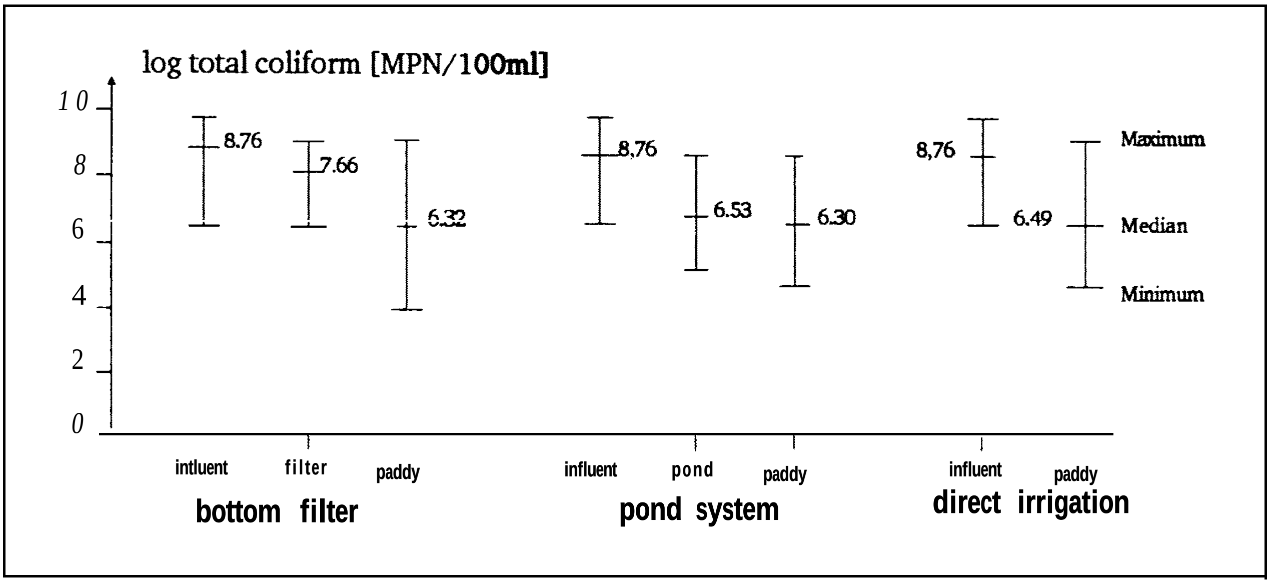


Fig. 5. Concentration of total coliforrms in influent, effluent of each bottom filter; pond system and paddies. Minimum, maximum and median values of sample run I.

Table 3. Inlet and outlet data of the paddy fields: sample run 3

Parameter	Be. Bottom filter		Be.trickling filter		Beneath pond		Direct irrigated	
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Eftluent
pH-level	8.23	8.17	8.19	7.95	8.86	8.25	7.21	7.54
solids (mg/l)	191.0	230.0	332.0	261.0	344.0	207.0	226.0	200.0
Org. matter (mg/l)	14.60	15.70	25.70	19.20	14.90	17.50	2 1.60	12.00
NH_4-N (mg/l)	8.42	4.62	2.50	2.30	1.40	0.72	17.00	4.62
PO_4-P (mg/l)	2.21	1.56	2.60	1.77	1.23	0.97	3.82	1.31

Be, beneath; F, filter

Table 4. Rice yields in tonnes/ha

Sample run	Period	Bottom filter	Trickling filter	Pond system	Direct irrigation
'	11/85-1/86	1.9	*	6.2	7.4
2	6/86-I0/86	0.10	0.09	0.4	0.14
3	2/87-6187	4.7	7.5	6.2	7.1
4	9/87-1 2/87	7.9	8.4	8.1	9.9

**, not installed in sample run 1*

technologies depends mainly on the level of adjustment and the price level. During the running of this project, special attention was paid to the following aspects:

Simple methods ofconstruction: Using earthworks and working with bamboo, zinc sheets and wood.

Application of local building materials: Bamboo materials were used for supports, as bars, earth reinforcements, water pipes, filter media and wall linings. Accessories and tools made from bamboo were used for carrying earth, harvesting and keeping fish. The filter bottom was lined with zinc sheets. The gutter and distribution device for the trickling filter discharge were also made from zinc sheets. Common tiles were used for covering the roofs against sunshine and rain. Wooden posts and bars were used only sparingly.

Participation of local people in construction and maintenance: One local carpenter and one metal worker were assisted by two unskilled workers for constructing the filter and pond systems. Members of a local family maintained the filters, ponds and paddies, including the cleaning of the distribution device daily for water discharge, as also of the pond edges and surfaces. Preparing the rice seed, planting and harvesting were included in their tasks. One member of the family was trained in taking water samples, analysing water parameters by means of simple methods, and in the daily recording of hydraulic and physical parameters.

Acceptance of local preferences and behaviour: The parameters of aquaculture such as selection of type of fish, stocking rate, initial size of fish, pond size and its depth were chosen after considering local preferences. Traditional techniques of rice culture were adopted and consisted of choice of rice, time of planting, duration of wet and dry periods, maintenance of paddy fields and choice of plant protection against diseases and damage caused by rodents or cicadas.

Only those filter systems which required a low input of energy were selected. A hand pump was installed to fill the supply tank of the trickling filter. The filter buildings were constructed in the local style. After assessing the dimensions, sizes of pipes, and selecting the materials, the local workers were instructed to build the filters. The responsibility of choosing types of the pole connections or selecting the shape of the roof was left entirely to them.

All these procedures have guaranteed a high level of acceptance. As the yields of rice and fish were distributed among the local family members and workers, their willingness to maintain the waste-water treatment plant was great.

Cost-benefit Analysis

Assessment of Cost

Capital cost

The capital cost of the bottom filter, the trickling filter and the pond system are summarized in Table 5, showing portions for material cost and salary, based on 3500 Rp per skilled man per day, and the material cost in the local market in Bandung. Bamboo poles were available at 800 to 1500 Rp per piece. The prices for boards varied from 3500 to 5000 Rp per piece. It is evident that the filter systems are four times more expensive than the pond systems. If the systems are constructed in rural areas, the material cost will decrease considerably as compared to the pond system because of the low cost of bamboo.

Annual cost

The annual cost comprises the cost of operation, maintenance and cost for rental of land. In Bandung, the cost for land was 800 Rp m- per year. The land required by the systems were 50 m' for the bottom filter, 7 m for the trickling filter and 160 m^2 for the pond system. Based on the experience from the project, the maintenance cost was assumed at 150 000 Rp year, for each system. After four years, the cost of the filter systems was found to be lower than that of the pond system.

Based on a design population of 20 persons, the

Table 5. Capital and annual cost of bottom filter, trickling filter, and pond system (in Rp)

costs	Bottom filter	Trickling filter	Pond system
Material cost	300000	300000	50000
Salary	660000	750000	200000
Total capital cost	960000	1050000	250000
Annual O.a.M.cost	150000	150000	150000
Annual rental cost	40000	5600	128000
Annual total cost	190000	155600	278000

I US $ = 1600 Rp; O.a.m, operation and maintenance

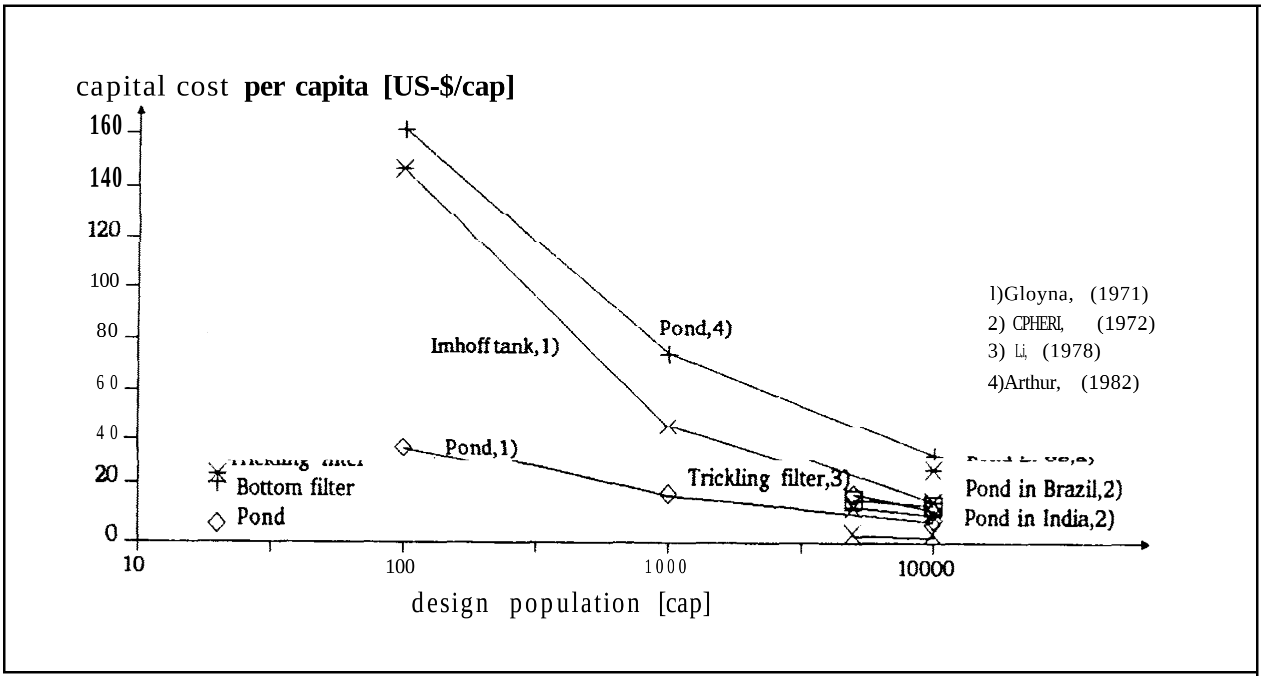


Fig. 6. Annualized per capita capital cost of different waste-water treatment sytems versus design population.

annualized per capita cost was calculated. The cost-effectiveness of the present design can be seen from Figure 6. A low-level of less than 20 US dollars per capita has already been achieved for a small design population of about 20 persons. For such small construction sizes, annualized per capita cost of 35 US dollars are cited for pond system or even 160 US dollars per capita for trickling filters.

Assessment of Benefit

To assess the utility of these systems, the economic benefits accruing have been estimated in terms of rice and fish production, savings in cost of water and fertilizer, and savings in medical costs.

Rice production

Assuming a price of 200 Rp/kg grains (12.5 US cents), an additional annual rice harvest of 4 tonnes/ha brings an economic income of 800 000 Rp/ha or 16 000 Rplcap.

Fish production

At a price of 1500 Rp/kg of market fish and taking 70 percent of the total weight of fish into account, an economic benefit of 7 million Rp/ha per year (4375 US dollars) is likely to be achieved, with a benefit of 3200 Rp/cap per year (2 US dollar/cap per year).

Savings in cost offertilizer and Water

Considering the market price of the constituents of raw water and the price of water itself, the economic turnover can be estimated. In series 1 to 3, an average concentration of organic matter of 500 mg/l which consists of ammonium-nitrogen, phosphate and suspended solids has been measured in the raw water. Assuming a market price of 500 Rp/kg of inorganic fertilizer, the economic value of raw water could be estimated at 250 Rp/m^3 (15 US cents/m^3). Bartone and Arlosoroff (1987) have reported a cost of 3-5 US cents/m" in Israel. If the irrigation water has to be supplied by public works agencies in Bandung, a price of 110 Rp/m^3 (7 US cents) must be considered. Assuming two annual 130 day rice growth periods, a daily water demand of 1 m for 20 persons and a price of 110 Rp/m of water, an annual water cost of 1500 Rp/cap per year *(93* US cents) can be saved in case of a reuse of waste-water.

Savings in medical cost

The filter and pond systems were installed to improve health conditions by reduction of helminths and pathogenic germs. Based on the statistics of the local health care organization (PUSKESMAS), the economic benefit of the waste-water treatments can be estimated. A total reduction of infection cases of ascaris and of diaorrhea among the farmers living nearby can be assumed. According to the local situation, the annual medical costs of about 10 000 Rp (6.25 US dollars) per person for helminth and diaorrhea control can be saved.

Conclusions

The applicability of pond systems and of trickling or bottom filters has been demonstrated. The advantages of the pond system are simple construction, low construction cost, good disinfection rates considering helminths, its eggs, cysts, amoeba and germs, low requirements of maintenance, high longevity, and the advantage of integrated fish protein production in higher level ponds. Disadvantages include the high degradation of phosphate and ammonium, the high rate of water loss due to evaporation and a high land requirement.

The advantages of the bamboo filter systems are simple construction, low maintenance requirement, good disinfection rate considering helminths and its eggs, low degradation rate of phosphate, low water losses and the lowest land requirement. Disadvantages are the construction cost which exceeds that for the pond system, low disinfection rate considering germs, no additional opportunity in terms of protein recovery and a lower life-span than the pond system.

Because of a reduction in the amount of helminths and germs, the operation of the waste-water treatment plants results in an improvement of health conditions but affects the subsequent rice culture. Yield loss was estimated at 15 to 20 percent. However, if located in arid regions anappropriate reuse of the waste-water will enable an additional rice harvest. In densely populated or mountainous regions the low land requiring filter systems should be preferred. If land and water are available at reasonable cost, pond systems are appropriate for waste-water treatment systems,

References

Anonymous 1972. Low Cost Waste Treatment. Central Public Health Engineering Research Insititute.

Arthur, J.P. 1982. Notes on the design and operation of waste stabilization ponds in warm climates ofdeveloping countries. World Bank Technical Paper No. 7. pp 106.

Bartone, C.R. & Arlosoroff, S. 1987. Irrigation reuse of pond effluents in developing countries, Water Sci. Technol. 19: 289-297.

Feachem, R.; McGarry, M. & Mara, D. (eds) 1977. Water, Wastes and Health in Hot Cimates. John Wiley and Sons. 399 pp.

Gloyna, E. F. 1971. Waste Stabilization Ponds. WHO. Geneva. pp 175.

Li, K.C.G. 1978. Aerated Lagoons. : 483-490. **In** Reid, G. & Coffey, K. (eds) Appropriate Methods of Treating Water and Waste Water in Developing Countries. Univ. Oklahoma.

Widjaja, E.A. 1988. Socio-ecological observations of bamboo forests in Indonesia.:9. **In** Inter. Bamboo Confer. 88, Prafance, France (June 7-9).

PROCEEDINGS OF
THE INTERNATIONAL
BAMBOO WORKSHOP,
NOVEMBER 14-18, 1988

BAMBOO ECONOMICS

Some Aspects of Bamboo Production and Marketing

Songkram Thammincha

Faculty of Forestry, Kasetsart University,
Bangkok 10903, Thailand.

Abstract

The varied uses of bamboos provide better employment opportunities and income distribution to the rural people. The production of bamboos is done with little capital and results in poor resource utilization. Some socio-economic aspects of bamboos as raw material for making bamboo-based products and as a primary product for export are discussed. A detailed study on the production and marketing of steamed bamboo shoots and a preliminary economic analysis for bamboo plantation establishment are presented. Research on production and marketing of bamboos is vital for the future development of bamboo resources.

Introduction

Bamboo is one of the most important minor forest products. It provides food, raw material, shelter and even medicine for a good part of the world's population (Austin *et al.,* 1983; Liese, 1985), and it continues to hold an important place in the rural economy of the developing countries especially in the Asia and Pacific region (Sharma, 1980, 1985).

Most of the people living in the rural areas of Thailand depend upon agriculture for their livelihood. Bamboo is generally grown as a living fence; the shoots are used as food and culms as building material and also for making handicrafts. The lack of income from agricultural crops during the rainy season is compensated by bamboo. Also the surplus bamboo shoots can be sold in the local market or preserved by steaming, pickling or drying for future consumption. Bamboo culms are used for making a variety of bambooware which bring additional income to the rural people (Thammincha, 1985).

Most of the people living in remote rural areas are poor. Their earnings from agricultural crops are not sufficient to cover their living expenses and many of them are in debt. Fortunately, bamboo offers an alternate source of income. The people gather bamboo shoots from the forest and sell them to the traders. Some even temporarily migrate hundreds of kilometers to the forest for gathering and selling bamboo shoots during the rainy season. They return to their village after tne rainy season in order to harvest their agricultural crops. The average roadside price of one kg of fresh bamboo shoots is two Baht. One may gather as much as 50 to 100 kg of shoots per day which brings in considerable income. Bamboo culms are cut more during the dry season as the forest is more accessible then. These are also sold as raw material to heavy industries.

With their free access to the forest and the ubiquity of bamboo, people tend to indiscriminately harvest it. The natural bamboo resource thus gets diminished. In the future, however, the scarcity of the bamboo resource will compel people to plant more bamboos and also use them more efficiently.

Bamboo-based industry is generally a low capital but labour intensive industry. The results of the research on production and marketing will indicate the appropriate means for improving the capabilities of the rural poor people in producing bamboo-based products.

Some Socio-economic Aspects of Bamboo Production

Bamboo culms are used in partial replacement of kenaf for pulp production at the Phoenix Pulp and Paper Company, located in Khon Kaen, Northeast Thailand. The daily demand of raw material is 300 tonnes of bamboo and 700 tonnes of kenaf. However, the supply of bamboo is inadequate. Bamboo culms are mainly obtained from natural forests, farmlands and home gardens. Heavy harvesting of bamboo shoots during the rainy season has resulted in the rapid depletion of the bamboo resource in the region. *Dendrocalamus asper* plantations in Prachinburi, about 400 km away from the factory, are the main source of raw material. Also, to meet the demand, bamboos are being transported from western Thailand which is 700 km away. With the spiralling transportation costs, raising bamboo plantations near the factory has become imperative.

The factory encourages farmers to raise bamboo by giving incentives such as guaranteed price, cheap seedlings and cuttings and access to credit facility. Yet, the planted area is far below the target. As the farmers are only familiar with cultivating rice, cassava, maize and other cash crops, they are reluctant to raise bamboo. They have no knowledge or experience of bamboo cultivation. Although bank loans with low interest rate are available, only a few farmers are eligible to get the loan from the bank. The size of the bamboo farm ranges from 0.2 to 1 ha. The farmers are not willing to sacrifice large farm areas for raising bamboo since subsistence crops are far more important to them. Intercropping of bamboo and cash crops is commonly practised by the farmers (Thammincha, 1985).

It is difficult to persuade the poor farmers to grow new crops which have a potential for higher production and greater economic return. Therefore, it is essential to have a thorough understanding of the technical, social and economic constraints of traditional farming systems (Young & MacCormac, 1986).

Pho-ngam village of Prachantakam district in Prachinburi province is known for brooms with bamboo handles and for bamboo furniture. Although there are only ten entrepreneurs, the products from this village are sold nearly all over the country. The bamboo products like armchairs, sofas, shelves, couches and ladders are made from *Bambusa nana* and *Thyrsostachys siamensis. The* entrepreneurs buy bamboo at the price of 5 Baht per a 6 m length of *T. siamensis* and 16 Baht per a 8 m length of B. *nana.*

Each entrepreneur employs six to eight workers in broom-making activities and two to four workers in bamboo furniture-making. Nearly all the entrepreneurs have completed only primary school education and have an experience of 5 to 20 years in this business. The problems they face are of low bamboo quality, increasing price of bamboo, non-durability of raw material and products, labour shortage during cultivating and harvesting seasons and low return.

Only female workers are engaged in broom-making while men make bamboo furniture. Since their main occupation is paddy cultivation, their participation in making bamboo products is limited to the dry season when they are free from farmland activities. One worker can make 50 to 60 brooms a day. They are paid on a piece-rate basis, at 0.80 Baht per piece. The daily earnings of broom-makers range from 40 to 50 Baht while those who make bamboo furniture earn 160 to 200 Baht. This off-farm income is very important for the workers who cultivate subsistence crops.

Bamboos are widely used as raw material for basket-making. Ratchaburi is famous for bamboo baskets owing to the expertise of the local people and the availability of raw material. *T. siamensis* is the main raw material, the rest being D. *strictus* and *B. blumeana.* These bamboos are harvested from the neighbouring natural forests of Kanchanaburi. A 8 m long culm of *T. siamensis* costs about 7 Baht. A basket 75 cm in diameter and 70 cm in height requires about 2.5 lengths. One person can make as many as three baskets of this size in a day. The net income one can get is 47.50 Baht per day. Bamboo wastes are sold as fuelwood.

Similar types of baskets are made for commercial purposes in some villages in Prachinburi province. Bamboo splits are prepared from the culms of *T. siamensis* of various lengths (6, 8 and 10 m). There are five sizes of baskets, Nos. 1 to 5, the smallest one being No. 5 of 30 cm diameter. Middle-sized baskets, No. 3, are the most favourite among basket makers. One person can make two to three of the largest baskets No. 1 with 100 cm diameter in a day, a similar number of No. 2 baskets, four to six pieces of No. 3, five pieces of No. 4, and two to three pieces of No.5 baskets. The daily output per person of No. 5 is lower because the baskets of this size are generally made by older people. The average net earning is 20 to 60 Baht/ person per day. The bamboo basket-makers face serious problems such as the increasing price of raw material and competition from substitute materials like plastic. Some of them want to give up basket-making but have no better alternative. Although income from basket-making is rather small it is very important for the rural poor people.

Bamboo culms are also exported. *T. siamensis* from the national forests of Kanchanaburi is the main species that is exported, the others being B. *arundinacea, D. brandisii* and *G. hasskar-liana.* The entrepreneurs buy *T. siamensis* culms of varying lengths of 2.0,2.5, and 4.0 m at the rate of 0.50, 0.70 and 1.50 Baht per piece, respectively. The diameter of these ranges from 1 to 2.4 cm. These are re-cut to 1.2, 1.5,2.0,2.4 and 3 m lengths. One entrepreneur exports about 300 large containers per year, whereas the others had 20 000 to 300 000 bamboo rods for export to West Germany, England

Table 1. Development of *Dendrocalamus asper* farms in Prachinburi Province

District	Area (ha) 1984	1985	1986	1987	Average yield kg/ha	No. of factories*
Muang	2368	2368	2888	4565	9375	19
Srakaew	640	875	1394	2381	9375	
Nadee	409	376	1488	1920	10625	2
Prachantakam	480	480	989	997	15000	3
Kabinburi	458	458	458	341	9375	1
Aranyapratet	46	82	96	96	10938	
Wattananankom		70	88	88	9375	
Srimahapote	56	376	396	20	7500	
Tapray a		8	8	20	7500	
Kokpeep	8	8	8	16	8125	
Wangnamyen		10	10	10	6250	
Klonghad				18		
Total	4465	5111	7823	103338	95938	25

*, new factories under- construction have not been included

and Italy.

Production and Marketing of Shoots from Bamboo Farms

Dendrocalamus asper Farms

Prachinburi province is situated in eastern Thailand, about 100 km from Bangkok. D. *asper* was introduced to this region from China about 80 years ago. Prachinburi has since then become the best-known centre for bamboo farms. The area of bamboo farms has expanded rapidly due to the higher economic returns they bring when compared with other agricultural crops. Earlier the main income was generated from shoot production, the value of culm production being of very little significance. However, the income from culms harvested from the farms has become more substantial during the past few years since culms over two years old have been sold as raw material to the pulp mill apart from those sold as building material and raw material for other bamboo-based products.

Branch cutting is one of the most commonly used vegetative propagation techniques for D. *asper.* Clump and rhizome cuttings are not feasible because these are too bulky. Although flowering of D. *asper* can be found every year, it is very difficult to get seeds because seed development is always incomplete. Since the bamboo plants obtained through vegetative propagation have the same age as their clump, it has been observed that about ten percent of the cuttings flower and die. Although it is believed that the intermast period of D. *asper* is about 80 years, it is difficult to predict the flowering season. If this situation prevails, there will be a high rate of failure in bamboo farm investment. Nevertheless, the farmers still go on expanding their bamboo farm area and new farmers join the old ones. Table 1 details information about bamboo farms in Prachinburi province.

The majority of fresh bamboo shoots are sold to 25 factories in Prachinburi province, the rest being sold in both the local market and the central market in Bangkok.

Fresh Bamboo Shoot Marketing

There are four groups of people involved in the marketing of fresh bamboo shoots (Fig. 1):

1. Farmers who sell bamboo shoots harvested from their farm to local middlemen and to bamboo shoot canneries. Some farmers also sell bamboo shoots directly to customers at the market place.
2. Local middlemen who buy bamboo shoots from farmers before selling them to bamboo shoot canneries and to middlemen from Bangkok and other provinces.
3. Factory owners who buy bamboo shoots from

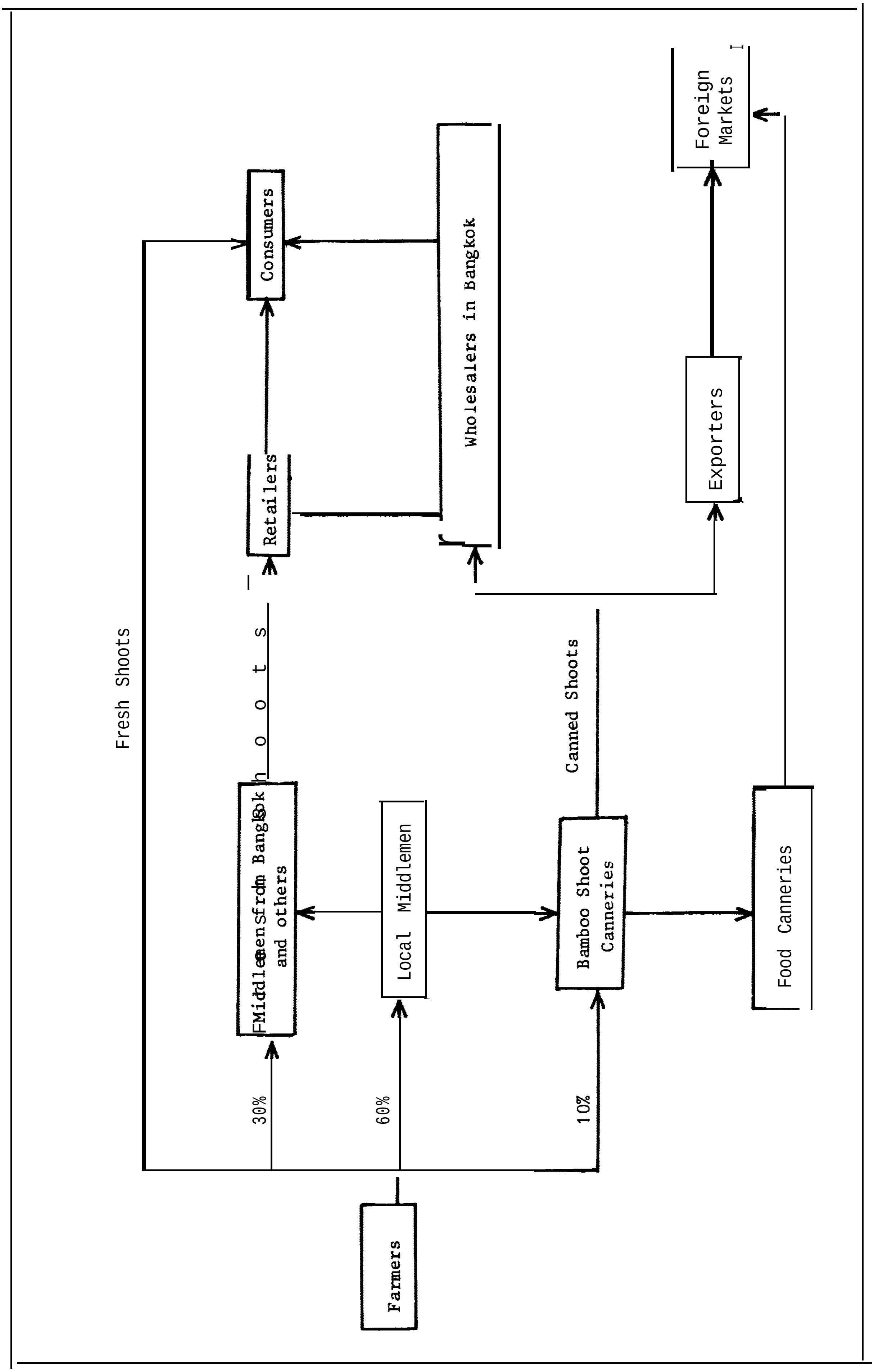


Fig. 1. Bamboo shoot marketing channels.

farmers and local middlemen in order to produce steamed bamboo shoots for export and to food canneries.

4. Middlemen from Bangkok and other provinces who buy bamboo shoots from Prachinburi before selling them to retailers.

There is much fluctuation in the price of fresh bamboo shoots with a high price at the beginning of the shooting season. This declines during the rainy season followed by a slight increase at the end of the rainy season. However, there is less fluctuation in the price of bamboo shoots sold to steamed bamboo shoot factories (Table 2).

Table 2. Monthly wholesale price of fresh bamboo shoots in Prachinburi in 1986 (Potharam & Panchatri, 1986)

	Price (Baht/kg)	
Month	Market	Factory
May	10-18	
June	7- 9	4.0
July	4- 5	3.5
August	3-4	3.5
September	4- 5	3.5

Steamed Bamboo Shoots Processing

Steamed bamboo shoots are the typical secondary products of bamboo farms in Prachinburi. There are at present 25 bamboo shoot canneries under operation. Some are under construction and some are in the process of applying for permission for starting.

Steamed Shoot Market

Domestic market

Bangkok is the central outlet for steamed bamboo shoots. Shoots of five bamboo species are used: *B. arundinacea*, *B. blumeana*, *B. nutans*, *D asper;* and *T. siamensis.* These shoots are prepared in four different forms: whole shoots, longitudinal half-cut, sliced and chopped shoots (Fig. 2).

Foreign markets

Bamboo shoots of *D. asper-* and *T. siamensis* are exported. More than 90 percent of the export consists of steamed shoots, the rest being deep-frost shoots and dry shoots.

Japan is the main market for steamed shoots of *D. asper-* (mainly from Prachinburi). More than 70 percent of the total export volume of steamed shoots are sent to the Japanese market and the rest to the United States, West Germany, Saudi Arabia, Hong Kong and other countries. The volume of export by Thailand in 1985 is presented in Table 3. The market share of Thai steamed bamboo shoots in the Japanese market has increased from 2.3 percent in 198 1 to 18.6 in 1985 (Potharam & Panchatri, 1985).

Table 3. Export of Thai steamed bamboo shoots in 1985 (Potharam & Panchatri, 1985)

	Amount	
Country	Tonnes	%
Japan	10265	73.04
United States	1238	8.8 1
West Germany	602	4.28
Saudi Arabia	437	3.11
Hong Kong	284	2.04
Denmark	302	2.15
Others	924	6.57
Total	14054	100.00

With an increasing share in the steamed bamboo shoot market in Japan, the area of *D. asper* farms will increase to some extent. However, an increase in bamboo farm area as well as an increase in the volume of shoot production may depend on two important factors.

1. The flowering of *D. asper:* Although it flowers sporadically, it will certainly hamper vegetative propagation, affect the productivity of the farms and make investment more risky.
2. The future trend of foreign markets. Taiwan is the largest steamed bamboo shoot producer of the world. There might be a possibility that less bamboo shoots will be produced in Taiwan due to different reasons. In such an event, the People's Republic of China and Thailand. the second and the third largest producers, will take more of the market share.

Economics of T. siamensis Plantations

While *D. asper* has been grown for a long time, other species are still being planted on a small scale though their uses are extensive. At the beginning of KU-IDRC Bamboo Project Phase I (1983-1984), seedlings of *T. siamensis* were planted with 4 x 4 m spacing on 128 x 128 m plots in Ratchaburi and Thongphapum located in western Thailand. Apart from fertilization experiments, the

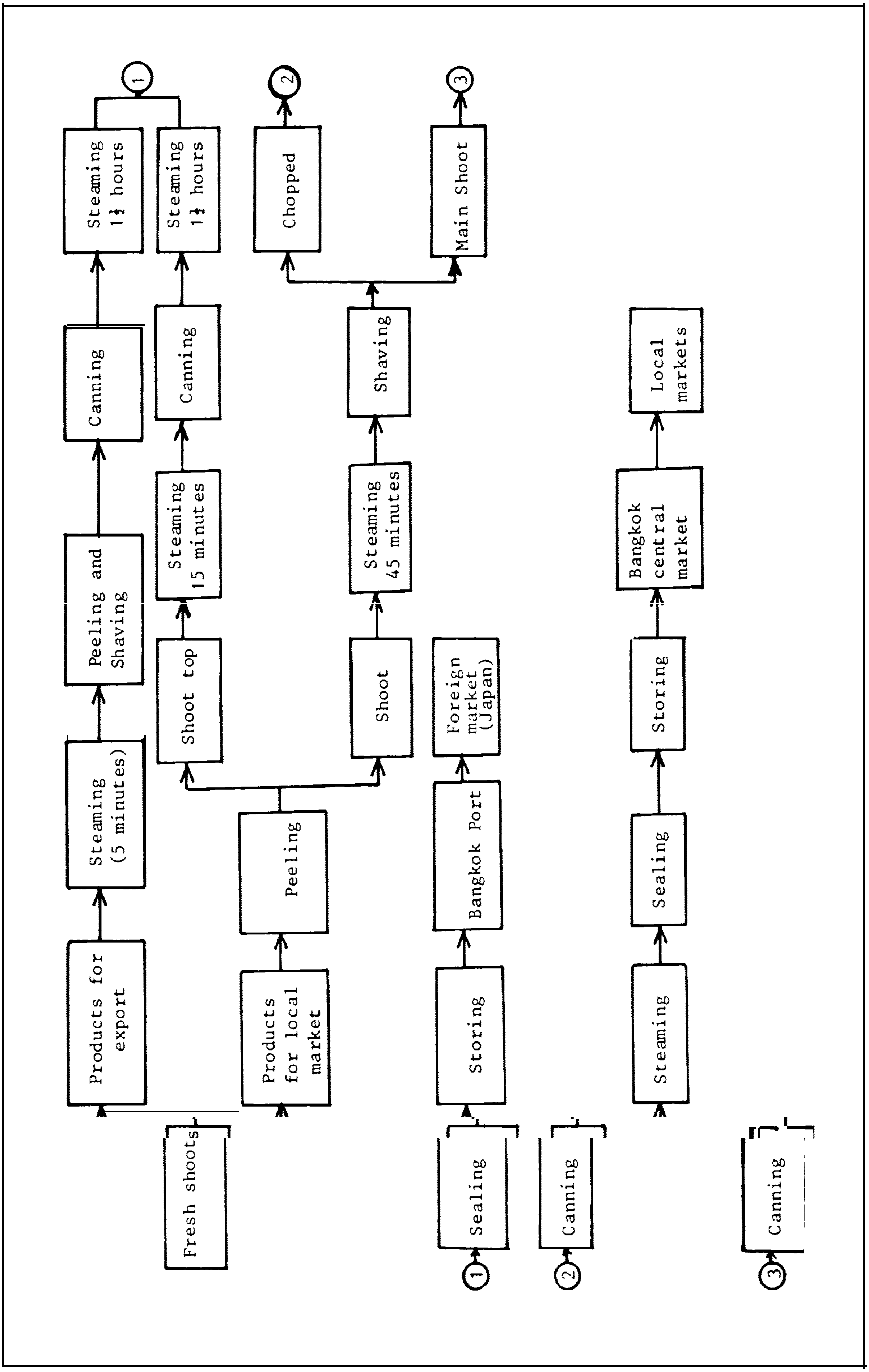


Fig. 2. Steamed bamboo shoot processing.

Table 4. Production of three-year-old *Thyrsostachys* siamensis plantation

Item	Ratchaburi	Thongphapum
No. of clumps/rai	100	100
No. of culms/clump	39	38
Average dbh (cm)	1.4	2.3
Exploitable culms/rai	2900	2800
Price, Baht/culm	0.50	0.75

Table 5. Cost-benefit analysis for three-year-old *Thyrsostuchys siamnensis* plantation at Ratchaburi

Year	Cost B/rai	Benefit B/rai	Net benefit	Present value under different discount rates					
				12%		14%		16%	
				Cost	Benefit	cost	Benefit	cost	Benefit
1	820		-820	732.14	-	719.3-	-	706.90	-
2	310	-	-310	248.00	-	238.46	-	229.63	-
3	760	1450	690	542.86	1035.71	513.51	979.73	487.18	929.49
Total	1890	1450	-440	1523.00	1035.71	1471.27	979.73	1423.7 1	929.49

Discount rate 12%, BIC ratio = 0.68; Discount rate 14%, BIC ratio = 0.67; Discount rate 16%. B/C satin = 0.65.

Table 6. Cost-benefit analysis for three-year-old *Thyrsostachys siamensis* plantation at Thongphapum

Year	cost B/rai	Benefit B/rai	Net Benefit	Present value under different discount rates					
				12%		14%		16%	
				cost	Benefit	Cost	Benefit	cost	Benefit
1	790	-	-790	705.36	-	692.98		681.03	-
2	610	-	-610	486.00	-	469.23	-	451.85	
3	1060	2100	1040	757.14	1500	716.22	1418.92	679.49	1346.15
Total	2460	2100	-360	1948.50	1500	1878.43	1418.92	1812.37	1346.15

Discount rate 12%, BIC ratio = 0.77; Discount rate 1470, B/C ratio = 0.75; Discount r-ate 16%, BIC ratio = 0.74.

economics of bamboo plantation was also studied at the end of the third year of planting.

Table 4 presents the extent of production of the three-year-old T. *siamensis* plantations in two locations, while Tables 5 and 6 present the details of simple economic analysis of cost and benefit of these plantations in Ratchaburi and Thongphapum, respectively. It can be concluded that the establishment of T. *siamensis* plantations is not profitable at the end of three years. However, it can be noticed that B/C ratio may exceed 1.0 after the fourth year onwards when shoot harvest has taken place during the rainy season and culm harvesting during the dry season.

Conclusion

The uses of bamboo both in Thailand and elsewhere are as broad and the variety of applications numerous. The results from the studies on production and marketing of bamboo products can be used as a guideline for the improvement of bamboo resource utilization as well as for improvement of income distribution.

References

Austin, R.; Levy, D. & Ueda, L. 1983. Bamboo. John Weatherhill, Inc. New York & Tokyo.

Liease, W. 1985. Bamboo-Biology, Silvics, Properties, Utilization. Schriftenreihe GTZ, No. 180. pp 132.

Potharam, A. & Panchatri 1985. Study Report on Shoot Production and Marketing of Dendrocalamus asper. Division of Marketing Economics, Department of Internal Trade, Bangkok. pp 64.

Sharma, Y.M.L. 1980. Bamboo in the Asia-Pacific Region.: 99-120. **In** Lessard, G. & Chouinard . A. (eds) Bamboo Research in Asia. IDRC, Canada.

Sharma, Y.M.L. 1985. Inventory and Resource of Bamboos.: 4-17. **In** Rao, A.N.; Dhanarajan, G & Sastry, C.B. (eds) Recent Research on Bamboos CAF, China & IDRC, Canada.

Thammincha, S. 1985. Role of bamboo in rural development and socio-economics : A case study in Thailand. **In** Rao.A.N.; Dhanarajan, G & Sastry, C.B. (eds) Recent Research on Bamboos. CAF, China and IDRC, Canada,

Young, R.H. & MacCormac, C.W. 1986. Market Research and Food Technology in Developing Countries.:3-13. **In** Market Research for Food Products and Processes in Developing Countries. Proc. Workshop Singapore.

Problems and Prospects of Traditional Bamboo-based Industry in Kerala*

P.K. Muraleedharan and P. Rugmini

Kerala Forest Research Institute,
Peechi 680 653, Kerala, India.

Abstract

This paper traces the history of the bamboo-based traditional industry in Kerala. It also looks at the organisational structure of the Kerala State Bamboo Corporation and other co-operative societies set up in the 1970s to ease the burden of the bamboo workers. The literacy rate among the bamboo workers ranges from 47 to 80 percent. Mat-weaving is the major source of income which is meagre. Shortage of raw material is also posing a serious problem. Measures to improve the raw material supply are suggested.

Introduction

In Kerala, the bamboo-based traditional cottage industry employs people belonging to the economically weaker and socially backward strata of the society. About 300 000 people are directly or indirectly dependent on this industry (Anonymous 1983) which is spread throughout Kerala with a greater concentration in the Angamaly-Kalady belt of Emakulam district, Nedumangad-Aryanad areas in Trivandrum district and Thallappilly taluk in Trichur district (Nair & Muraleedharan, 1983). The industry uses both thinner bamboos (reeds: *Ochlandr-a* spp.) and thicker bamboos *(Bambusa arundinacea* and *Dendrocalamus str-ictus).* Mats and baskets are the two major products of this industry. In this paper, the evolution of the structure and the working of the traditional bamboo-based cottage industry and the socio-economic conditions of the workers in this sector are analyzed.

Structure of Bamboo-based Industry - A Historical Analysis

Weaving mats and baskets using bamboo is a traditional occupation of certain scheduled castes and tribes. In the early years, the production of bamboo products was carried out partly for self-consumption and partly for meeting the requirements of the landlords under whom the weavers worked as bonded labourers.

The manufacture of bamboo products on a commercial basis began in the second half of the 19th century. Bamboo products, especially mats, had been shipped from Cochin to Bombay at the close of the 19th century (Anonymous 1884). In those days, the mode of production of bamboo mats was very simple. After collecting the raw material from forests or homesteads, the weavers produced the mats in their houses and later sold them in the local markets or to households.

Despite its humble origins, the industry grew rapidly during the 1930s as a result of the high demand for mats from the British authorities in India. The bamboo mats being cheap, portable, strong and able to withstand any climatic conditions, were found to be highly suitable for the construction of tenements in the war-front. The hostility between Britain and Burma was a blessing to this industry and the demand for mats increased. The industry attracted more workers from other communities to meet the demand. During the Second World War, the demand for bamboo products, especially mats, further shot up, thereby bringing about two major changes in the industry:

(i) The industry witnessed a structural change. The British agents were at the helm of affairs and acted as financiers and buyers of mats. They provided capital to the local wholesale merchants, who in turn, without involvement in the production process controlled the industry by financing retailers. The middlemen appropriated the profits

* *KFRI scientific paper no. I90*

without passing on the benefits to the weavers (Kumar, 1985).

(ii) Division of labour was introduced in the industry, bamboo cutting and weaving were controlled by two separate sets of capitalists, enabling them to supply raw material and mats without delay. Also, with the beginning of cutting of bamboo from deeper within the forest, a new group of people specialized in the transportation of bamboo came into existence.

After the war, the demand for mats from the British slumped creating a crisis which affected both the production and employment prospects in the industry. Assuming the role of the British agents and without altering the structure of the industry, the wholesale merchants attempted to solve the crisis in two ways: (1) exploring new markets in other States in the country (as a result of which Maharashtra emerged as the bulk purchaser of bamboo mats from Kerala) and (2) slashing down the wages of the workers by 50 percent'. In this context, the weavers had no control over procurement of raw material or trade of mats. They were left with no other alternative, but to accept whatever was offered.

In 1951, a committee was appointed by the government under the chairmanship of Mr Nanukuttan Nair to study the various aspects of forest wealth in Kerala. It studied the problems faced by forests in general and by the bamboo-based industry in particular and in its report pointed out that a large number of bamboo workers were reeling under the exploitation of the merchants. The committee recommended that the long chain of intermediaries between the primary producer and final consumer be reduced (Anonymous 195 1).

Present Scenario

A series of struggles were organized by various political parties during the 1960s which demanded the upliftment of bamboo workers in Kerala. In 1970, the state government appointed a commission to enquire into the state of affairs and to suggest measures to improve the conditions of the industry and that of the workers. After considering the different alternative organizational set-ups that would promote the industry, the commission recommended the constitution of a State-owned corporation to streamline the activities. As a result, the Kerala State Bamboo Corporation was set up in 1971 with the support of different political parties (Nair & Muraleedharan, 1983).

The Kerala State Bamboo Corporation is a public limited company owned by the Government of Kerala. The main objectives of the Corporation are:

1. To develop and promote industries based on bamboo, reed and cane products.
2. To undertake the manufacture and trading of bamboo, reed, and cane products.
3. To provide financial, technical, marketing and developmental assistance and also to give guidance to any establishment, undertaking or enterprise, of any description whatsoever, which is likely to facilitate or accelerate the development of cottage industries based on bamboo, reed and cane in the State of Kerala.
4. To promote, establish and operate sales offices such as emporia, showrooms, publicity offices, stalls and centres with the objective of improving the marketing of bamboo, reed and cane anywhere within and outside the State.

Working of the Corporation

In order to fulfil the above objectives, the Corporation is engaged in various activities such as collection and distribution of bamboo to societies and traditional workers, purchase of mats from the workers and marketing them. The Corporation has a monopoly over the procurement and distribution of raw material to the traditional sector. About 12 000 families engaged in bamboo processing are registered with the Corporation. The cutting of bamboo in the forest areas is carried out only by registered cutters who are attached to the Corporation's collection centres. After collection, the bamboos are bundled and transported to depots situated at different processing centres in the State. At present, the Corporation is allotted 30 000 tonnes of bamboo out of which about 30 percent is earmarked for harijans traditionally engaged in making baskets and other handicrafts'. The raw material supplied by the Corporation depots to the weavers is only for making products as prescribed by the Corporation and the workers have to sell the products in return to the Corporation (Table 1). The Corporation markets the products within and outside the State, and the latter accounts for about 78 percent of the total sales turnover (Kumar, 1985). Major buyers of mats from the Corporation are the Food Corporation of India, and Central and State Warehousing Corporations, besides private sugar mills.

In addition to the above functions, a number of welfare measures for increasing the productivity

---

B ed on personal communication with some old workers in the industry
rmation gathered from the Bamboo Corporation

Table 1. Extent and value of mats purchased by the Corporation

Year	Quantity (in million sq. feet)	Value (in million Rs.)
1977-78	800.3	6.0
1978-79	531.7	3.9
1979-80	742.6	5.9
1980-8 1	828.2	6.9
1981-82	845.1	7.8
1982-83	698.8	7.4
1983-84	648.3	8.0
1984-85	460.5	7.2
1985-86	505.7	8.2
1986-87	533.0	10.1

Source : Kerala Stare Bamboo Corporation

and for improving the socio-economic conditions of the weavers have been taken up by the Corporation:

1. The Corporation introduced a supply-incentive scheme in 1976-77. Initially, this benefit was aimed at those who produced more. Subsequently, however, this was extended to all workers under the Corporation.
2. The Corporation extends credit facilities to purchase raw material to about 5000 weaver families. In addition, each family is given a loan ranging from Rs. 100 to 160 on the condition that the loan be deducted from the wages of the weavers in easy instalments over a period of one year.
3. Another scheme introduced by the Corporation is housing loans for reconstruction and repair of houses. Each family registered with the Corporation is given Rs. 6000 out of which Rs. 5000 is given by the Housing Board as subsidy and the rest by the Corporation.
4. The workers' welfare scheme, launched during 1978-79, is another notable programme of the Corporation. Under this programme, a sum of Rs. 250 is presented to each worker at the time of marriage of his children; every school-going child of the weaver is given Rs. 25 and college student Rs. 250. This scheme further covers accident relief and financial help for undergoing eye operations.

Co-operative Societies

Besides the Corporation, about 40 co-operative societies are involved with a total strength of about 5000 workers (Nair & Muraleedharan, 1983). The structure and functions of the co-operative societies in Kerala are based on the Kerala Co-operative Societies Act, 1969. A majority of these societies are formed by the harijans who are traditionally dependent on mat and basket production. The State Government also gives liberal financial help to these societies in the form of(i) a major part of the share capital, {ii) grants for purchase of land, (iii) providing building grants, and (iv) meeting part of the expenditure incurred on pay and allowances of managerial staff during the first five years of the establishment (Nair, 1986). In order to eliminate intermediaries, the co-operative societies encourage thrift, entrepreneurship among members, promotion of self-reliance, etc. Although the societies have no direct access to the raw material they collect the same from the Corporation and supply it to the workers.

In a vertically structured organization such as the Bamboo Corporation, the scope for worker's participation in decision-making is very limited (Nair & Muraleedharan, 1983). The existence of an employer-employee relationship between the management and workers has led to strikes and lock out. In spite of all these problems, as the Corporation holds control over the procurement of raw material and marketing, it has been able to not only discourage but also eliminate private traders.

Socio-economic Conditions of Bamboo Workers

A sample survey was conducted to ascertain the socio-economic conditions of bamboo workers and the extent to which the present structure helps them to improve their living conditions. The samples were selected from Angamaly, Trichur and Nedumangad which are the three major bamboo-processing centers in Kerala. The sample size was 45 households, 15 from each of the above three places. While the Bamboo Corporation supplies raw material directly to the households in Angamaly, the co-operative societies and private traders are the suppliers of raw material in Trichur and Nedumangad. The major socio-economic variables examined were caste, literacy, land ownership, income and indebtedness.

About 90 percent of the sample households in Angamaly and all households in the other two places were Sambavas, the traditional bamboo workers, who may be Hindus or non-Hindus (Table 2.1). The non-Hindu Sambavas are converted Christians and they dominate Angamaly. The average size of the family ranges from seven to nine members and a majority of them are involved in the processing of bamboo, either in its cutting or weaving. The highest literacy rate was found in Angamaly, followed by Trichur and Nedumangad. In

Nedumangad, illiterates account for as high as 53 percent (Table 2.2).

Households with no land were more in Nedumangad (40%), where many bamboo workers live along roadsides or stream banks without proper title deeds (Table 2.3). Among the landed households, the majority own dry lands, mostly homesteads, in which a variety of crops were being cultivated. In Angamaly, about 28 percent of the selected households own wet lands in which rice, the staple food of the people, is grown.

Weaving was found to be the major source of income of the sampled households. The average monthly income of the bamboo workers is very low; for instance, about 40 percent of the households in Nedumangad were earning less than Rs. 200 per month (Table 2.4). In this regard, the households at Angamaly were in a better position, since their average monthly income was higher than that in the other two places. Angamaly being the headquarters of the Bamboo Corporation, the households here enjoyed benefits from the Corporation by means of a greater supply of raw material and earnings from welfare schemes. The average number of mandays employed per worker was estimated to be 220 in Angamaly, 178 in Trichur and 148 in Nedumangad.

None of the households in these places were free from indebtedness. They were indebted to the Corporation or to the societies or to private traders. Private traders were the major source of finance to the households in Nedumangad and the debt incurred was deducted from the earning at the time of selling. In the context of indebtedness, distress sale was quite common among the workers in Nedumangad. Underemployment coupled with distress sale resulted in acute poverty among the workers here.

Table 2. Socio-economic conditions of bamboo workers in selected areas

Table 2.1. Percentage distribution of households according to caste

Caste	Angamaly	Trichur	Nedumangad
Hindu Sambavas	40	93	86
Non-Hindu Sambavas	53	7	14
Others	7		
Total	100	100	100

Table 2.2. Percentage distribution of bamboo workers according to educational status

Status	Angamaly	Trichur	Nedumangad
Illiterate	26	20	53
Primary	40	60	47
Secondary	34	20	
Total	100	100	100

Table 2.3. Percentage distribution of households according to land ownership

Ownership	Angamaly	Trichur	Nedumangad
Landless	6	20	40
0.10 ha	20	13	40
0.10-0.20 ha	40	20	13
0.20 ha	34	47	7
Total	100	100	100

Table 2.4. Percentage distribution of households according to monthly income indebtedness

Income (Rs)	Angamaly	Trichur	Nedumangad
< 200	13	27	40
200-300	33	54	47
300-400	41	13	13
400-500	13	6	·
Total	100	100	100
Indebtedness			
< 500	40	53	66
500- 1000	53	26	34
1000	7	21	·
Total	100	100	100

Social backwardness seems to go along with economic backwardness. The women workers constituted the majority of the bamboo workers. The survey has shown that they were less educated and poorer. For them, employment opportunities in alternative spheres were negligible. On the

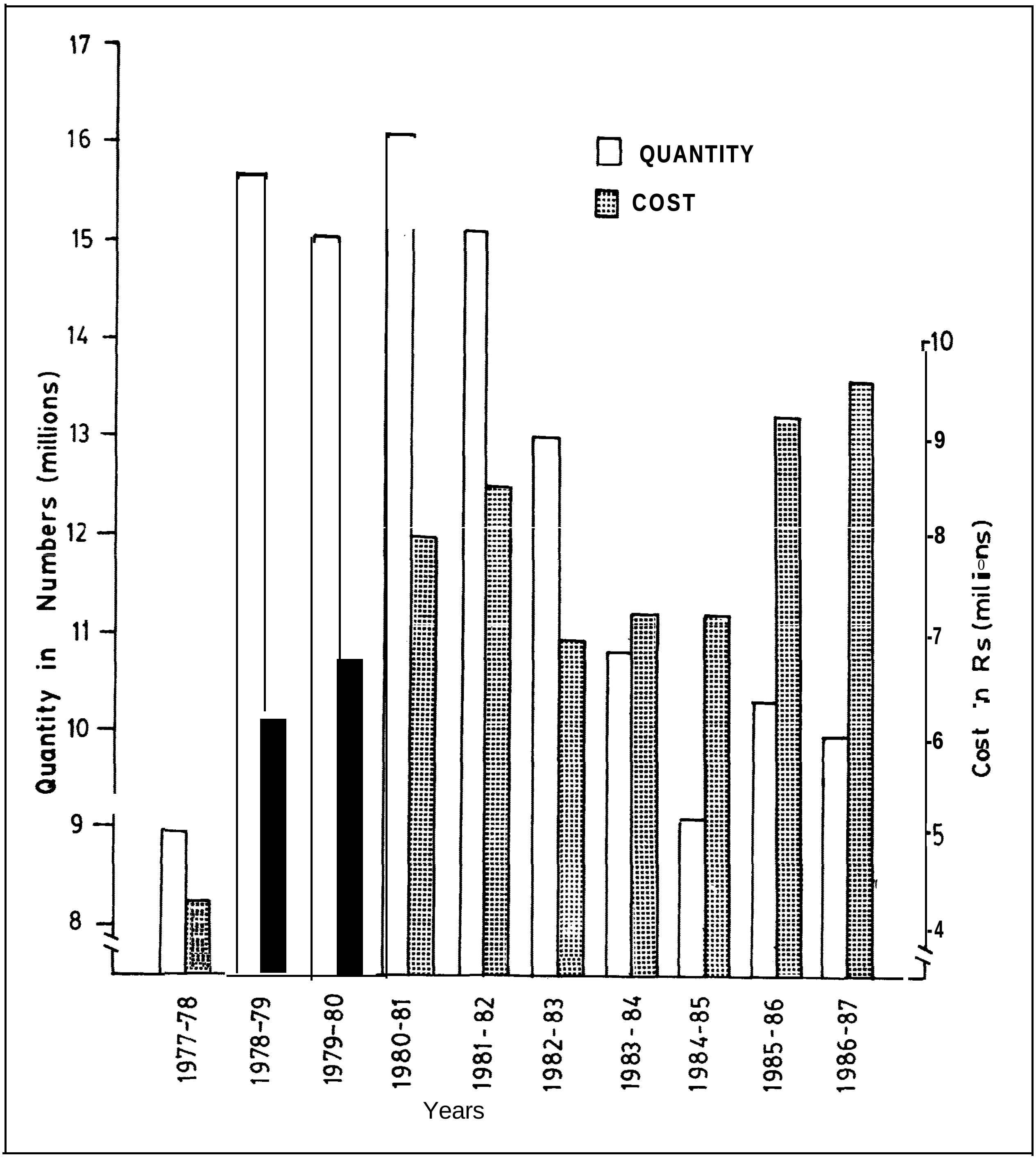


Fig. I. Quantity and cost of production of reeds (1977-87).

whole, the majority of the women workers were in a state of perpetual misery and degradation.

Many of the sampled workers in Angamaly, who were formerly workers under private traders, expressed satisfaction at the functioning of the Bamboo Corporation. However, the benefits from the Corporation, do not cover many of the workers. They indicated that the supply of raw material from the Corporation had been dwindling year by year which adversely affected their employment and income. Improvement in the living conditions of bamboo workers in Kerala can be brought about by augmenting employment by increasing raw material supply.

Shortage of Raw Material

Most traditional industries in the developing countries have been suffering from non-availability of sufficient raw material and the bamboo-based industry in Kerala is no exception to this. The situation is becoming more acute as the resource base in the forests is disappearing at an alarming rate.

The Bamboo Corporation, although established as early as 1971, commenced the extraction of reeds from forests on its only in 1977. Thereafter, it has been playing the role of a monopoly supplier of reeds to the traditional sector. The Corporation has been permitted to extract 15 000 tonnes in 1977-78, 25 000 in 1983 and 30 000 in 1988 as against a total estimated requirement of 36 000 tonnes per year. However, the actual collection of reeds from the forests has been far below the target. For instance, while the Corporation was granted rights to collect 25 000 tonnes in 1986-87, the actual collection was only 12 134 tonnes, accounting for 48 percent of the target.[3] Deforestation of reed-bearing areas for other uses, especially agriculture, multipurpose river valley projects, settlements and forest plantations are important factors contributing to the decline in the availability of reeds (Nair, 1986).

Of the estimated 300 000 tonnes of reed available annually (Asari, 1978), the share of traditional industry is only ten percent. Pulp and paper units procuring reeds from the forests do not adhere to the rules prescribed by the government, often resulting in the virtual extinction of reed-bearing areas. Reed-bearing areas are also susceptible to forest fires. The reed cutters of the pulp and paper mills camping in the forest are responsible for frequent fires which destroy a sizeable quantity.

Occasional flowering of reeds, their subsequent death and illegal cutting by settlers and agents of private traders from within and outside the State are some of the other reasons for the shortage. Besides, the cost of extraction of reeds has gone up, as a result of which there is a slump in the output (Fig. 1). This has caused not only increased unemployment but also a decrease in income of the bamboo workers.

Conclusion

Since the beginning of the present century, there have been a series of changes in the structure of the traditional bamboo-based industry, the most notable being the establishment of some institutions such as the Bamboo Corporation and co-operative societies in the 1970s. With a monopoly control over procurement and distribution of raw material and marketing of products, the Corporation was able to set free a majority of the workers from the clutches of middlemen and traders. However, most of the workers are still in the grip of poverty. The shortage of raw material is the major problem which is the result of the short-sighted policy of the government which neglects the basic needs of the traditional workers. The fact that an industry with 300 000 dependents is allotted only ten percent of the total available raw material in the State is not a justifiable one, considering its employment potential. Thus the allotment of raw material to the traditional sector needs to be enhanced. A number of measures may be suggested to strengthen the raw material position of this industry. Separate reed-bearing forest ranges should be earmarked for the three reed-procuring agencies and their cutting should be confined to the respective areas allotted. This is essential to avoid competition for the declining reed resources in the State. Strict adherence to cutting rules prescribed by the government and compulsory regeneration work should be done by the reed-procuring agencies.

Acknowledgements

We are indebted to several persons who helped us during the course of this study. In particular, thanks are due to Dr K.S.S. Nair, for giving permission to carry out this work, to Dr S. Sankar and Mr C. Mohan for their discussion and comments on earlier drafts and to the officials of the Bamboo Corporation for providing information.

References

Anonymous 1884. Joint report on administration of the Travancore Forests Goverment. Press, Trivandrum, India.

Anonymous 1951. Forest Wealth of Kerala. Goverment. Press. Trivandrum, India.

Anonymous 1983. Diary. Government Press. Goverment of Kerala, Ernakulam, India.

Asari, P.K.S. 1978. Industry-oriented management plan for reeds. Kerala Forest Department, Trivandrum, India (unpublished).

Kumar, A. 1985 The impact of the working of the Kerala State Bamboo Corporation in the development of bamboo industry in Kerala. Ph.D. Thesis. Univ. Cochin, Kerala.

Nair, C.T.S. 1986. Bamboo reed based industry in Kerala State, India. **In** Appropriate Forest Industries. FAO Forestry Paper No. 68. FAO, Rome.

Nair, C.T.S. & Muraleedharan,P.K. 1983. Rural institutions for development of appropriate forestry enterprises: A case study of reed industry in Kerala State, India KFRI Research Report 18, KFRI Peechi, India.

[3] *Based on information gathered from the Bamboo Corporation*

Inter-sectoral Allocation of Bamboo Resources: The Social and Economic Issues*

Mammen Chundamannil

Kerala Forest Research Institute, Peechi 680 653, India.

Abstract

In Kerala, the traditional sector and the modern industrial sector compete for the limited bamboo resource. Although the government allocates the resource to both the sectors, the requirements are hardly met. This paper looks at the social problems faced by the traditional sector and also suggests ways to manage the natural resources.

Introduction

Bamboo is used in the modern industrial sector for the production of pulp and paper and in the traditional sector for making mats and baskets. In Kerala, the government controls almost all the bamboo reed and most of the bamboo resources. In Palghat and Trichur districts, many homesteads cultivate bamboo for use in fencing and as a support for the banana crop. In the industrial sector, the Kerala Newsprint Mill, a public sector unit and two private sector units, the Gwalior Rayons and the Punalur Paper Mills use bamboo and reeds for manufacturing newsprint, rayon and paper, respectively. In the traditional sector, the Kerala State Bamboo Corporation (KSBC) is the largest user of bamboo and reed. The KSBC extracts reeds and supplies them to the mat and basket weavers in the traditional sector. However, weavers settled near the forests obtain their requirements directly from the forests as the Corporation is unable to meet their full requirements because they have to meet the demands of the weavers settled in urban and semi-urban areas. Both the industrial and the traditional sectors have an assured market for their products but the current availability of raw material is not sufficient to meet their requirements fully.

In the last couple of decades, bamboo, which was an abundant resource and considered inexhaustible, has become a scarce item. Under this changed circumstance, the government as the owner and chief supplier has had to ration this resource in the best possible manner. This paper deals with the problems of allocation of this resource both to the industrial and traditional sectors in Kerala State.

Brief History of Bamboo Exploitation and Use

Traditionally, bamboo has been used for the construction of houses, furniture, sheds, fences, mats and baskets. The leaves of the reeds are used for making thatch and in the reed growing areas, many houses built exclusively of reeds still exist. The advantages of using them were that it was cheap, readily available and did not require expensive tools or expertise in utilization for structural purposes or for making handicrafts.

Bamboo was not a commercial crop and hence could be removed freely from the forest by the people living near it. However, in 1932, the Puduval Rules, stipulated by the erstwhile-Travancore Government, assigned forest land for cultivation, and the mature bamboo growing in the assigned land was sold at the rate of British Rupees 3 for every 100 culms.

Mats and baskets used for agricultural purposes were made for self-consumption or were sold within the village itself. It is only since 1920 that the commercial production of mats has started in a small way. During the mid-1930s, at the commencement of hostilities in Burma, the British govemment demanded large quantities of mats to put up sheds for the army. Suppliers located around Angamaly co-ordinated and controlled the production of this new profitable trade. The Second World War gave a big boost to this activity and large quantities of reed mats moved out of Angamaly. The sudden spurt in demand broke the caste barrier and all sections of the population around Angamaly were drawn to this trade which previously was a caste-based occupation.

* KFRI scientific paper- no I89

After the war, there was a sudden drop in the demand for mats and consequently the prices crashed. The traders were quick to transfer this impact onto the weavers by cutting the price of the mats. However, the market recovered rapidly as the sugar mills which were coming up in Maharashtra required mats in large quantities in their factories as dunnage and for making labour sheds in the sugar fields during the time of harvest. The buoyant market did not, however, improve the condition of the weavers as the traders kept the profits to themselves. The need for government intervention in this traditional industry became pronounced and the committee appointed by the government to look into the matter submitted its report in 1970 recommending that a government-owned Corporation be set up to take over this trade for the welfare of the workers. Thus, in 197 1, the Kerala State Bamboo Corporation was formed (Kumar, 1985).

The Second World War and the developments thereafter not only changed the condition of the market but also drastically altered the availability of the raw material. The Forest Resources Survey recorded that between 1940 and 1970 the area of forest lost to agriculture, plantations and reservoirs was 3450 km in Kerala (Chandrasekharan, 1973). This does not include the extent of bamboo forests cleared for raising teak and other plantations. The disappearance of forests from the vicinity of the reed workers settlement and the recession of the forest boundaries necessitated the dependance on intermediaries for obtaining raw material. The Bamboo Corporation now has 59 depots supplying reeds and is serving around 12 000 weaver families.

In the industrial sector, the Punalur Paper Mill was built in 1890 with a capacity of 750 tonnes per year. In 1937, a modernization programme was inititated with the technical advice of the Forest Research Institute, Dehradun. The paper market became buoyant with the outbreak of the Second World War and its production increased rapidly. The plant capacity was increased to 33 000 tonnes per annum in 1972 and further to 50 000 tonnes in 1975.

Raw material is supplied to the mill on the basis of a long-term agreement with the government. The current long-term agreement signed in 1982 provides for 85 000 tonnes of reeds and 40 000 tonnes of pulpwood which are sufficient for 50 percent capacity utilization. The quantity actually obtained by the mill is much less than that promised in the agreement. A maximum of 55 113 tonnes of reeds were consumed in 1976-77. During 1984-85 the mill obtained 19 622 tonnes of reeds and in 1985-86 only 2162 tonnes (Anonymous 1988). The mill laas been closed since 1986. Shortage of raw material is one of the causes for the closure.

The Gwalior Rayon SiIk Manufacturing (Weaving) Co., another unit in the industrial sector, uses bamboo for the production of rayon grade pulp. The unit started production in 1963. Bamboo growing in the Nilambur, Wyanad, Kozhikode, Palghat and Nemmara divisions have been reserved for this factory on the basis of a long-term agreement signed with the government. Sixty thousand tonnes of bamboo was promised annually from the forests. The Gwalior Rayons has a rated capacity of 200 tonnes/day.

The Kerala Newsprint Ltd., a subsidiary of the Hindustan Paper Corporation, is the other industrial sector unit using reed. The mill has an installed capacity of 80 000 tonnes of newsprint per year. The government has promised to supply 189 000 tonnes of reeds per year. Production started in 1982-83.

The Nature of Inter-sectoral Conflict

There is a conflict of interests between the industrial and traditional sector because neither of their requirements of bamboo and reed are fully met. Extraction by one sector directly affects the availability to the other. In this conflict three parties are involved: the modern pulp and paper units, the traditional sector and the government which allocates the resource to the two sectors. Both the industrial and the traditional sectors have a valid claim and a genuine grievance. While the modern sector has been assured sufficient raw material by the government on the basis of a long-term agreement, the traditional sector similarly has a claim which the government recognizes in the allotment policy.

The problem of shortage of raw material arises because of two reasons. First, the original assessment of the growing stock could be incorrect and secondly, the impact or the result of the extraction on the regeneration might have been wrongly assessed. There could also be a third reason which is that the resource-bearing forests have been converted into arable lands or reservoirs built, thereby affecting both the stock as well as the flow of the resource.

The nature of extraction by the two sectors is also a matter of conflict. While the extraction activity of the traditional sector is necessarily dispersed because they use only mature reeds, the industrial sector adopts a more concentrated type of extraction which is cheaper. Large quantities are required and maturity is not an important consideration in pulping. The extraction of the immature stock by the industrial sector delays the regeneration and availability of mature reeds in the subsequent years which the traditional sector can utilize. In the absence of the industrial sector, the traditional sector can continuously use a reed area for extraction while the activity of the industrial sector creates a time delay in the availability of reeds.

The conflict is accentuated because the competition is between a sector which has an enormous demand with respect to the availability of the resource while the other sector has a limited but specific demand. It has been shown that when the availability of a resource is sufficient for two sectors needing the same, the relationship can be complementary and when the resource is scarce the relationship becomes competitive (Anonymous 1984). When two sectors are in a competitive relationship, the economic power of each determines the order of primacy or the pecking order.

The supremacy of the industrial sector in terms of its economic power and access to credit in relation to the traditional sector makes the result of the competition a foregone conclusion. Besides its economic superiority, there is the political clout which the industrial sector can bring to bear. The closure of an industrial unit with its organized and vocal labour force can be more embarassing to the government than unemployment or starvation in a much larger section of the silent population. Further the industrial sector has a much better access to the bureaucratic citadel because they can afford to employ retired senior officers of the government as their representatives. Given the rigid hierarchy of a bureaucratic set-up, a senior officer, even after retirement, commands respect and has enough contacts to secure an order or speed up matters which is not the case when a worker from the traditional sector approaches the same office.

The disparity between the sectors in their economic status influences their ability to withstand increase in the cost of raw material. Although the Kerala State Bamboo Corporation has been exempted from paying seigniorage since 1983 for the reeds collected from the forests, the transporation charges and the extraction expenses from the interior parts keep increasing as the more accessible areas are exploited by the industrial sector. The economic resources of the industrial sector enable it to maintain sufficient inventory of the raw material which is both unaffordable and impractical for the traditional sector because of the quality requirement. Decay and pest problems in cut reeds affect the marketability of mats and baskets while for pulping these factors can be ignored.

The Economic and Social Issues Involved

A comparison of both sectors on the basis of various economic parameters revealed that while the fixed capital required for mat and basket-weaving in the traditional sector does not exceed Rs. 50, that in the modem pulp and paper industry is over Rs. 70 000 (Nair, 1986). The consumption of reeds per worker per year is 1 .2 tonnes in the traditional sector while it is 38 tonnes in the industrial sector. Further, the wages and salaries per tonne of reeds is Rs. 750 per worker while it is only Rs. 284 in the modern sector. Power and fuel consumption is negligible in the traditional sector while it is enormous in the modern sector.

The abiding merit of the modern sector is that it has high forward and backward linkages which contribute to economic development. The paper industry also helps in conserving foreign exchange through its import substitution effects. The objective of national self-reliance is also served by the paper industry. On the environmental front, however, the pulp and paper industry has a poor record and a bad reputation of polluting the water system. Perieira (1973) estimated that 150 tonnes of water is required to produce one tonne of paper. The present reed and bamboo extraction practices of the industrial sector results in resource depletion which affects not only its competitor but also their own future supplies. Reeds have almost disappeared from Punalur, Kulathupuzha and Neyyatinkara areas where the Punalur Paper Mill first started extraction. If the current practices continue, the sustainability of the resource will be irreversibly affected.

The modern industrial sector is capable of diversifying its raw material base or develop new technologies to suit the available raw material in the long run. It can also diversify its production or switch over to a more remunerative field. In comparison, the very survival of the traditional sector and its workers will be at stake if the raw material availability is cut. The workers of the traditional sector lack resources, education and a knowledge of other useful skills to earn a livelihood in the event of a collapse of their industry.

In this context it may be argued that the traditional workers only get a pittance and even the market for their products is threatened by substitutes. Would it be better for them and everyone else if they are weaned away from this activity? This is a pertinent and valid question. Certainly, if they have an option to earn a better income they would happily accept it. At present, however, they have no option. No paper company can absorb them in significant numbers. It can be accepted that they should be provided skills and employment in some other activity. However, this will take time. Planned withdrawal of the workers to some other occupation is one alternative, but in the interim period they must be assured of sufficient raw material.

Appropriateness of both sectors can be assessed on the basis of their contribution to the generation of basic needs income and the production of basic needs goods. In the traditional sector the bulk of the value added is in the form of wages to poor artisans. In comparison, the generation of basic needs income is low in the industrial sector. Both the industrial as well as the traditional sector produce basic needs goods, but here again the proportion is low in the industrial sector as rayon and speciality papers cannot be considered as basic needs goods.

What Should be the Crucial Considerations While Managing Natural Resources

Five important rules for the management of natural resources are listed:

1. Ensuring priority for the most appropriate end uses.
2. Ensuring priority for the uses which provide benefits to he maximum number of people.
3. Assuring sustainability of resource availability. Or if sustainability is impossible as in a static finite resource, determine and enforce the most optional path of resource run down.
4. Promoting activities which cause least environmental pollution during processing and utilization.
5. If the resource base is shrinking then a carefully determined and consistently chalked out programme for phasing out the least appropriate ones should be implemented.

These rules can serve as an approach to evolving an appropriate management plan for the utilization and conservation of the reed resources in the State.

Government Policy and the Limitations of the System in Pursuing a Rational Policy

The government has the power to legislate and frame rules on all aspects of production, supply and use. It can provide raw material or withhold supplies. It can fix the price of raw material from the forests. It has the power to tax the produce or subsidize a product or process. It can also provide credit facilities. How the government uses these powers will depend on the policies followed.

In a given situation, the factors influencing government policy are difficult to analyse. Some of the important elements that usually contribute to policy-making are: (1) precedence, (2) the political clout of the different groups, (3) the political and economic priorities of the government and (4) an understanding or ignorance of the actual situation. Of these, points three and four require some elaboration. For example, the government may be committed to ‘development’; therefore, the definition or the perception of development will be of crucial importance. If development is seen as the establishment of modem industries or the growth of employment in the industrial sector. then promotion of industries becomes the policy. If on the other hand development is equated with full employment or eradication of poverty, then the policy would be different.

Understanding of the situation needs access to knowledge or the availability of critical studies. The haste with which many decisions have to be made do not allow time for critical study. Therefore, an inappropriate or outdated policy arises out of ignorance of the real situation and this is one of the limitations of the government in pursuing a rational policy.

In the context of allocation of reed resources between sectors, a crucial limitation is the post-war rush to ‘development’. Development is often defined to favour the modern sector. Several international agencies like FAO, UNDP recommend a policy for industrial development which is followed without realizing that we have not built up sufficient institutional safeguards essential for forest conservation and for the survival of the forest industry. Among the three industrial units using bamboo, the Gwalior Rayons has just reopened and is extracting undisclosed concessions from the government after a closure of about three years and the Punalur Paper Mill continues to be closed for the third consecutive year.

Efficient but often misleading lobbying by big industrial units is another contributing factor for inappropriate policies. The Forest Department for its part being the sole owner of the forest resources prefers to serve a few large consumers who are easier to manage and ignore many small consumers.

Conclusion

The government in its desperate bid for ‘development’ and to catch up with the living standards of the affluent nations has promised what it does not have and has permitted diversion of resource-bearing forests to other uses. Forgetting its primary function as manager of natural resources to ensure sustainability of production and utilization, it has permitted destructive over-exploitation by the modern industrial sector. This has exposed a large population of workers to the threat of starvation.

References

Anonymous 1984. Intensive Multiple Use Forest Management in Kerala. FAO Forestry Paper 53, FAO, Rome.

Anonymous 1988 (mimeo). Administrative Report of the Forest Department for the Year 1987-88. Kerala Forest Department. Trivandrum, India.

Chandrasekharan, C. 1973. Forest Resources of Kerala : Aquantitative assessment. Kerala Forest Department. Trivandrum, India.

Kumar, N. A. 1985. The Impact of the Working of the Kerala. State Bamboo Corporation in the Development of the Bamboo Industry in Kerala. Ph. D. Thesis. Univ. Cochin, India.

Nair, C.T.S. 1986. Bamboo Based Industry in Kerala State, India. In FAO Appropriate Forest Industries. FAO Forestry Paper 63. FAO, Rome.

Pereira, H.C. 1973. Land Use and Water Resources, Cambridge Univ. Press, London.

The Uses of Cichu (*Sinocalamus affinis* and its Importance in Rural Economics in South-west China

Wenyue Hsiung

Nanjing Forestry University, Nanjing, China.

Abstract

Cichu (Sinocalamus affinis) (Rendle) McClure is a medium-sized bamboo belonging to the sympodial group widely occuring in the low altitude areas of South-wrest China, and commonly planted along river banks and also in the farmer's homesteads. This commercially important bamboo species can be easily propagated using rhizome stocks. Its straight culms with long inter-nodes are characterized by high fibre content, small vascular bundles and high tensile strength. They are flexible, can be easily split into strips of Jtarying thicknesses and are widely used in the weaving of traditional bamboo articles as well as for paper-making and mat-board manufacture. It plays an important role in the rural economics in South-west China.

Introduction

Cichu, which means flexible bamboo, is a common name referring to species of the genus *Sinocalamus*. Of these, *S. affinis* (Rendle) McClure is the most important one, commonly occurring in low altitude areas such as Sichuan, Yunnan, Guizhou, Hunan, W. Hubei, Guangxi and S. Shaanxi. Sichuan Basin is the centre of its distribution with more than 150 000 ha under bamboo cultivation (Fig. 1). The species has straight culms with long internodes, high fibre content, small vascular bundles and high flexibility and is used for traditional bamboo articles, agricultural implements, pulp, paper and mat-boards.

Biology and Silvicultrre

S. affinis is a medium-sized bamboo of the sympodial type growing densely in clumps. Its culms are slender, straight, drooping at the top, about 6-15 m in height with a 4-6 m branchless

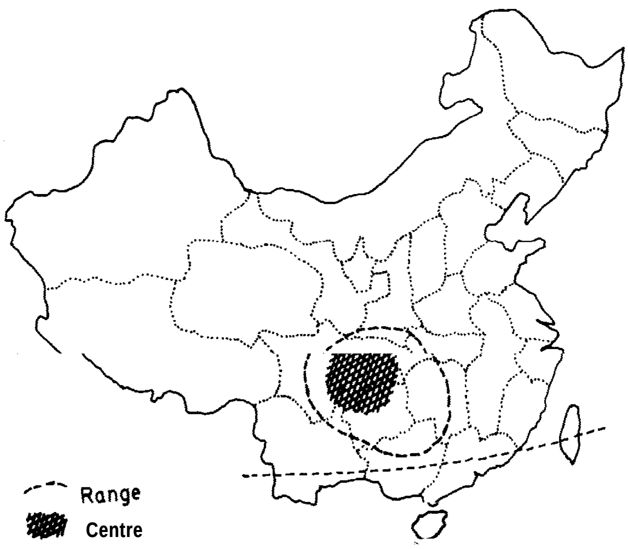


Fig. 1. Distribution of Sinocalamus affinis in South-west China.

length, 4-8 cm dbh, and are cylindrical in shape and flat-noded. Their internodes are remarkably long, 20-30 cm in the basal part and 60-70 cm at mid-culm, with a 4-6 mm wall- thickness. Their branches are short, slender and numerous on each node. Rhizomes are short and bulky, with three to four pairs of lateral buds. Rhizomal buds differentiate in April-May, sprout in June, emerge as culm shoots in July-August and grow continually until late October or early November in a span of 100-120 days. Except for a few shoots that sprout in the early season, most lateral buds of young culms remain dormant during the winter and burst almost simultaneously from the culm sheath at each node in the spring (Hsiung & Zhou, 1974; Hsiung, 1978; Xiang, 1983; Wu & Che, 1984).

S. *affinis* is a subtropical bamboo with a relatively shallow rhizome-root system. Ecologically, it cannot stand heavy frost and drought and needs a warm, humid climate and fertile soil for fast growth and high production. It is commonly planted along river banks, roadsides, homesteads and low slopes where flood sediments, farming residues and accumulated dirt make the habitat favourable for culm growth and clump development. S. *affinis* propagates very well and has a high yield of shoots. More than 86 percent of the new culms that emerge are of good quality. It is estimated that the proportion of the newly-formed culms to the old ones is about 1 :l in managed groves. In fact, 95 percent of new culms come from old mother culms. Some of them even give rise to two or three daughter culms in a growing season. Mother culms more than three years old lose their sprouting capacity completely due to the deterioration of their shoot buds. Therefore, in managed bamboo plantations one to two year-old culms are cultivated for propagation and production and those over three years old are harvested for utilization (Hsiung & Zhou, 1974; Xiang, 1983).

In Sichuan Basin, it is estimated that 400-500 clumps/ha and 30-40 culms for each clump are produced under managed conditions. Thus 12 000 - 20 000 culms/ha can be expected. If the average fresh weight of individual culms is assumed to be 4 kg, the standing culms available could be 48-80 tonnes/ha and accordingly 20-30 tonnes are available for harvest annually in the same unit area. Taking all managed and unmanaged cichu stands in Sichuan into consideration, there would be about 10-20 billion standing culms which works out to be around 4-8 million tonnes roughly. Consequently. the annual turnover could be as much as 153.0 million tonnes.

Properties

Cichu is inferior in terms of hardness, compression and bending strength, when compared to other large and thick-walled species. However, its straightness, node flatness, long internodes, high fibre content and flexibility make it suitable for basketing, matting, pulping and paper-making. The anatomical structure of culms is of considerable value for determining their quality in terms of utility (Grosser & Liese, 1971; Jiang & Li, 1982. As indicated in Table 1, the vascular bundles of cichu culms are very small and less than 0.1 mm^2 in cross-section, numerous (900/cm^2) and densely arranged with one or two rows of parenchymatous cells near the periphery. But toward the centre of the culm, the vascular bundles become larger. The specific gravity of the outer culm wall is much greater than that of the middle and inner parts.

In contrast to *Phyllostachys pubescens,* which is the most useful bamboo covering a large area and having the highest production and use in China. culms of *Sinocalamus affinis* have a much higher fibre content and less parenchymatous tissue (3 1.6% and 63.0% for the former and 47.8% and 46.5% for the latter, respectively: Hsiung & Zhou, 1974; Hsiung, 1980). According to Yee and Shen (1946), the tensile strength and tensile modulus of S. *affinis* are greater than that of *P. puhescens,* particularly in the internodes (Table 2). Such properties are ideal for basketing. matting and

Table 1. Specific gravity and vascular bundles (V.B.) distribution of culms of *Sinocalamus affinis*

Wall part	Specific gravity Internode	Specific gravity node	No, V.B. /cm^2	X cross-sectional area of V.B. ($10^{-3}cm^2$)	Total cross sectional-area (cm^2/cm^2)
Outer	0.702	0.775	900	0.96	0.783
Middle	0.493	0.608	281	2.33	0.609
Inner	0.433	0.541	195	2.85	0.545

***V.B.**, Vascular bundle*

Table 2. Culm properties of *Sinocalamus affinis* and *Phyllostuchys pubescens*

Properties	*Sinocalamus affinis*	*Phyllostachys pubescens*
Vessels and protoxylem(%)	5.7	5.4
Sieve tubes and parenchyma cells (%)	46.5	63.0
Fibres (%)	47.8	31.6
Internodal tensile strength (kg/cm’)	2730.0	1347.0
Nodal tensile strength (kg/cm^2)	1345.0	1561.0
Internodal tensile modulus (kg/cm’)	260000.0	117628.0
Nodal tensile modulus (kg/cm’)	160000.0	123329.0

paper-making. This is the major reason why farmers and craftsmen in Sichuan prefer cichu to other bamboos.

Uses

Baskets and Containers

Rock-baskets for construction of dams and dikes can be made of cichu culms. They are split into 2-3 cm wide strips without removing off their inner part, except for the nodal diaphragms, and are woven into big baskets with openings of l0- 15 cm for filling rocks. These are slender and are locally termed as dragon or sausage baskets. The ends are sutured. The baskets are about 70-100 cm in diameter and l0-30 m in length. They are used to build dams across the river or dikes along the river banks to reinforce the dam or dike position by filling rocks or cement and are known as gabions or anchor basket. The famous Dujiang Irrigation System in Guanxian, Sichuan, was constructed using rock baskets during the time of the Qing Dynasty, about 2300 years ago. Though the system has been rebuilt with steel-concrete recently, rock baskets are still used as important supplements.

Baskets used for domestic and other purposes and containers can be made from sliced bamboo strips. Their size, shape and fineness are dependent on the end use and market demands. The big and coarse variety are used for packing vegetables, fruits, fish, crops and other agricultural produce while the small and fine ones are used as hand-carrying baskets and even highly finished articles. It is roughly estimated that more than 500 different basket items and containers are made of strips of cichu culms in Sichuan alone.

Cables and Ropes

Bamboo cables are known to be one of the oldest structural elements in the history of engineering and have been used for constructing suspension bridges. The Anlan Bridge at Quanxian, Sichuan, the most famous Chinese suspension bridge in history, was entirely constructed using cichu bamboo cables in the third century BC. It is about 300 m long and 3 m wide, with 10 cables supporting the bridge floor and five on either side forming the rails (Temple, 1986). Cichu culms are the most suitable material for cable-making. They are split into strips of about 1.5 cm width and then twisted together to form a bridge cable of about 6-8 cm in diameter. It is reported that a bamboo cable of such size is strong enough to support four tonnes in a span of up to 76 m. Many bamboo cable bridges, smaller and simpler than the Anlan one, are still commonly seen in South-west China although the latter has been recently rebuilt with steel cables. For towing boats against the river currents, cables and ropes are made using cichu culms, with their inner part shaved off and then twisted spirally. Ropes for common uses are made of even finer strips obtained from the outer parts of culms. It has been reported that bamboo ropes are much stronger than linen ropes of the same size. Another type of rope, known as fire rope and which is not used for mechanical purposes but for kindling, is made from the culm shavings of *S. affinis.*

Mats and Boards

Different types of mats and sheets of varying width and thickness can also be made by interweaving strips of cichu culms. For house construction and for drying agricultural crops, mats used should be big and strong and hence wider and thicker strips are needed. Strips used for making sleeping mats and packing sheets should be smaller and thinner. As for weaving fancy articles such as pictorial curtains and screens, lady-fans, vase or cup slip-covers, etc., only the outer part of cichu culms is selected and then split into wire-like strips of amazing uniformity and fineness. During World War II, the Chinese Bureau of Aeronautical Research studied bamboo-mat boards and made bamboo mat oil tanks. They split cichu culms into thin strips, interwove them into bamboo-mats, glued three-four layers of mats together and pressed them into boards which finally were moulded into oil tanks of appropriate size. Today, the technology used for the manufacture of bamboo-mat boards is highly developed. Numerous varieties of bamboo-mat boards are produced from culms of S. affinis and other bamboos in Sichuan and are used for the purpose of decoration or making furniture, walls, ceilings, floors, and also for packaging and other constructional purposes.

Pulp and Paper-making

Traditional pulp and paper-making have long been practiced in Chinese rural areas. In Sichuan, young culms of S. *affinis are* rated as ideal for traditional paper-making. They are harvested the moment they complete their height growth and before foliage development. They are then cut into sections and split into wide strips which are soaked in a pool with quick lime for three to four months. After they are well-rotted, the fibre mass is washed to remove the lime and ground into pulp by a stone roller. The disintegrated fibres are good for making coarse papers or fibre plasters. For making fine and print papers, however, they need more grinding and washing to remove the defective fragments. The fibre mass is then reduced to a fine pulp with wooden rakes. A fine mesh screen mould is lifted from a vat which contains a watery solution of fine pulp. The remaining layer of sedimental fibres are drained and carefully peeled off as a sheet of paper. Such traditional processes previously used in old paper mills, are still commonly practised in the countryside with available bamboo resources. Many modern paper mills also increasingly use bamboo pulp for producing high quality papers. For example, the Changjian Paper Mill at Yibin, Sichuan, uses 60 percent of bamboo pulp in their production, half of which comes from cichu culms, including young and old ones.

Economic Importance

Bamboo handicrafts are an important sideline occupation which greatly benefits the rural areas of South-west China. There are many kinds of bamboo products which vary greatly in quality and quantity, depending on material supply, market situation and technical skill.

In Sichuan, peasants spend about 100 days for farming every year and use the rest of the time for sideline production. Basket and mat-making are important occupations and have been well-developed on a traditional basis. Both young and old men and women are geared as a team to share the work such as culm-harvesting, splitting, slicing, weaving, marketing, transportation, etc. It is estimated that income from bamboo handicrafts makes up to 50-70 percent of the annual income for each family. For many years the Chinese government has encouraged and facilitated the development of rural industries which greatly promoted bamboo handicrafts in Sichuan. Bamboo products, particularly baskets and mats, in the Chengdu area are produced with quality and in large quantity and variety; the Chengdu area has specialized in batch production. They are not only sold in local markets but also exported to other provinces and even abroad. To cite an instance, Damingchan in Chengdu suburb which is a small rural town with a population of 10 000 is actually a 'basket village'. Each family owns a number of cichu clumps around its homestead and engages in basket-weaving work. Farmers make different types of fine baskets using some of their own bamboo material and some from the market. Their products are mostly sold to other provinces and some are exported to foreign countries such as Japan, Singapore, United States and West Europe. In 1987, the total cash income of the whole village was more than five million yuan (RMB) and US $50 000 in foreign exchange. According to the village manager, eight million yuans and US $100 000 are expected in 1988. Other villages specialize either in making baskets for agricultural use or in producing different mats for specific purposes. Meanwhile, village workshops or factories are being organized on the basis of family handicrafts with financial and technical support of the local government. They try hard to mechanize the processing operation in order to improve the working efficiency and product quality.

Recently, the bamboo-board industry has rapidly been developed for supplementing the timber supply. Bamboo-mat board is an important product in Sichuan. The bamboo mats mainly come from the nearby farmers who follow the instructions of the board factories and interweave bamboo sheets one m wide and two m long during the slack seasons and monsoons. Each sheet is sold for 1.5-2.0 yuans. Every 100 kg of fresh culms (15-20 yuans at current market rate) could produce 30 or more sheets which can be traded for 45-60 yuans. In fact, bamboo mat-making for the board factories becomes an important sideline occupation with a stable cash income in rural areas. Farmers who do not have enough labour or lack technical experience have to sell their culms to other basket and mat-makers.

Conclusion

In Sichuan, *Sinocalamus affinis* is the most commonly found bamboo, yet the most valuable one because of its wide distribution, easy propagation, high fibre content and excellent tensile strength. Basket and mat-making are traditional sideline occupations and have become even more important in terms of turnover and profit. Traditional pulping and paper-making are still being used in the production of low grade papers, whereas modern paper mills are increasingly using bamboo as raw material due to the short supply of wood pulp. Moreover, manufacture of bamboo-mat boards has become a high-demand industry. Undoubtedly the development of both traditional and modern bamboo-based industries will stimulate the full use and simultaneous development of the bamboo resources.

References

Grosser, D. & Liese, W. 1971. On the anatomy of Asian bamboos with special reference to their vascular bundles. Wood Sci. Technol. 5: 290-312.

Hsiung, W.Y. & Zhou, **EC. 1974.** Silviculture of Bamboos. Agricultural Press. Beijing, China.

Hsiung, W.Y. 1978. Sinocalamus *affinis.* **In** Cheng, W.C. (ed) Silviculture of Chinese Important Trees. Agricultural Press. Beijing, China.

Hsiung, W. Y. 1980. Anatomical characteristics of *Phyllostachys pubescens.* Sets. Bot. Sin. 22: 343-348.

Jiang, X. & **Li, Q. 1982.** A preliminary study of vascular bundles of bamboos native to Sichuan. Bamboo Res. **1:** 17-21.

Temple, R.K.G. 1986. China - Land of Discovery and Invention. Patrick Stephens Ltd., London.

Wu, M. & **Che,** G. X. 1984. Cultivation of *Sinocalumus affinis.* Sichuan Forestry Soc. Chengdu.

Xiang, X.M. 1983. A study on growth of *Sinocalamus affinis.* Bamboo Res. 2: 25-29.

Yee, **C.F.** & **Shen, L.G. 1946.** Properties of cichu *(Sinocalamus affinis)* grown in Sichuan. Tech. Report Chinese Aeronaut. Res.Bureau No.27. Chengdu.

PROCEEDINGS OF
THE INTERNATIONAL
BAMBOO WORKSHOP,
NOVEMBER 14-18, 1988

PROSPECTS FOR RESEARCH AND DEVELOPMENT IN BAMBOOS

The Costa Rican Bamboo National Project

Ana Cecilia Chaves and Jorge A. Gutierrez

Costa Rican Bamboo National Project,
P.0. Box 4540, San Jose, Costa Rica.

Abstract

The Costa Rican National Bamboo Project is a comprehensive five year project on cultivation, house construction, extension, research and development related to bamboo. The general conditions that justify such a project, its organization and main goals are described. Its relevance for the country and the Caribbean region is discussed. Related activities are mentioned. If successful, the project will incorporate bamboo as a key material in house construction and as a source of additional income for rural households, representing a major contribution to the program of sustainable economical development in which the Costa Rican government is actively engaged.

Project Background

The economic crisis that struck Costa Rica in the early 1980s severely affected the construction industry. House construction in 1982 was 26 percent below the 1980 figures. Even the public sector, the traditional leader in low income house construction, performed poorly. As a result, the shortage of houses was estimated in 1984 as 125 000 units, a very high figure for a country with a population of 2.5 million living in 500 000 households. Besides, a population growth of 2.8 percent per year, more than 200,000 refugees from the other Central American countries, the poor condition of 32 percent of the houses and a very low payment capacity of most of the families, make the situation extremely critical. Consequently, the government has given housing top priority and has defined a goal of 80 000 new units during the 1986-90 period.

In Costa Rica, timber traditionally plays a preeminent role as a construction material. The situation is entirely different in the rest of Latin America, where adobe is predominant. However, rapid deforestation has made wood scarce and expensive, giving way to new construction methods involving masonary or precast concrete. Wood houses dropped from 86 percent of the total number in 1963 to 60 percent in 1984. In addition, construction technology and labour skills have also diminished from the excellent levels half a century ago.

The substitution of wood for construction with more complex technologies has produced three inconvenient effects: (1) it has increased the cost, as self-construction is not possible and the materials are generally more expensive, (2) it has stimulated the migration from rural areas to the cities, where most of the massive construction programs have been developed and (3) the higher foreign component of the new materials has negatively affected the country's trade balance.

To overcome these negative effects it is important to stimulate massive construction programs in rural areas with low cost materials and technologies appropriate for self construction. The scarcity of wood has resulted in the necessity for substitution with materials which are inexpensive, resistant and accessible in rural areas. Bamboo satisfies all these requirements and the Costa Rican Bamboo National Project has been conceived as a necessary and rational answer, introducing into the country a new but well-proven building technology.

Being a small country, with very limited nonrenewable resources, Costa Rica has become very conscious about its limits of growth and the need for developing its renewable resources, most notably hydroelectricity and biomass, within a project of sustainable economic development. The concept of sustainability involves a balanced development producing a fair distribution of income and good quality of life among all the population, using the available resources in such a way that they will also be available for the future generations in required quantities. Bamboo clearly fits into this concept and the project may be considered as a pioneer not only for Costa Rica but also for the entire Central American and Caribbean region.

Project Description and Goals

The Costa Rican Bamboo National Project has been officially endorsed by the Costa Rican Government through the Ministry of Housing and Human Settlements, the Ministry of Planning and Economic Policies and the Ministry of Foreign Relations. The total amount of funds comprises a donation of USD 2 733 000 from the Government of the Netherlands and a USD 4 000 000 loan from the Central American Bank for Economic Development (CABEI). The United Nations and the Netherlands (UN/TN) component has a duration of three years and is due to finish in December 1990. The CABEI component has a four year duration which excludes the cultivation activities that will continue until the sixth year, when commercial production will become available. Because there has been a one year delay in the initiation of the CABEI component, the total duration of the Project will be five years, except for cultivation which will last seven years.

The Project defines three main goals that can be summarized as follows:

(a) Construction of 760 bamboo houses in 38 rural communities and Indian reserves throughout the country. These houses are considered as models for a future sustained self-construction program of 7500 houses per year in the rural sector.

(b) Cultivation of 700 hectares of *Bambusaguadua (Guadua angustifolia)* that will provide the necessary material for constructing the planned 7500 houses per year. The plantations are being located in strategic sites of the country having the necessary agroecological conditions to supply the required material for different construction sites.

(c) Training of more than 1000 professionals, technicians and family heads in cultivation, production, preservation and use of bamboo for house construction and in the administration of small community business dedicated to those activities.

For each of the above goals the Project has a Department which is in charge of developing the activities required to achieve the planned results. There is also a Research and Development Department whose responsibilities are to provide technical support to the entire Project and to obtain systematic and meaningful information from all its activities and products in order to improve the knowledge about bamboo and its uses, and transfer this knowledge to the beneficiaries.

Cultivation Program

Although there are about 30 bamboo species belonging to 10 genera growing in Costa Rica (Liese, 1988b), the only species ideal for construction and also widely available throughout the country is *Bambusa vulgaris.* This species was brought from Asia for the banana plantations, where it was extensively used as props to support the plants at the fruiting stage. However, for house construction, *Bambusa guadua* is preferred because of its length, erectness, thickness and strength. At present, this species grows only in a few places and that too in limited quantities. It is, therefore, necessary that it is extensively cultivated in order to produce enough material for the future program of constructing 7500 houses per year. For that purpose, 700 hectares of land distributed throughout the entire country will be planted with bamboo. The land belongs to several public institutions who have agreed on a future rational permanent harvesting program. The average production has been conservatively estimated at 6000 culms/ha per year.

Of the 700 hectares, the UN/TN component will plant 200 hectares during a three year period (1988-90), and the CABEI component the remaining 500 hectares during a four year term (1989-92). Vegetative propagation of the bamboo is carried out predominantly by culm segments buried horizontally in the ground at 15 to 20 cm depth in nurseries adjacent to the plantation sites. Once shoots and roots develop from the nodes, they are permanently transplanted to the plantation site, with spacing ranging from 3 x 3 to 5 x 5 m depending on the site conditions. An experimental nursery initiated two years ago at Guapiles in the Atlantic Region using this procedure has been quite successful, producing culms of up to 11 cm in diameter (Fig. 1). Sizes up to 18 cm in diameter are expected in the third year

Fig.1. Bambusa puadua. Two year oldnwsely in Guapiles, Costa Rica.

Fig. 2. Bamboo prototypes for rural construction in Costa Rica.

and hence, production for construction may be initiated seven years after planting.

Construction Program

The use of *Bambusa guadua* for house construction is quite common in some regions of Colombia and Ecuador where it has been an alternative for low income groups both in urban and rural sites for long (Hidalgo, 1974; Castro, 1985; Moran, 1986; Arcila, 1988). The round bamboos are used as structural material for columns, braces, wall framework, floors and roof structure, and split bamboo, called "esterilla", is used as cover for walls, floors and ceilings. It is covered with mortar of either mud or cement for insulation against noise. In Colombia, this system has gained acceptance among engineers and architects as well as official recognition from governmental financial institutions, which have contributed to its dissemination even to the medium income groups (Arcila, 1988).

Given the lack of tradition in bamboo construction in Costa Rica, an experimental project comprising four houses was initiated two years ago with the cooperation of the Colombian architects Jorge Arcila and Oscar Hidalgo. The houses (Fig.2) were constructed following four different construction procedures, two of them on flat land and the other two on a slope. Fifteen technicians were trained in construction techniques and methodologies. Material requirements, labour efficiency and cost were recorded, and deterioration after construction was continuously monitored. At present, the houses have been adopted as the Project headquarters, a decision that has greatly contributed to their acceptance by the potential beneficiaries,

As knowledge about bamboo deterioration is incomplete and *Bambusa guadua* is scarce in the country, the 760 houses projected during the period 1988-92 will be constructed using timber for the structural framework and *Bambusa vulgaris* for "esterilla". Also "cana brava" *(Gynerium sagittatum* Aubl. = *Saccharum sagittatum),* which grows abundantly as a weed in many parts of the country, will be used for wall partitions instead of "esterilla". As the cultivation program proceeds, some guadua will also be used for construction, specially for the 160 houses comprising the CABEI component that will be constructed mostly towards the end of the period.

Extension Program

The program which envisages the construction of 760 houses in 38 rural communities will certainly contribute to the housing needs in those impoverished areas. Most importantly, it will be part of a massive extension effort conceived to transfer a new but proven construction technology. Each of the 38 chosen communities comprises 20 beneficiaries who have been selected and trained to enable their active participation in the construction of their own houses under the direction of one of the technicians previously trained in the pilot project. Their new skills will allow them, under the supervision of the Project, to organize a small community enterprise for production of pre-fabricated panels and components for the new houses. The financial support required for these commercial establishments will come from the payments of the mortgage of their own houses, which will gross a special credit line in a financial cooperative.

Extension is also crucial for the raising of bamboo, not only within the 700 hectares that the Project will plant but in the additional areas that undoubtedly will be planted by others as the demand for the material increases. For this purpose, all the practical methods and basic knowhow are being written down in the form of easy to follow manuals with as many drawings and simplified instructions as necessary to make them understandable to the rural folk. Similar manuals have been prepared for construction and have already been tested in the extension programs being offered prior to the actual construction of the houses.

Self-construction and self-management are, doubtless, very complicated ways to accomplish defined goals within a rigid deadline. However, this Project has been essentially conceived as a method of promoting self-sustainable economic development of the rural areas, through the introduction of simple but appropriate technologies based on a material that can become abundant and easily available as a renewable natural resource. Extension is, therefore, crucial to the success of the scheme.

Research and Development Program

Although the Project's main goals are not research-oriented, it is obvious that research must supplement all other activities in order to avoid unnecessary mistakes and obtain as much meaningful information as possible for improving the techniques and procedures in bamboo silviculture, preservation, house design, construction and social organization. Furthermore, profitable production techniques must be explored which can later be transferred to the commercial establishments that will be created in the rural communities to continue the activities even after the Project is over.

Given the countless uses that bamboo has been put to in so many countries and its long history of use, it is surprising that little effort has been devoted to understand the many questions that this amazing plant and its applications pose, although significant progress has been achieved in the last decade (Liese, 1988a).

In Costa Rica, which had no tradition in the use of bamboo, little was known about it even in the universities and research centers. The Project is, therefore, contributing to imparting training in these institutions with carefully defined research projects to be carried out by them with assistance from the Project's permanent staff and international consultants. Three projects have been defined so far.

Physical and Mechanical Properties of Bamboo

It is very important to define procedures to determine the most relevant physical and mechanical properties of the Bambusa guadua from different geographic areas. Tests on moisture content, shrinkage, compression, shear and bending strengths, stiffness and bond are presently being carried out at the Forest Products Laboratory of the University of Costa Rica. The results will define standard test procedures and correlations of different variables such as density, culm position, node or internode, age, geographical location, etc. with strength and stiffness.

Effectiveness of Bamboo Preservation Techniques

This is considered a crucial research project not only because of the high vulnerability of bamboo to deterioration by fungi and insects, but also because there is very little experience even in wood preservation in Costa Rica. Tests are presently being carried out by the Forest Products Laboratory of the University of Costa Rica and the Wood Laboratory of the Technical Institute of Costa Rica. These include the determination of the penetration and fixation characteristics of different chemical components and their effectiveness as preservatives.

Efficacy of immersion and dip-diffusion on bamboo culms and "esterilla", and the effect on bond capacity between "esterilla" and mortar will be studied. Depending on the results obtained from this project, a more advanced project will be undertaken which would include the Boucherie treatment.

Behaviour and Capacity of Structural Components and Joints

For this project the terms of reference are under preparation for private bidding between the two above-mentioned institutions. The main objective is to determine the capacity and structural behaviour of bamboo structural components, most notably wall panels and different structural joints. Research on these topics is very scarce in the world, but quite important in order to allow for rational and economic designs of structural systems that are going to be extensively repeated (Janssen, 198 1).

Besides these projects which require specialized equipment and must be carried out at research centers, additional research is being carried out by the Project in the following areas:

Silviculture

The 700 hectares of cultivation provides a unique opportunity for studying the growth patterns and behaviour of *Bambusa guadua* obtained from several regions of the country and planted in different geographic and climatic conditions. The influence of techniques of propagation, planting density, weather and soil conditions, felling cycles, chemical fertilization, injuries, diseases, growth, size, etc. and its effects on mechanical properties and natural preservation capacity are being carried out.

Construction Management

As the Project is a self-construction program to be carried out by unskilled workers, it is extremely important to develop techniques for measuring their labour efficiency and construction quality. Besides, a precise record of materials and weather conditions is being individually kept in order to correlate all these variables with the future performance of the houses.

Social Organization

As with construction, the Project offers a unique opportunity for studying different organizational schemes and its effects on the quality of work, acceptance, motivation and productivity. In addition to these research activities, the Project is interested in developing parallel sub-projects that are related to the main objectives, and that can be transferred to the organized rural communities, together with the rural bamboo industries.

One of the most interesting projects is the utilization of vegetal fibres for the production of corrugated roofs and wall panels. Training in this area was given by a F.A.O. consultant (Nnabuife, 1987). The equipment necessary to obtain the fibres from vegetable residues from forest and agriculture (bamboo included) has been offered by the Costa Rican Department of Forestry to the Project, and a feasibility study is presently underway. The use of fibre corrugated roofs instead of the imported galvanized steel corrugated roofs presently being used is a more consistent, economic and rational alternative for a bamboo house in a rural community.

The Research and Development Program is establishing an Information Center on bamboo on all the different areas comprising the Project. This Center will provide information to all persons and institutions interested in bamboo, not only in Costa Rica but in the entire Central American and Caribbean region.

Conclusions

Within the concept of sustainable economic development, the Costa Rican Bamboo National Project represents an excellent opportunity of introducing into the country, a new material and a proven technology for house construction in rural areas. The Project will also make a significant contribution by supplementing family income and acting as a vehicle for the establishment of rural commercial enterprises financed with the mortgage payments of their own houses.

Finally, if successful, the Project may be considered as a pilot project for the entire Central American and Caribbean region where the social conditions and the house deficit are even more critical in quantity and quality.

Acknowledgements

The authors wish to acknowledge the financial and managerial support provided by the Government of the Netherlands, the Central American Bank for Economic Integration (CABEI) and the United Nations through its office of United Nations Development Program (UNDP), the United Nations Centre for Human Settlements (HABITAT) and the International Workers Organization {IWO). The active support and confidence of the Costa Rican Government to this Project is also acknowledged.

The authors also thank all their colleagues and personnel at the Costa Rican Bamboo National Project, whose enthusiasm, quality and intensity of work are the real foundations for making this dream a reality.

References

Arcila, J. 1988. Documento evaluativo - **Bambusa** *guadua.* Applicaciones en Colombia, Consultants Report No. 3 for the United Nations Center for Human Settlements, Project COS/87/001, 1988 (in Spanish).

Castro, D. 1985. La Guadua, the versatil bamboo, Fundacion para la Educacion Superior (FES), Bogota Colombia, 1985, pp 137. (in English and Spanish).

Janssen, J.J.A. 1981. Bamboo in Building Structures, Ph.D. Thesis. Eindhoven Univ. Technol., The Netherlands.

Hidalgo, 0. 1974. Bambu, su cultivoy aplicaciones, Estudios Tecnicos Colombianos Limitada. Cali Colombia, 1974, pp 3 18 (in Spanish).

Liese, W. 1988a. Progress in Bamboo Research, Proc. 2nd. Inter. Bamboo Confr., Bambouseraie de Prafrance. France (June).

Liese, W. 1988 b. Bamboo preservation in Costa Rica. Consultants Report for United Nations Center of Human Settlements, Project COS/87/001, (September) pp 29.

Moran, 5.1986. Uso del Bambu en Ecuador, **In** 1st Inter. Bamboo Confr. Mayaguez, Puerto Rico (June 28% 30 198.5) Universidad Laica Vicente Rocafuerte, Guayaquil, Ecuador, pp 46 (in Spanish).

Nnabuife, E.L.C. 1987. Costa Rica: Training on the utilization of panels. Consultants Reports. F AO, United Nations, Rome, Italy.

Bamboo as an Alternative Material in the Context of Diminishing Resources

W. Liese

Institute for Wood Biology, Hamburg University,
Leuschnerstrasse 91, D 2050 Hamburg 80, West Germany.

Abstract

The various applications of bamboo al-e discussed. Attention is drawn in the paper to the limiting characteristics of the plant in terms of the newer applicatiom being envisaged.

Bamboo Production and Utilization

The ongoing destruction of forest areas especially in the sub-tropical and tropical belt is, in many countries, accompanied by a shortage of timber. Both factors have led to an increasing awareness of the multifunctional services that bamboo can provide. It is noteworthy that at the IUFRO Planning Workshop on Increasing Productivity of Multipurpose Tree Species for Asia held in 1984 in Sri Lanka, participants from 12 countries placed bamboo among five of the most important species for top priority activities. It is estimated that about USD 4.5 billion in revenue is generated by bamboo annually in terms of goods and employment.

In China, India and Bangladesh, bamboo has served mankind since ages for countless uses. In China, the results from the recent research activities have already led to significantly improved cultivation, management and processing practices with an increased production of bamboo culms. An improvement in the quality of bamboo products has also been achieved. However, in countries with rich bamboo resources, adequate attention is not paid to the cost calculation of bamboo production.

There are regions in the world with a similarly long tradition of bamboo utilization such as Japan and Taiwan. Nevertheless, a distinct decline in bamboo utilization and processing can be observed. The cultivation area and the yield of bamboo harvested have decreased substantially, mainly due to the pressure on land. The general economic and technical development requires costly machinery and, in turn, higher wages, which do not favour the use of a relatively cheap natural material like bamboo for construction when compared with timber or plastic for the manufacture of furniture and other commodities.

In countries like Malaysia and Costa Rica. bamboo was for a long time regarded as a weed which hardly attracted the interest of the foresters. Therefore, no special attention was paid to its utilization until new developments came about in recent years. In Chile, bamboo is still treated as an unwanted weed in the forest, hindering silvicultural management and harvesting operations. Since it hardly finds a market in Chile with its large surplus of fast-growing softwoods and its rich hardwood forests, the culms of *Chusquea are* used for furniture as a substitute for rattan, which does not grow in this region.

Current Interest in Bamboo

The growing awareness of bamboo not only as a material but also as a lovely plant is not restricted to the countries of its origin. In North America and Europe, Bamboo Societies have been founded recently and conferences held with many papers presented before a large audience. The attitude of such groups is hardly directed towards the utilization of bamboo products, but more to its decorative aspects. Thus, in the past few years, several frost-resistant species have been introduced mainly from China to the countries of the temperate region. At the Bambouseraie de Prafrance, about 150 species are growing; the bamboo nursery Eberts in southern Germany has about 130 species of which 30 are of commercial value. This appreciation of bamboo as an "alternative material" has not resulted from an awareness of diminishing resources, but from the basic need for a more natural surrounding in our daily life that contrasts all the technical progress around with the increasing use of cement, plastic and glass. This increasing public interest is also expressed by two rather comprehensive television films on bamboo in the United Kingdom and in Germany.

Only eight years ago, the first IDRC workshop on Bamboo Research in Asia was held in Singapore. It can be regarded as a path-breaking event as numerous conferences and activities have followed since then, such as the IUFRO World Congress in 1981 in Kyoto, Japan; the American Bamboo Society meeting in 1983 at Mayagues, Puerto Rico; the Second International Bamboo Workshop by IDRC and the Ministry of Forestry, China in Hangzhou in 1985; IUFRO World Congress in 1986 in Ljubljana, Yugoslavia; the founding of a European Bamboo Society in 1987; the Second International Bamboo Conference in 1988 in France, and finally this Third IDRC-supported International Bamboo Workshop organized by the Kerala Forest Research Institute, India. Thus an impressive enthusiasm and activity for bamboo have developed world-wide due to the input by national organizations and international assistance.

If we consider the various fields where bamboo has recently found wider and even new ways of application they may be grouped as follows:

- The ornamental value of bamboo for indoor and outdoor use is becoming increasingly appreciated in Europe and North America. A better knowledge of horticultural species is much wanted.
- Due to its fast growth and intensive rhizome development, bamboo is used for establishing windbreaks and for soil stabilization. It is also an ideal plant for social forestry.
- The delicious taste of shoots and considerable yield have led to an increase in the area of plantations for shoot production; the primary management goal has changed from culms to shoots. In Japan, the production of bamboo shoots is steadily increasing; in China, bamboo culm plantations are being converted to shoot production and even in Southern Europe (in Italy) shoot production has been started especially keeping the Japanese working in Central Europe in mind. An improvement in quality and quantity due to better species selection appears possible.
- The excellent properties of the culm are being utilized for constructing buildings and houses with more refined designs and technologies than are usually applied to simple housing in rural areas.
- Bamboo handicraft items are coming into the market. This is facilitated by special training centers, and the material is often used as a substitute for rattan.
- Processed bamboo products using a more sophisticated technology such as microwave heating for flattening bamboo or steam explosion technique for chemical disintegration, are technically feasible. Their production and demand appear still limited. In China, more than 100 small-scale factories produce about 10,000 tonnes of bamboo plywood or bamboo particle-board.

Limitations in the use of Bamboo

Many researchers, in all continents, now work on bamboo and are trying to explore its wider application and utilization. Not everyone has sufficient knowledge and experience to appreciate the limitations of bamboo as for any other natural raw material. Presently, we are trying to extend the limits of the past experience by applying new results and techniques. In this context, however, we need to be aware of certain limiting characteristics of the plant and its products so that its natural limits are not overstretched. Some important biological aspects that need to be kept in mind are given below.

An increasing demand often leads to premature felling of the culms. This reduces the biological productivity of the remaining culms for new shoots. In addition, the prematurely harvested culms are more liable to splitting and biological attack.

Unlike some wood, bamboo does not have any toxic substances to make it resistant. Consequently, bamboo culms remain liable to biological degradation whenever the environmental conditions are suitable for fungi or beetles.

Unlike wood, bamboo does not possess anatomical pathways which enable a radial penetration of preservatives. Even worse, its outer skin is highly refractory towards penetration, and any uptake from the inside is also limited. In spite of several attempts, no method for the preservation of bamboo has been developed which is equally technically feasible, cheap, and environmentally safe. As a consequence, when utilizing bamboo, for example, for constructional purposes, certain restrictions have to be taken into account. Bamboo is also liable to splitting during drying. Whereas the strength properties are hardly influenced by such cracks the uptake of moisture by the inner part of the culm may lead to a higher rate of biological deterioration.

Many people now realize the great potential of bamboo in the context of declining timber resources. For this purpose we are trying to find ways of improving the growth, management and utilization of bamboo. In addition to knowing about the achievements and positive results, we also need to be educated about the failures and difficulties in order to avoid them in the future.

In recent years many achievements have been obtained through research. These results need to be applied on a larger scale. The research activities so far have mainly been directed towards biological questions and to a lesser degree to the equally important field of utilization. The limited research on the utilization aspects of bamboo is mostly properties-oriented and not product-oriented. We almost completely lack knowledge in the field of marketing research. It must be known, for example, which properties are necessary for the products people want to have. Otherwise they will buy in due course, baskets and other articles made of plastic, which are colourful, durable, and even cheaper than those made from bamboo.

Above all, we have to be aware of the limited social acceptance of bamboo by the rural people. If our efforts should lead to a wider utilization of bamboo, we have to consider this social context carefully. If we do not balance our efforts with the market behaviour of the people with their freedom to choose what to buy, we may fail in the application of our work.

Bamboo Production: Imperatives and Research Strategies

A.D. Krikorian[1] and A.N. Rao[2]

[1]Deportment of Biochemistry, Division of Biological Sciences, State University of New York at Stony Brook, NY II 794-52 15 U.S.A.

[2]Department of Botany, National University of Singapore, Lower Kent Ridge Road, 0511, Republic of Singapore.

Abstract

The relatively limited amount of basic research that has been done on bamboos belies their importance to tropical, subtropical and even temperate economies. Improved bamboo production and management schemes are central to fuller, yet responsible exploitation of these important resources. Obviously, information from basic research is fundamental to improved capability, considered planning and decision making. Fortunately, information which has hitherto been largely accessible only with difficulty is beginning to be pulled together and published. This kind of activity must be sustained and regularized. Major limitations to bamboo production could be overcome by more effective propagation methods. Tissue culture should play a significant role in realizing this objective. Tasks that need to be accomplished by co-operation and by informed consensus to make the potential a reality include: 1) prompt consolidation and preparation of a database from existing laboratory and field studies for- assessment of the feasibility of using excised shoot tip, tissue, cell and protoplast culture for the preservation, multiplication, storage and distribution, and improvement of bamboos in any given place; 2) definition of key areas of basic and applied research necessary for full implementation of co-operative research efforts to permit any obstacles to be dealt with efficiently; 3) identification and/or assemblage of superior species or clonal germplasm collections rom which materials can be freely withdrawn; 4) discussion of the best configuration of laboratory workshops and training schemes that can be convened to optimize skills and improve capacity of researchers; 5) initiation of co-ordinated preparation of detailed research plans and proposals to address comprehensively the goals and needs in various different and contrasting settings: 6) examination and discussion of the development of tissue culture practices complementary in both the short and long term context to those used in conventional garden and field practices. Much of this capability may, in fact, already be within reach without this fact being fully appreciated. This being so, it is essential to improve and foster open communication among workers. Suggestions on how to obtain and consolidate information, and to identify the exact status of affairs are proposed via the comvention of strategic working groups. The first step in working towards solutions is to identify. accurately, what the problems are.

Introduction

Bamboos represent one of the world's great natural and renewable resources. The subfamily Bambusoideae of the Poaceae family (the grasses) is comprised of six groups: the *Oryza* group, the *Anomochloa* group, the *Bambusa* group, the *Dendrocalamus* group, the *Phyllostachys* group and the *Arundinaria* group. The *Oryza* group alone includes about 20 genera (cf. Dahlgren *et al.*, 1985). The genera and species are far from being completely described. Therefore. one is only too keenly aware that the amount of available information on bamboos, like many other plant groups, is at once staggering and frustrating (cf. Holttum, 1956; Metcalf, 1960, p. 540 et ff; McClure, 1966a.

b, 1973; Calderon & Soderstrom, 1973,1980; Austin & Ueda, 1975; Janzen, 1976,1985; Soderstrom & Calderon, 1979; Marden, 1980; Higuchi, 198 1; Soderstrom & Young, 1983; Farrelly, 1984; Liese, 1985 for a sampling of the broad range of coverage available). Much of the information is, however, very incomplete and that which is available is still scattered and less accessible than one might otherwise like. Also, in addition to this already published literature, there are, of course, those current findings from on-going research efforts, often reflected in reports of parochial or very limited circulation, that frequently take quite a long time to emerge in the so-called "open" literature, if ever. The forestry community, for whatever reasons, has traditionally been particularly conservative in its publication traditions. Also, even when published in the "open" literature, access may be limited for reasons as unawareness or even cost. All this has, expectedly, contributed to the information gap and led to otherwise avoidable duplication of effort and redundancy.

Concerted efforts have been made to make more of the recent developments available and to highlight the importance of work on bamboos by means of international workshops. The International Development Research Centre (IDRC) and the International Union of Forestry Research Organizations (IUFRO) sponsored a successful workshop in Singapore in 1980 (cf. Lessard & Chouinard, 1980) and another was sponsored by these two organizations in cooperation with the Ministry of Forestry, Peoples' Republic of China in October 1985 in Hangzhou (cf. Rao et al., 1987). The published proceedings of these workshops have had substantial distribution and have generated considerable interest. It is hoped that works such as these can be circulated in still greater numbers and will have more heuristic value.

Recommendations on research needs and priorities generated from each of these workshops have emphasized that much more still needs to be done to stimulate further basic research and that the ongoing efforts need to be supported, sustained and nourished. In this connection, consolidation of information on and results from work already carried out has been undertaken. One example of this is that preparations for a bibliography of papers on published research carried out in China on bamboo in the last ten years have been finalized and access to this publication should open up a whole new area of information (Anonymous 1988a, b). Access in English translation to key papers from the extensive literature in Chinese and Japanese could similarly provide new insights. Also, greater access through translation to papers published in Spanish and Portuguese on work carried out in Latin America, and in French on work carried out in Africa (including Madagascar) would similarly be very helpful.

As the efforts to stimulate and coordinate research on bamboo progress and mature, new formats and meeting configurations will need to be experimented with to facilitate and hasten further priority developments. This paper suggests a possible format for a network on bamboo by means of a regularly convened international working group, and outlines some of the research areas that could be addressed in one small category of effort, namely, plant tissue and cell culture.

Needs and Recommmendations on How to Meet the Needs

We feel that the most urgent priority in addition to stimulating more basic research on bamboos is to *provide a vehicle for effective co-ordination of efforts and collaboration on issues of common importance.*

"Networking" is increasingly being appreciated as a logical approach to developing working relationships among scientists from different countries (cf. e.g. Plucknett & Smith, 1984). While the main objective of networking, namely, to realize benefits of collaboration in a cost effective way, is easily appreciated by all, the difficulty lies in developing and implementing an efficient scheme that does minimal violence to the primary objective on account of what is increasingly (and distastefully) recognized as "micromanagement".

Traditionally, scientists have carried out networking on a "one on one" basis or in small groups ever since the beginning of science. This will, in our view, continue to be the choice vehicle. Workshops such as this one and earlier ones which were more specific as to scientific methodology-namely tissue culture, will retain their great importance and value (cf. Rao, 1982). Nevertheless, it is becoming increasingly clear that scientific developments in areas of significance to those seeking to foster bamboo production and use, *albeit not necessarily directly carried out on bamboos,* are too rapid and the consequences of unawareness, mis- and disinformation so potentially disastrous that a mechanism which further optimizes access (i.e. quickly and cheaply) to accurate information and which is stimulatory and conducive to generation of new data specifically for bamboos be established.

It is recommended that an *international working group on bamboo be established to deal, on a regular- and continuing basis, with a range of relevant problems.*

By establishing a working group, comprised of individuals representing a balanced coverage of problem areas, it is anticipated that one will have provided a vehicle for *stimulating development of both "appropriate" and "futuristic technologies" and the use of the best multilevel capabilities.*

Our conviction is that interested, concerned and, above all, knowledgeable people exist in several sectors of the community in numbers sufficient to form a critical mass - scientific, academic, governmental and quasi-commercial and commercial, whose participation in such a working group would provide the necessary scientific and technical infrastructure and thus serve as a major thrust to the overall objectives of those committed to promoting bamboo work in all its aspects. No doubt a substantial amount of expertise already exists. In the U.S.A., for example, the American Bamboo Society publishes a Newsletter and a Journal. In Japan, there is the Japan Society for Bamboo Development and Protection. The help of a number of such organizations, worldwide, needs to be sought. Their membership comprises a resource of immense amounts of knowledge. Annotated membership lists should be obtained, calls for identification of researchers and technologists working on bamboo should be issued to a wide range of agencies and groups, and a directory should be compiled that includes means of rapid communication wherever possible. (A beginning towards a world directory of bamboo researchers is to be found in Higuchi, 1981.) Not only do such people have to be identified, *but an intellectually and pragmatically attractive forum for engagement of an appropriate representation from their ranks fol their involvement and co-ordination must be established.*

An early objective of such a working group would be to provide and/or draw "consensus conclusions" by means of detailed position papers and the like as to various national and regional needs. It would be expected that specialized and potentially instructive examples of handling local needs would also emerge here and perhaps serve as models for developing and/or utilizing "appropriate technologies". Based on such consensus conclusions, it is expected that one can then set progressively more realistic and informed priorities for the working group.

It is more than likely that many of such long term priorities and needs have already been set by various countries but it will be part of the consensus-building operation to formalize them to a maximal extent. The projection is that the vast majority of priorities will be common to most, if not all. Priorities may change, of course, as new developments occur. It is expected that agenda items of the working group will evolve and focus, as needed, on specific and urgent problems.

It is anticipated, for instance, with a degree of certainty that inadequate production and availability of clean planting stock will comprise, for many if not most, a major limitation to optimizing the growing and utilization of bamboo on the scale that it requires and deserves.

A major and early agenda item of the working group would therefore be to assess the status of germplasm availability, and propagation techniques, ranging from the more traditional and conventional (if there really are any such - cf. e.g. Abeels, 1962; Lin, 1970; Prange, 1974; Kondas, 1982; Farrelly, 1984) to those involving latest developments such as tissue culture. One would anticipate the publication of as detailed as possible and profusely illustrated a guide to, or position paper on, germplasm collection, availability and propagation. *Publication should include video cassette format as well as conventional book form.*

The publication on propagation would represent a group effort which would be written by such devices as assignment of special topics to individuals or small splinter groups, put together and then collectively honed and polished. Alternatively, circulation of preliminary and working drafts by mail to individuals for consideration and modification can further expedite matters. Ideally, computer technology when available could be used to communicate.

The working group by this mechanism would provide aforum for prompt, effective dissemination of new findings of-findings that have long been in practice in one location or setting but are unknown to or inadequately appreciated by others in different places. It would be expected that regular updatings and revisions would be carried out. Prices would be kept to the absolute minimum.

Special attention would be given by the working group to the latest developments in plant tissue culture.

The means for assessing the need or desire to integrate the same into production schemes would be expected to emerge. If it turns out that sufficient capability already exists, then the means to facilitate transfer of the biotechnology would be discussed and established. This would entail modification of the biotechnology so as to find a convenient and cost-effective transfer and implementation strategy. (More about this later.)

The working group would develop a mechanism and serve as a focal point for providing training where needed in a specific technology.

In the event, as it can be projected with certainty that, much more basic and applied research and development is needed, a splinter or sub-group or panel of the Working Group would be established to deal exclusively with the problems of newer approaches such as tissue culture. This relatively small group would have permanent core members which would be supplemented as needed with guest advisors, consultants, etc. Some members of the splinter group might also serve on the Working Group or in other splinter groups.

As appropriate, the subgroup would convene tissue culture and related workshops and issue and broadly circulate technical position papers and guidelines on latest methods.

It is anticipated that *this panel or subgroup (and related ones dedicated to othes relevant areas) would comprise a crucial component of the working group and provide on a continuing basis, recommmendations and guidelines to the Working Group .*

The establishment of an effective Working Group would by virtue of its analytical, coordinative, scientific, technical and educational roles be able to provide a unified voice to donor agencies at the local, national, regional and international level. This unified voice would not only have the requisite clout and credibility but would permit optimizing the chances of gaining necessary resources from both private and commercial organizations as well as international and national ones.

At the outset, the Working Group would necessarily be modest and considerably smaller than its desired and eventual full strength and capacity membership. As an evolving structure, it is to be expected that the Working Group would undergo growth, adjustment and refinement as the needs of the user community evolve and develop. The subgroups or panels would "self-destruct" as their periodic priorities were dealt with and completed. They would, however, by the nature of the work they do be expected to be in operation for relatively long periods.

The more detailed objectives and format of the Working Group would have to be carefully worked out and convincingly presented to some potential donor agencies. While it would be difficult to provide dollar values on the impact bamboos have for the world at large, reasonable extension would have to be made based on those figures that are available to convince potential donors that the amount is very high. Financial help would be sought to establish an ongoing and regularised activity. The first phase should last no fewer than five years.

Funding sources for such a venture would have to be carefully considered, of course, but the broader the base and the more agencies involved the better. (Sharing of financial responsibilities is always attractive.) A major caveat would be that any funds for research and development should not become consumed in the interest of bureaucracy and paperwork. The best way to minimize overhead costs is to make certain that the majority of people in the Working Group be scientists actively engaged in research.

Some Tasks and Objectives as They Relate to Tissue Culture

The area selected for a bit more development here relates to a subgroup or panel on tissue culture. Other relevant topics would be covered by appropriate splinter groups. Among the tasks that should be addressed at a tissue culture panel or subgroup workshop would include how:

1. To prepare in a form suitable for dissemination existing bamboo tissue culture achievements.
2. To further modify, develop and ultimately perfect existing shoot tip and nodal culture procedures so that they can be extended to as wide a range of species and genotypes as possible.
3. To utilize or develop technologies to demonstrate conclusively that material propagated is free from bacteria, fungus, specific pathogen, virus and even from mycoplasma (if such exist in bamboos).
4. To disseminate to the maximum extent allowable by regulations "clean" bamboo genotypes hitherto unavailable or of limited availability for "field" and site testing.
5. To develop meristem, cell and protoplast culture methods so as to permit decisive evaluation of the potential of these methods for rapid, clonal multiplication on the one hand, as a means of generating useful variation on the other and as a vehicle for eventual genetic engineering as yet another.
6. To assess whether long term and clonal storage can be achieved by using any of the procedures under (2) and (5).

Because plant tissue culture work is interdisciplinary, and depends, at its best, on access to substantial base-line data, it is anticipated that the subgroup would have to deal with problems of access to germplasm. Existing germplasm collections would have to be identified. The International Board on Plant Genetic Resources (IBPGR) in Rome would be asked to participate in this effort. An inquiry would have to be conducted to determine the most profitable areas to explore for or collect bamboo germplasm, if such is deemed necessary and we predict it is. In order to determine whether germplasm can be exchanged, existing rules and quarantine regulations would need to be compiled by country and a detailed position paper prepared (cf. Kahn, 1979,1988; Parliman &White, 1985). Since bamboos are taxonomically in the family Poaceae: Gramineae: subfamily Bambusoideae: tribe Bambuseae, and as grasses are perceived, whether infested or diseased or not, as constituting a major potential threat to cereal and sugarcane production, the regulations are sure to be stringent and severely restrictive. In the U.S.A., material (like all members of the Poaceae) is only importable without problems from Canada, and if it derives from any place else, it is permitted for research purposes only - that too by special so-called departmental permit - and only with fairly stringent control. Otherwise it is forbidden. In the early days, there was considerable concern over introduction of smuts (cf. Anonymous 1967; Appendix 1; Table 1).

Some attention has been paid to fungal diseases of bamboo (cf. papers in Rao *et al.,* 1987) and traditional means to establish whether bacteria and fungi-free material has been achieved in vitro are more or less easy to implement. At least they are straightforward. Testing by specific nutrient broth for bacteria and fungi has been generally outlined by tissue culturists concerned with mass propagation and, provided precautions are taken and monitoring is rigorously exercised, one can anticipate that problems can be handled for the bamboos (cf. Schaffner, 1979).

Screening by electron microscopy for presence of virus or mycoplasma is, of course, more arduous, but this too can be implemented. Tests by serology (ELISA) for virus is yet another means of pathogen indexing. This latter testing is far more difficult and work needs to be done. A major difficulty is the use of methods to detect and identify viruses, the presence or identity of which have yet to be disclosed. Even here, however, methods exist to show the presence of foreign nucleic acids (cf. Hamilton *et al.,* 1981). Most plants that have been propagated for long periods by vegetative means have been found to contain viruses. Bamboos may well be one of these plant groups. The fact is, of course, that production of strictly virus-free planting stock can only be assured if the methods to detect them in cultured material exist. Efficiency of thermotherapy in combination with meristem culture (cf. Kartha, 198 1; Schaefer- Menuhr, 1985) will have to be evaluated. It should be recalled that thermotherapy per se is no guarantee of clean stock production. Rigorous monitoring must be carried out. The whole effort is not a casual one {cf. Fig. 1) but should be done especially when international germplasm movement comes into consideration. While it is arguable whether one should "bother" when materials are being investigated within the country of origin, the fact remains that the base-line data concept demands knowledge of viruses, etc.

Apparently disease-tolerant clones that are known to be free of pathogen in one area should indeed be tested in as many areas as possible. It would be desirable to get as many of them as possible into axenic culture. It seems that a prudent and responsible programme could find the means whereby material established to come from a non-infected area could be excised and imported into various countries for investigation.

A quarantine area, or its equivalent, could ensure limitation of any potential hazards. For example, a laboratory outside the normal bamboo growing area, say in a temperate climate for tropical species, could fill this requirement. Material could be excised in one area, put through conventional microbiological testing procedures for fungi and bacteria detection, and thermotherapy and meristem culture, examined by electron microscopy, etc. to ensure absence of virus, and then multiplied by nodal or shoot tip or meristem culture for field planting, again in a quarantined area. These would then be provided to appropriate investigators using proper quarantine procedures. While this would be a somewhat complicated procedure, it has great promise for making available, relatively quickly, bamboos which have high potential for use.

The often limited and very restrictive bamboo germplasm base in certain areas of the world is explainable on historical, ecological, phytogeographical preference and/or over-exploitation and mismanagement grounds. Surely the time has come to take measures towards seeing whether the base can be expanded without negatively altering or damaging that already existing. One can appreciate that one should not merely "trade one set of problems for another", but to ignore the availability of potentially valuable germplasm is another! Stringent guidelines for quarantine and import restrictions must be respected for traditional materials but newer procedures provide the potential to circumvent restrictions which may, in a new and specific context, no longer be relevant - carefully monitored or indexed tissue cultures are one example of this (cf. Hewitt & Chiarappa, 1977; Kahn, 1988).

The task of disseminating bamboo genotypes hitherto unavailable or of limited availability for worldwide or multiple site field testing and evaluation should be a natural outcome of the successful

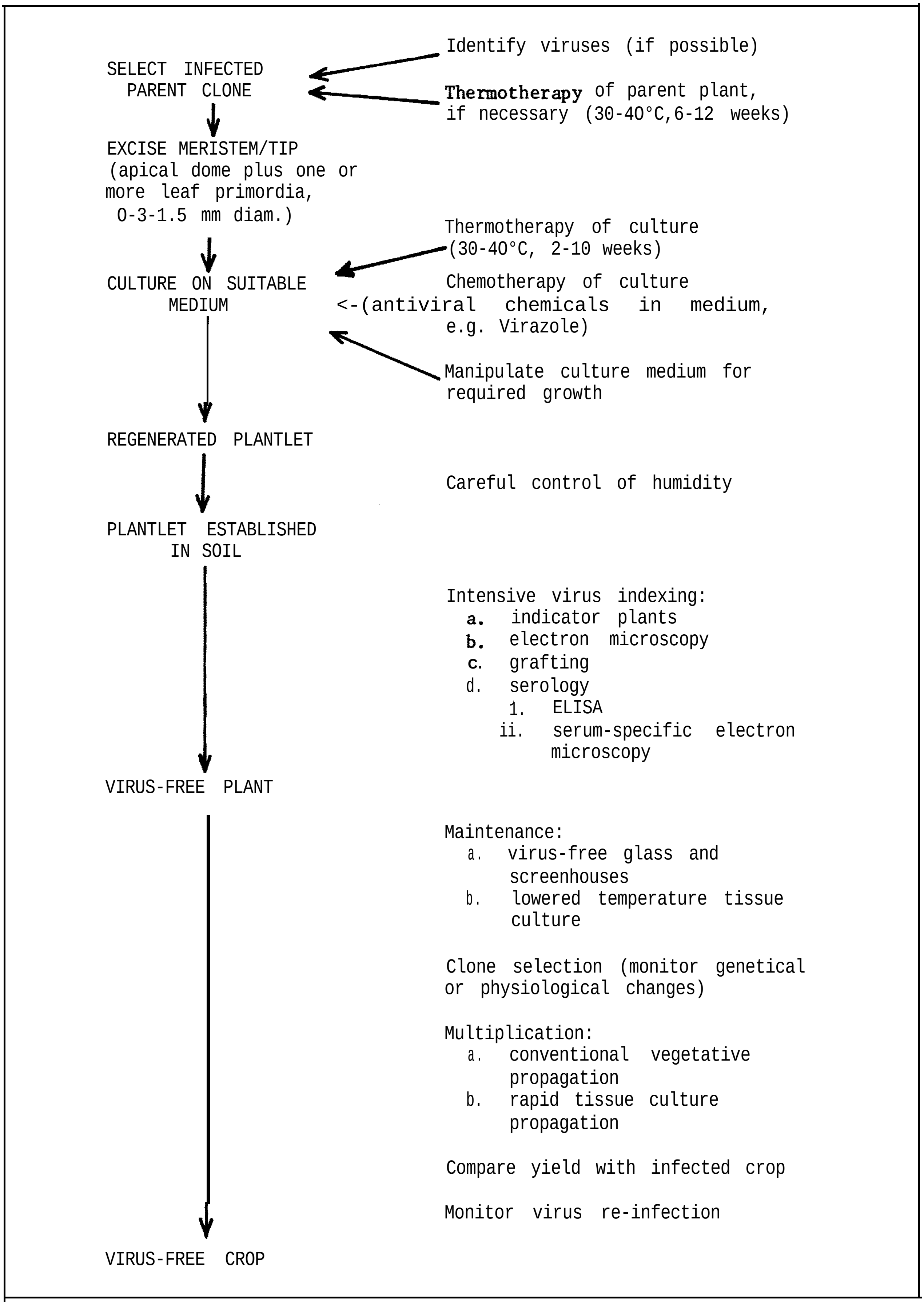


Fig. l. Schematic representation of the sequence of events involved in the production of a virus-free "crop". Note that this is merely a guideline which emphasizes the complexity of the operation. Scheme reproduced with permission of Dr Frederika Quak, Wageningen, The Netherlands.

achievement and realization of the previous task, covered above.

A number of different kinds of research organizations exist which can participate in the effective distribution of tissue cultured or other clonal materials for field testing. These organizations could be encouraged to make arrangements for testing and evaluation.

While the tasks outlined at 1, 2, 3 and 4 emphasize meristem, shoot tip or nodal bud culture techniques, it is well known that mature, living, plant cells from some plants may be induced in vitro to proliferate, to multiply more or less indefinitely, to release free cells and small units and to produce somatic embryos and hence form plantlets that can develop normally. The classic model for this is the carrot (cf. Krikorian, 1982).

This has led to the recognition that potentially, all the living mature cells of the plant body retain intact in their nuclei the full information of the zygotic nucleus, and moreover, in their cytoplasm, the ability to make that information fully effective. Whether controlled cell *culture* techniques will be readily applicable to very many bamboos is very well worth testing. If it proves practical, as we suspect it is, the objective would be to control the development so that somatic cells, growing in isolation from the plant body, would recapitulate the behaviour of zygotes or fertilized eggs faithfully. If all this were feasible today, it would add greatly to an understanding of development and could, simultaneously provide the long-sought means for clonal, asexual propagation of plants in very large numbers from somatic cells (cf. Krikorian, 1982). Also, if it were feasible to use free plant protoplasts, it would be an equally powerful tool in genetics and plant breeding. The full exploitation of these ideas and methods despite numerous facile claims for their routine application await, *for all plants,* a more complete understanding of the systems in question. Studies on the nature of the developmental controls which obtain in cultured bamboo cells and protoplasts could not only lead to the production of large numbers of clonal plants but help us achieve a better understanding of the controls of development and lead the way to the basis of a new system for genetic modification and micropropagation. Bamboo seen in this context, would be a useful and informative model system.

The induction of totipotent cell suspensions of monocotyledons, both those grown as annuals or perennials, is generally appreciated as being rather difficult to achieve but it is indeed within reach since impressive progress is being made in a number of laboratories. At Stony Brook (USA), suspensions are routinely initiated from a number of clones of the perennial Liliaceous genus *Hernerocallis,* the daylily (cf. Krikorian *et al.,* 1986). The same has been done with the African oil palm *(Elaeis guineensis)* (cf. Krikorian & Kann, 1986), More recently, morphogenetically competent cell suspensions have been generated from a seeded diploid, ornamental banana - *Musa ornata* Roxb. (cf. Cronauer-Mitra & Krikorian, 1988b) and some triploid, essentially seed-sterile edible banana and plantain clones as well. Figure 2 provides, schematically, the inter-relationships of several levels of organization of aseptically cultured "units" and their theoretical capability or potential for giving rise to new plants. One can start with a relatively large unit structure, say a nodal explant, and progressively go to a smaller and smaller size of morphologically competent unit. In this scheme, the isolated protoplast is seen as the ultimate of a reduced unit (cf. Fitter & Krikorian, 1982).

There is a large body of information on sugarcane tissue culture and somatic embryos can now be produced in profusion (cf. e.g. Ahloowolia & Maretzki, 1983; Ho & Vasil, 1983; Maretzki, 1987). The task for sugarcane technologists is to integrate the methods into the broad picture. This is not a casual activity and requires a number of conditions to be met. The volume on "Sugarcane Improvement by Breeding" (Heinz, 1987) provides an excellent example of a holistic approach to this kind of process. This volume could, incidentally, serve as a model for one of the several kinds of publications needed on bamboos. Sugarcane has been worked on infinitely more extensively, but even on a much more limited scale, such a work should be attempted for bamboo as soon as possible and revised as information warrants. Lack of an authoritative publication emphasizing experimentation and procedures that pulls a great deal of information together in a single place is sorely needed.

The cereals, long considered very difficult to work with (cf. e.g. Thomas *et al.,* 1979), have yielded to skilled hands and much progress has been made here as well (cf., e.g. Maddock, 1985; Vasil, 1988) and here too somatic embryos can be regenerated in profusion. The extensive work on rice is but one good example (cf. e.g. Anonymous 1982; Power *et al.,* 1984; Cocking *et al., n.d.;* Yamada & Loh, 1984; Abe & Futsuhara, 1986).

It remains, of course, to be seen whether all bamboos will respond with the same degree of vigour as the cereals and other grasses. But bamboos are after all, woody grasses! And one should be anxious to try to achieve in bamboo what has

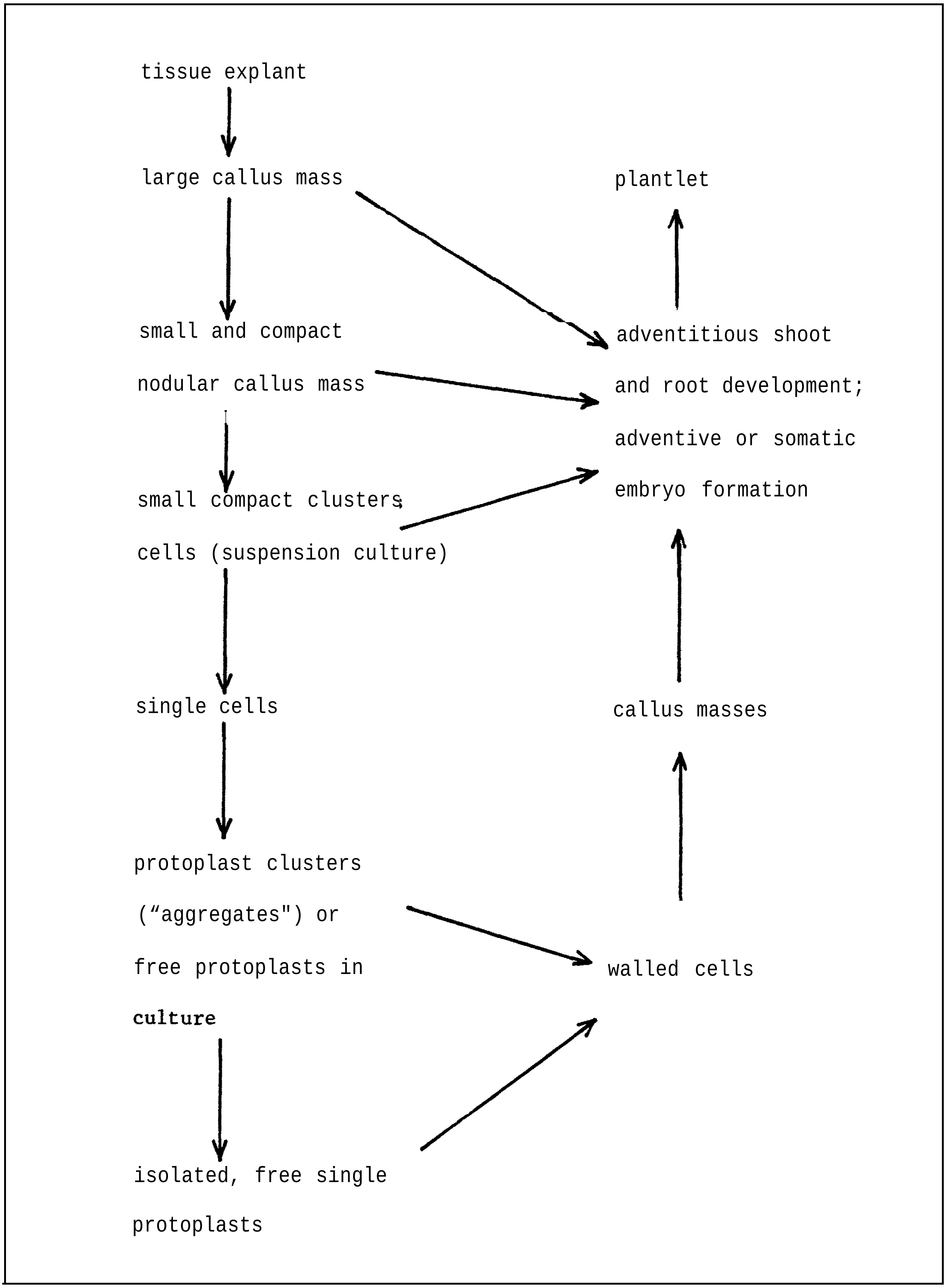


*Fig. 2. Relationships of pr-opagational units in aseptic or tissue culture from the perspective of size. On the left-hand side of the scheme, one goes progressively from a large unit, a cutting including a nodal bud, all the way down to an isolated, free protoplast. Each **of these units** and levels **of** organization provides, in theory, a means **of** regeneration. The challenge is to develop and perfect the capability so as to be able to use each **of** these capabilities as needed or desired.*

been achieved in rice, etc.!

A good start has indeed been made on bamboo tissue culture and a number of laboratories have begun to make some real progress (cf. Huang & Murashige, 1983; Nadgir *et al.,* 1984; Rao *et a/.,* 1985; Yeh & Chang, 1986, 1987; El Hassan & Debergh, 1987).

The morphology of bamboos presents more than a few reasons to be optimistic as to realization of broad and real tissue culture achievements (c.f. Fig. 3). Not only does tissue culture have the potential to increase multiplication rates, but by producing much smaller plantlets in vitro, the miniaturization process per se enables studies on anatomy, morphology, biochemistry, physiology, etc. to be carried out more readily. Flowering in vitro has been well documented for a number of tissue cultured materials (cf. Scorza, 1982; Tisserat & DeMason, 1985; Krikorian & Kann, 1986: Ammar et *al.,* 1987) and the potential for studying this in bamboos is increasingly becoming apparent (cf. unpublished studies in the Department of Botany, University of Delhi).

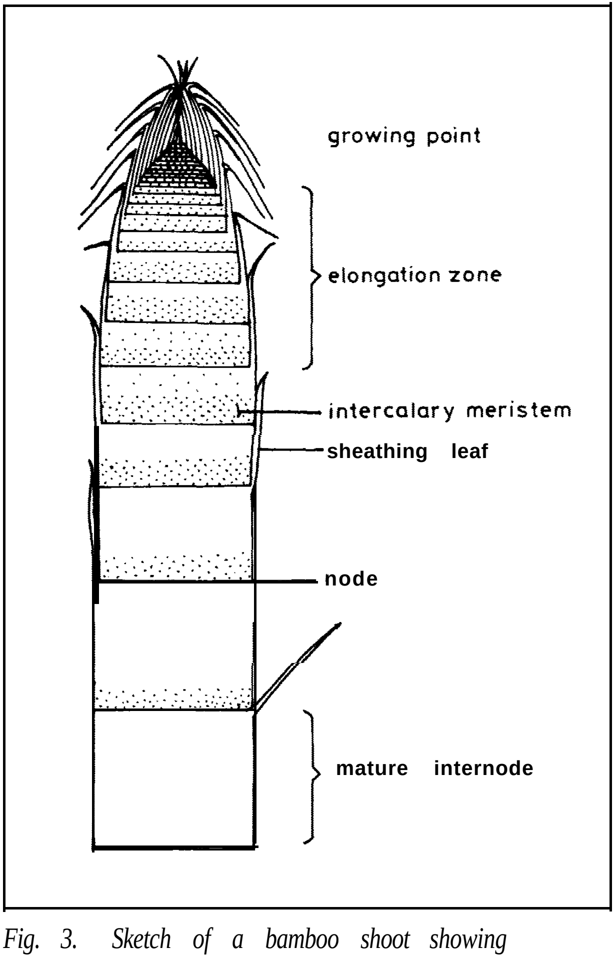


Fig. 3. Sketch of a bamboo shoot showing growth areas. The intercalary meristematic regions which show active new growth are more densely stippled;, the less densely stippled represent slightly older growth and the unstippled areas represent oldest growth. Of necessity, the tissue culturist is concerned with the zones of active growth. Redrawn from Porterfield (1930).

As grasses with compact apices, nodal buds, and intercalary meristems (cf. Hsiung et a1.. 198 l), bamboo experimentation may justifiably, at least to some extent, draw on that body of information which derives from work on cereals and sugarcane. The principles already established for those grasses and other monocotyledons should hold. Figure 4, from a classic paper on sugarcane (Venketraman. 1926), emphasizes, for instance, that the size of a cutting will have an impact on regeneration potential and efficiency. One could draw, by analogy, the conclusion that nodal cuttings in vitro could provide a point of departure for investigation. The bigger the explant, the greater the success potential. Yao and Krikorian (198 1) showed that rice could be multiplied very conveniently in vitro from aseptically cultured nodes with the use of the auxin 2,4-D. (See also Kumari et *al.,* 1988.) No one is suggesting that bamboos should or will behave precisely like *Oryza* but the point is that relatively simple approaches might provide some major opportunities and leads. Years ago sorghum was shown to respond to simple non-aseptic vegetative multiplication strategies (cf. Rea Karper, 1932). People were surprised it could be done.

Arguments that primary explants from soil grown bamboo are difficult to get clean and aseptic and hence the problems are really at the "grass roots level", so to speak, are legitimate (cf. Knauss & Miller, 1978) but there are many means of getting explants, even of field-grown material, disinfected (cf. George & Sherrington, 1984) including the use of antibiotics. While there may be some problems with the use of some antibiotics, etc. (cf. e.g. Thurston *et al.,* 1979), more options are now available to tissue culture workers. In extreme cases one can resort to direct use of modern antibiotics, fungicides and bactericides in the culture medium. There is an increasing body of information which confirms that this is a very useful device (cf. Staritsky et al., 1983; Shields et al., 1984; Hauptman *et al.,* 1985; Haldeman et al., 1987). Work at Stony Brook with rice nodes utilized a combination of fairly extreme measures for sterilization (c.f. Yao & Krikorian, 1981). Other problems such as darkening, blackening, etc. can likewise be dealt with (cf. Krikorian, 1989 and references there cited). Protoplast work likewise has its potential for proper development (cf. Krikorian *et* al., 1988 for some work on protoplasts from perennial monocotyledons).

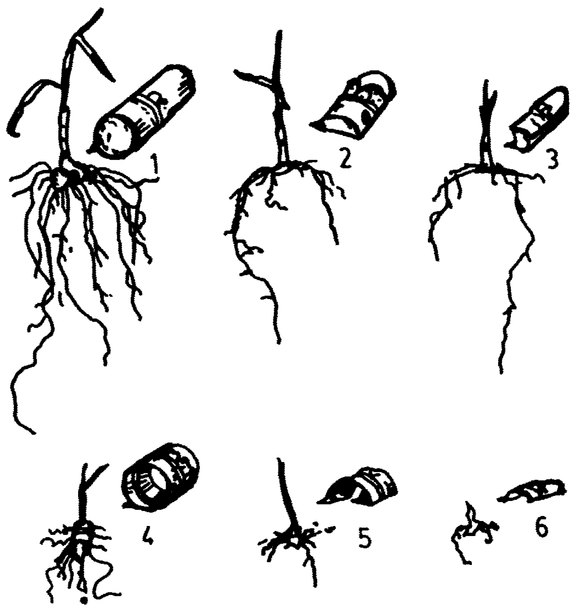


Fig. 4. Diagrammatic representation of the "irreducible minimum'' of a cutting ofsugarcane that has to be planted with the bud to ensure vigorous "'germination". L, single budded "set" with inch of internode on each side; 2, us in 1 except sliced longitudinally into two equal halves--the bud half being planted; 3, similar to 2 but only bearing a quadrant of the set; 4, similar to 1 but the "pith" removed; 5, similar to 2 but the "pith" removed; 6, similar to 3 but the "pith" removed. The effect of the removal of increasing portions of the cutting on germination are cleat: (From Venketraman, 1926).

Far too little attempt has been made to study the basic mineral requirement of bamboos in vitro. Embryo culture work was attempted many years ago (cf. Alexander & Ramana Rao, 1968). Sometimes the media one tests for nominally recalcitrant plant species are simply too rich or concentrated, and/or overly supplemented with additives. A systematic evaluation of the minimal needs should help put things on the right track.

In those countries which are more economically developed, there is frequently the concern that tissue culture procedures are labour-intensive and hence expensive - perhaps prohibitively so. On the other hand, in less economically developed countries, the negative aspect of the labour intensiveness diminishes considerably and takes on the aspect of a positive feature. Opportunities for employment open up and the involvement of many hands makes rapid progress a possibility. This is all true, of course, and should be put in its proper place and temporal context. In the beginning, it will indeed be a potentially preferred approach to decide on a given strategy without pre-occupation as to potential labour-intensive aspects. Indeed, tissue culture is labour-intensive.

In this connection, it should not be overlooked that what may be termed a "tissue culture mentality" albeit without asepsis can be explored as well. In those industries involved in research on the mass multiplication of conifers, etc. the use of cytokinin applications in the field to foster bud break, followed by the rooting of sprouts under ex vitro conditions has shown considerable promise (cf. Krikorian, 1982 and references there cited). A number of preparations are now on the market and have demonstrated value in a number of horticultural applications. Pro-shear Growth Regulator™ by Abbott Agricultural Products Division, N. Chicago, Illinois 60064 contains the cytokinin N-phenylmethyl)- 1 H-purine-&mine (2 % w/w) and is advertised as bud promoter. Such compounds should be tested on bamboo. There also ought to be an inventory made of what kinds of chemicals have been tested on bamboos for multiplication motives (cf. e.g. Wang, 198 1 for use of ethylene: Uchimura, 1984 and Seetalakshmi *et al.,* 1983 for auxins and coumarin). Alternatively, what could be termed combination strategies can be adopted. For instance, aseptic culture might be adopted to effect germplasm introduction and multiplication of a critical 'mother block' of clean plants but more traditional, non-aseptic methods could be used for multiplication and distribution of plantlets as the situation dictates.

But the real task will be to develop as promptly as possible those methods that permit use of cell suspensions to generate large numbers of plantlets or propagules, preferably somatic embryos. The ultimate requirement for sheer numbers, even for research, will dictate that totipotent cells be worked with as early on as possible.

Capability of working with cells and protoplasts will also provide the necessary basis for more sophisticated molecular biology manipulations. Figure 5 shows that even here, there is a logical relationship between status of cultures, status of the propagational units involved, and the definitive morphological events. The number of plantlets producible is greatest with the strategy of multiplication via suspension cultures (cf. Krikorian, 1982; Krikorian et al., 1986; Vasil, 1986). In the case of somatic embryos from suspensions, the production of somatic embryos and their potential encapsulation as "artificial seeds" also becomes a realistic possibility (cf. Redenbaugh et al., 1988).

There has always been the problem of establishing and assessing the best means of establishing any tissue or cell culture-derived propagule in soil in a pot or in the field (cf. George & Sherrington, 1984). Hardening off procedures have sometimes been slow, inconvenient and plantlet losses may be high. A relatively simple means of acclimatising in vitro generated plantlets (including those from somatic embryos of rice) has been reported by Selvapandiyan et *al.*, 1988). Here the procedure of "painting" with glycerol or liquid paraffin and other simple, inexpensive mixtures to prevent desiccation is decidedly "low tech". Success rates were virtually 100 percent. All this shows that "where there is a will, there is a way". Time will, of course, show whether this approach can work with bamboo propagules,

One of the more interesting and important points that will eventually emerge from tissue culture work is the reason why bamboos of the monopodial (running) habit should be so much more easy to multiply vegetatively than those with sympodial (clump) habit. Since the sympodial types are perhaps more important and common in the tropics and subtropics, this is no minor matter (cf. Cobin, 1947). Whether a special nutrient reserve in a morphologically recognizable rhizome is a requirement in vitro for propagule establishment and growth is another major question (cf. Kondas, 1982).

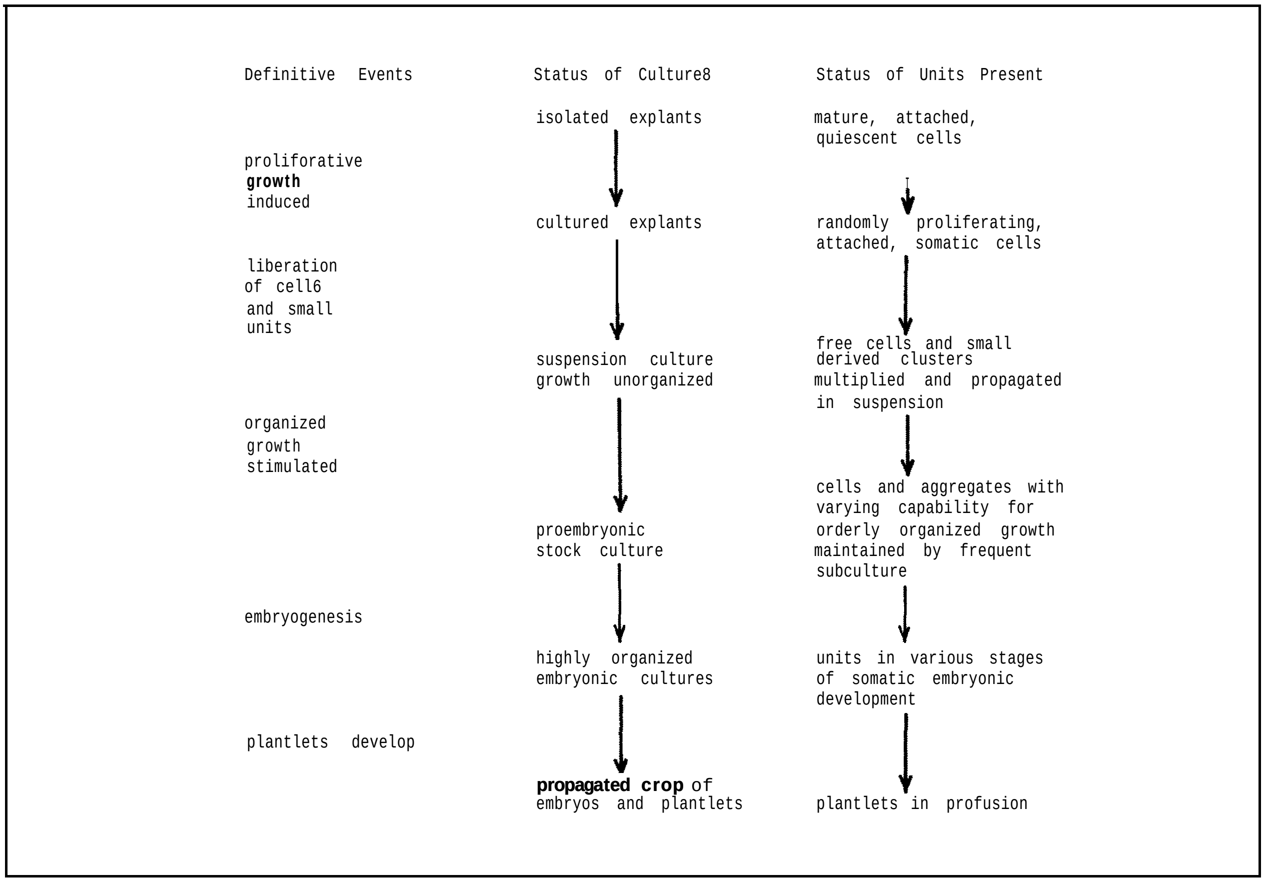


Fig. 5. Events and relationships as they pertain to culture status when one seeks to generate plantlets in quantity from suspension cultures. A scheme such as this should one day be applicahle to the task of bamboo multiplication in quantity form virtually all species and clones.

Whether there ever will be widespread and intensive monoclonal cultivation of bamboos in an agroforestry context remains to be seen. The fear that monoclonal plantings of any sort can spell disaster has been expressed and appreciated for years (cf. Hartley, 1939; Day, 1973). The more we learn, however, the more we can make intelligent decisions on management schemes including monoculture. First, we need the options so we can test and evaluate them.

Gaps in plant germplasm collection and maintenance strategies in all our plant resources have also been appreciated for years (cf. Creech & Reitz, 1971). The simple fact remains that germplasm maintenance is not a simple matter. Much more attention has been placed on food crops (Plucknett et al., 1987) but the problems are complex and no doubt apply to bamboos as well.

Caveats

Despite the potential attractiveness of an effective working group, to prompt, interpret and evaluate research progress, the fact remains that without a major commitment from those relatively few working on bamboos, the plan we have put forward here in summary form could be a design for disaster or failure. There must be convincing evidence that there is an effective advocacy group for bamboo and that the individuals to be involved are intent on making the activity work. The format of a working group implies, of course, that one who participates is willing "to work". "Homework" assignments will necessarily be made and expectations of task completion must be fulfilled. If a firm commitment is not apparent, then there should be enough dedication to reality to recognize that the time is not right for establishment of the group.

We feel there is no time like the present for generation of discussion and activity.

Simultaneously, the fact is that throughout history, a relatively small and dedicated group of individuals have made the difference. With leadership and a realistic, not overly grandiose, format which is conducive to accomplishment, there should be every reason for a Working Group such as the one described here to succeed.

There should be no doubt that the challenges will be great. In some tropical and subtropical countries, the rate of forest destruction is so great that there seems little hope for reversal of the tide. Perhaps this fact in itself should incite one to undertake the formation of a group that can speak out yet again, however late, to the appropriate local, national and world bodies.

Knowledge on the basic biology of bamboos is far from adequate. Like many other plants of great use to man (woody and herbaceous alike), exploitation has generally been the "norm" without adequate attention to stabilizing supply via re-planting and basic study. While we can talk all we wish of "databases", somaclonal variation generated via aseptic cell and tissue culture (cf. Larkin & Scowcroft, 1981) and the like, no amount of talk can replace good scientific inquiry and documentation. When one analyzes the dearth of basic plant physiological knowledge on such things as growth, reproduction and flowering in bamboos, it becomes quite intimidating (cf. Janzen, 1976; 1985). Too little is known about virtually all aspects of the physiology of bamboos. Only relatively recently has any modem work been done on the detailed anatomical structure and sequence of embryogenesis (cf. e.g. Reeder, 1962; Philip & Haccius, 1976) and that too of only a few species or groups. Years ago some very interesting but preliminary work was carried out on grafting in monocotyledons (bamboo was included in the studies - cf. Muzik & LaRue, 1954).

It is critical that there be a *commitment to the development of appropriate technologies* (cf. Krikorian, 1988a, b). At a time when much is being said about "high technologies", workers who have commitments to realization of practical objectives play a crucial role in establishing strategies for priorities to be met even as more basic and theoretical work goes forward.

The hope is that the more advanced strategies for multiplication will be realized within the next decade. There is every reason to believe that this objective could be reached for a reasonable number of crucial species and clones. Even when this capability is achieved, however, one will be confronted with additional, perhaps even greater. challenges. Figure 6 provides a few examples of problems that are inherent in development and/or transfer of "advanced technologies" such as tissue culture. Tissue culture must be put into a broad and proper context (cf. Thompson. 1985; Krikorian. 1989). If the Working Group is as effective as it ought to be, the infrastructure will have been thought out and put in place to make the implementation a practicality.

As more basic information is accrued on the basic cell, protoplast and tissue culture, the challenge will be to attempt cryopreservation (cf. e.g. Kartha, 1985), "real" genetic engineering and modification of the bamboo genome in considered ways (cf. Sybenga, 1983 for a thoughtful analysis of what the "new" approaches really have to offer for any breeding program).

The idea of the working group, therefore, is one

Potential problems in technology development or transter

1. Ignorance of proposed technology
(a) The potential user group is unaware of the existence of the technology and'or the proposed new uses of an existing technology,

(b) The potential user group is unaware of the limitations of the technology.

(c) The potential user group is not capable of understanding the technology or its use.

2. Lack of developers of new technology
(a) Insufficient manpower or resources to develop the new technology.

(b) Insufficient emphasis or cammitment placed upon the development of the new technology.

3. Possessive'restrictive attitude of the technology developer
The holder of the technology will: (i) not release it, or do so at a prohibitive cost; or (ii) place restrictions on its use.

4. Failure of change agents
(a) The number of change agents is not sufficient to produce an impact; or b) change agents are ineffective in their job.

5. Misunderstanding of users' problems, or of their possible solutions
Faculty identification by agencies and advisors of users' problems, or of solutions to those problems.

Fig. 6. Potential problems in development and/or transfer of issue culture technology (adapted from Ahmed & Grainge, 1985).

of continuing activity and appraisal. It will be a body committed to the creation of opportunities for bamboo improvement and utilization by all those who wish to do so.

Acknowledgements

Years of funding for tissue culture activities for one of us (A.D.K.) by the U.S. National Aeronautics and Space Administration is gratefully acknowledged for it has provided the mechanism whereby a broad base of experience has been gained. Various grants over the years from N.S.F., U.S. Agency for International Development, Weyerhaeuser Company, United AgriSeeds, Phyto-Resource Research, etc. are also recognized.

References

Abe, T. & Futsubara, Y. 1986. Genotypic variability for callus formation and plant regeneration in rice (Oryza *sativa* L.). Theor. Appl. Genet. 72 : 3-10.

Abeels, P. 1962. Multiplication of bamboos. Indian For. 88: 48 1-487.

Abloowalia, B.S. & Maretzki, A. 1983. Plant regeneration via somatic embrygenesis in sugarcane. Pi. Cell Reports 2: 2 l-25.

Ahmed, S. & Grainge, M. 1985.The use of indigenous plant resources in rural development: Potential of the neem tree. Inter. J. Develop. Technol. 3: 123-130.

Alexander, M.P. & Ramana Rao, T.C. 1968. In vitro culture of bamboo embryos. Curr Sci. 37: 4 15.

Ammar, S.; Benbadis, A. & T'ripathi, B.K. 1987. Floral induction in date palm seedlings *(Phoenix dactylifera* var. Deglet Nour) cultured in vitro Can. J. Bot. 65: 137-142.

Anonymous 1967. Bamboo Quarantine 34. Plant Quarantine Division. Agricultural Research Service, As published in 7CFR, Revised January 1, 1967.

Anonymous 1982. Rice Tissue Culture Planning Conference. International Rice Research Institute (IRRI) P.O. Box 933, Manila, Philippines. pp 114.

Anonymous 1988a. Catalogue of Chinese Bamboo Literature. CAF-IDRC, Beijing, China.

Anonymous 1988b. Bamboo Abstracts 1: l-69. CAF-IDRC, Beijing, China.

Austin, R. & Ueda, K. 1975. Bamboo. Photographed by D. Levy. Weatherhill, New York.

Calderon, C.E. & Soderstrom, T.R. 1973. Morphological and Anatomical Considerations of the Grass Subfamily Bambusoideae Based on the New Genus *Maclurolya.* Smithsonian Contrib. No. 11,55 pp.

Calderon, C.E. & Soderstrom, T.R. 1980. The Genera of Bambusoideae (Poaceae) of the American continent: Keys and comments. Smithsonian Contrib. No. 44, 17 PP.

Cobin, M. 1947. Notes on the propagation of the sympodial or clump type of bamboos. Proc. Florida State Hot-t. Soc. 60. 181-184.

Cocking, E.C (n.d.). Plant Regeneration from Rice Protoplasts and Transformation Assessments. Training Course Manual. Plant Genetic Manipulation Group, Department of Bot., Univ. Nottingham NG7 2RD, England. p 44.

Creech, J.L. & Reitz, L.P. 1971. Plant germplasm now and for tomorrow. Advances in Agronomy 23: l-49.

Cronauer-Mitra, S.S. & Krikorian, A.D. 1988a. Adventitious shoot production from calloid cultures of banana. Pl. Cell Reports 6: 443-445.

Cronauer-Mitra, S.S. & Krikorian, A.D. 1988b. Plant regeneration via somatic embryogenesis in the seeded diploid banana Musa *ornata* Roxb. PI. Cell Reports 7: *23-25.*

Dahlgren,R.M.T.; Clifford, H.T. & Yeo, P.F. 1985.The Families of Monocotyledons: Structure, Evolution and Taxonomy. Springer Verlag, Berlin, Heidelberg, New York, Tokyo.

Day, P.R. 1973. Genetic variability of crops. Ann. Rev. Phytopathology 11: 293-3 12.

El-Hassan, A.A. & Debergh, P. 1987. Embryogenesis and plantlet development in the bamboo *Phyllostuchys viridis* ('Young) McClure. Plant Cell, Tissue & Organ Culture 10 : 73-77.

Farreily, D. 1984. The Book of Bamboo. Sierra Club Books, San Francisco,

Fitter, M.S. & Krikorian, A.D. 1982. Plant Protoplasts: Some guidelines for their preparation and manipulation in culture. Behring Diagnostics, Hoechst. P.O. Box 12087, San Diego, CA 92 112 U.S.A. pp 29.

George, E.F. & Sherrington, P.D. 1984. Plant Propagation by Tissue Culture. Handbook and Directory of Commercial Operations. Exegetics Ltd. Eversley, Basingstoke, England.

Haldeman, J.H.; Thomas, R.L. & McKamy, D.C. 1987. Use of benomyl and tifampicin for in vitro shoot tip culture of *Camellia sinensis* and C. *japonica.* Hort. *sci. 22: 306-307.*

Hamilton, R.I.; Edwardson, J.R.; Francki, R.I.B.; Hsu, H.T.; Hull, R.; Koenig, R. & Milne, R.G. 1981. Guidelines for the identification and characterization of plant viruses. J. Gen. Virol. 54: 223-24 1.

Hartley, C. 1939. The clonal variety for tree planting. Phytopathology 29: 9.

Hauptmann, R.M.; Widholm, J.M. & Paxton, J.D. 1985. Benomyl: A broad spectrum fungicide for use in plant cell and protoplast culture. PI. Cell Reports 4: 129-132.

Heinz, D. J. (ed) 1987. Sugarcane Improvement Through Breeding. Elsevier, Amsterdam, Oxford, New York, Tokyo.

Hewitt, W.B. & Chiarappa, L. (ed) 1977. Plant Health and Quarantine in International Transfer of Genetic Resources. CRC Press, Cleveland, Ohio [now Boca Raton, Florida].

Hewitt, W.B. & Chiarappa, L. (eds) 1977. Plant Health and Quarantine in International Transfer of Genetic Resources. CRC Press, Cleveland, Ohio [now Boca Raton, Florida].

Higuchi, T. (ed) 1981. Bamboo Production and Utilization. Proc. Group 5.3A. Production and Utilization of Bamboo and Related Species. XVII IUFRO World Congress Kyoto, Japan, September 6 17, 198 1, Kyoto. International Union of Forestry Research Organizations: Japan Society of Bamboo Development and Protection. Wood Research Institute, Uji, Kyoto, Japan 213 pp.

Ho, W. -J. & Vasil, I.K. 1983. Somatic embryogenesis in sugarcane (Saccharum officinarurn L.). I The morphology and physiology of callus formation and the ontogeny of somatic embryos. Protoplasma **118:** 169-180.

Holttum, R.E. 1956. The classification of bamboos. Phytomorphology 6: 73-90.

Hsiung, W.-Y.; Din Z.-F & Li, Y.-F. 1981. Intercalary meristem and intemodal elongation of rhizome shoots: 150-156. In Higuchi, T. (ed) Bamboo Production and Utilization. Wood Research Institute, Kyoto University, Uji, Kyoto, Japan.

Huang, L.C. & Murashige, T. 1983. Tissue culture investigations of bamboo. I. Callus cultures of Bambusa, *Phyllostachys* and **Sasa.** Bot. Bull. Acad. Sin. (Taipei) 24: 31-52.

Janzen, D.H. 1976. Why bamboos wait so long to flower. A. Rev. Ecol. Syst. 7 : 347-391.

Janzen, D.H. 1985. Bambusoideae : 113 In Halevy, A. (ed) Handbook of Flowering. Vol. II. CRC Press, Boca Raton, Florida.

Kahn, R.P. 1979. Tissue culture applications for plant quarantine: 185-201. In Maramorosch,K. & Jirumi, H. (eds) Academic Press, New York.

Kahn, R.P. 1988. Plant Quarantine: Principles, Concepts and Problems. 3 Vols. CRC Press, Inc. Boca Raton, Florida.

Kartha, K.K. 1981. Tissue culture techniques for virus elimination and germplasm preservation. : 123- 138.In Rachie K.O. & Lyman, J.M. (eds) Genetic Engineering for Crop Improvement. The Rockefeller Foundation, New York.

Kartha, K.K. (ed) 1985. Cryopreservation of Plant Cells and Organs. CRC Press, Boca Raton, Florida.

Knauss, J.F. & Miller, J.W. 1978. A contaminant, *Erwiainia-carotovora,* affecting commercial plant tissue cultures. In Vitro 14: 754-756.

Kondas, S. 1982. Bamboo biology, culm potential and problems of cultivation. Indian For. 108: 179- 188. (Also to be found in Higuchi, 198 1. 184- 190).

Krikorian, A.D. 1982. Introductory essay to: Growth and organized development of cultured cells. II. Organization in cultures grown from freely suspended cells. Steward, EC.; Napes, M.O. & Mears, K. Classic Papers in Horticultural Science. **In** Janick J.(ed). W.H. Freeman Co., San Francisco.

Krikorian, A.D. 1988a. Plant tissue culture: Perceptions and realities. Proc. Indian Acad. Sci. Pl. Sci. 98: 425-464.

Krikorian, A.D. 1988b. The context and strategies for tissue culture of date, African oil and coconut palms. In Mott, R.L. & Dhawan, V. (eds). **In** Applications of Biotechnology in Forestry and Horticulture. Plenum Press, New York.

Krikorian, A.D. 1989. Tissue culture for tropical woody plants: The context, prospects and problems. **In** Rao, A.N. & Yusoff, A. M. (eds) Seminar on Tissue Culture of Forest Species. Kuala Lumpur, June 15- 18, 1987. Jointly organized by Forest Research Institute Malaysia and International Development Research Centre, Canada with active participation of Asian Network in Biological Sciences. ANBS.

Krikorian, A.D. & Kann, R.P. 1986. Oil palm improvement via tissue culture. Pl. Breed. Rev. 4: 175-20 1.

Krikorian, A.D.; Cronauer-Mitra, S.S. & Fitter Corbin, MS. 1988. Protoplast culture of perennials. Scientia Hortic. (in press).

Krikorian, A.D.; Kann, R.P.; O'Connor, S.A. & Fitter, M.S. 1986. Totipotent suspensions as a means of multiplication.: 61-72. **In** Zimmerman. R. (ed) Tissue Culture as a Plant Production System for Horticultural Crops. USDA Symp. Maryland. Martinus Nijohff/Dr. W. Junk. The Hague, Netherlands (Oct. 20-23, 1985 Beltsville).

Kumari, D.S.; Sarma, N.P. & Rao, G.J.N. 1988. Micropropagation of cytosterile rice stocks. IRRN (International Rice Research Newletter) 13 : 5-6.

Larkin, P.J. & Scowcroft, W.R. 1981. Somaclonal variation a novel source of variability from cell cultures for plant improvement. Theor. Appl. Genet. 60: 197-2 14.

Lessard, G. & Chouinard, A. (eds) 1980. Bamboo Research in Asia. IDRC, Canada.

Liese, W. 1985. Bamboo-biology, silvics, properties. utilization. Schriftenreihe der GTZ, no. 180, Deutsche Gesellschaft fur Technische Zusammenarbeit. TZ-Verlagsgesellschaft GmbH, Federal Republic of Germany.

Lin, W. -C. 1970. La Culture du Bambou a Madagascar. 20 pp. Publiee avec le Contours du Centre de Formation pour 1 'Artisanat du Bambou Sino-Malagasy.

Maddock, S.E. 1985. Cell culture, somatic embryogenesis and plant regeneration in wheat, barley, oats, rye and triticale: 13 I- 174. **In** Jones, M.G.K. (ed) Cereal Tissue and Cell Culture. Martinus Nijhoff, Dordrecht, The Netherlands.

Marden, L. 1980. Bamboo, the giant grass. Natn. Geogr. Mag. **158 : 502-529.**

Maretzki, A. 1987. Tissue culture: Its prospects and problems: 343-384. **In** Heinz, D.J. (ed) Sugarcane Improvement through Breeding. Elsevier, Amsterdam, Oxford, New York, Tokyo.

McClure, EA. 1966a. The Bamboos, a Fresh Perspective. Harvard Univ. Press, Cambridge, Mass.

McClure, EA. 1966b. A glossary of the bamboos. Taxon **15: 220- 235.**

McClure, F.A. 1973. Genera of Bamboos Native to the New World (Gramineae: Bambusoideae) Soderstrom, T.R. No. 9. (ed). Smithsonian Contrib. Bot. 148 pp.

Metcalfe, C.R. 1960. Anatomy of the Monocotyledons. I. Gramineae. Oxford Clarendon Press.

Muzik, T.J. & LaRue, C.D. 1954. Further studies on the grafting of monocotyledonous plants. Am. J. Bot. 41: **448-455.**

Nadgir, A.L.; Phadke, C.H.; Gupta, P.K.; Parsharami, V.A.; Nair, S. & Mascarenhas, A.F. 1984. Rapid multiplication of bamboo by tissue culture. Silvae Genet. 33: 219-223.

Parliman, B.J. & White, G.A. 1985. The plant introduction and quarantine system of the United States. Pl. Breed. Rev. 3: 361-434.

Philip, V.J. & Haccius, B. 1976. Embryogenesis in Bamhusa arundinacea Wild. and structure of the mature embryo. Beitr. Biol. Pfl. 52: 83- 100.

Plucknett, D.L. & Smith, N.J.H. 1984. Networking in international agricultural research. Science 225: 989-**993.**

Plucknett, D.L.; Smith, N.J.H.; Williams, J.T. & Anishetty, N.M. 1987. Gene Banks and the World's Food. Princeton Univ. Press, Princeton, New Jersey.

Porterfield, W.M. 1930. The mechanism of growth in bamboo. China J. 13: 86-91; 146153.

Power, J.B.; Chapman, J.V. & Wilson, D. 1984. Laboratory Manual - Plant Tissue Culture. Plant Genetic Manipulation Group, Nottingham NG7 2RD, England.

Prange, P.W. 1974. Formacao de mudas de bambu imperial (Pampusu *vulgaris* Schrad var. vittata A et C.Riv). Brasil Florestal (Rio de Janiero). Instituto Brasileiro de Desenvolvimento Florestal. 5 : 47-53 (In Portuguese with English summary).

Rao, A.N. (ed) 1982. Tissue Culture of Economically Important Plants. Proc. Inter. Symp. Singapore (April, 28-30).

Rao, A.N.; Dhanarajan, G. & Sastry, C.B. (eds) 1987. Recent Research on Bamboo. Proc. Inter. Bamboo Workshop. Hangzhou, China. (October 6- 14, 1985).

Rao, I. Usha; Rao, I.V. Ramanuja & Narang, Vibha 1985. Somatic embryogenesis and regeneration of plants in the bamboo *Dendrocalamus strictus*. Pl. Cell Reports 4: 191-194.

Rea, H.E. & Karper, R.E. 1932. Propagating sorghum by cuttings. Am. J. Bot 19: 464-476.

Redenbaugh, K.; Fujii, J. & Slade, D. 1988. Encapsulated plant embryos.: 225-248. **In** Mizrahi, A. (ed) Biotechnology in Agriculture. Alan R. Liss, New York.

Reeder, J.R. 1962. The bambusoid embryo: A reappraisal. Am. J. Bot. 49: 639-641.

Schaefer-Menuhr, A. (ed) 1985. In Vitro Techniques, Propagation and Long Term Storage. Martinus Nijhoff/Dr. W. Junk Publ. Dordrecht, Netherlands.

Schaffner, C.P. 1979. Animal and plant tissue decontamination.: 203-214. **In** Maramorosch. K. & Hirumi, H. (eds) Practical Tissue Culture Applications. Academic Press, New York & London.

Scorza, R. 1982. In vitro flowering. Hort. Rev. 4: 106-127.

Seethalakshmi, K.K.; Venkataesh, C.S. & Surendran, T. 1983. Vegetative propagation of bamboos using growth promoting substances. 1. *Bamhrsa halcoa* Roxb. Indian J. For. 6: 98- 103.

Seivapandiyan, A.; Subramani, J.; Bhatt, P.N. & Mehta, A.R. 1988. A simple method for direct transplantation of cultured plants to the field. PI. Sci. 56: 8 l-83.

Shields, R.; Robinson, S.J. & Anslow, P.A. 1984. Use of fungicides in plant tissue culture. Pl. Cell Reports 3: 33-36.

Soderstrom, T.R. & Calderon, C.E. 1979. A commentary on the bamboos (Poaceae:Bambusoideae). Biotropica 11: 16 I- 172.

Soderstrom, T.R. & Young, SM. 1983. A guide to collecting bamboos. Annals Missouri Bot. Garden 70: 128-136.

Staritsky, G.; Hovers, I.H.W. & Zandvoort, E.A. 1983. Rifampicin, an effective antibiotic against bacteria in cultures in vitro. Acta Bot. Neerl. 35: 49 l-497.

Sybenga, J. 1983. Genetic manipulation in plant breeding, somatic versus generative. Theor. Appl. Genet. 66: 179-201.

Thomas, E.; King, P.J. & Potrykus, I. 1979. Improvement of crop plants via single ceils *in* vitro-an assessment. Z. Pflziichtg. 82: l-30.

Thompson, A.E. 1985. New native crops for the Arid Southwest. Econ. Bot. 39: 436-453.

Thurston, K.C.; Spencer, S.J. & Arditti, J. 1979. Phytotoxicity of fungicides and bactericides in orchid culture media. Am. J. Bot. 66: 825835.

Tisserat, B. & DeMason, D.A. 1985. Occurrence and histological structure of offshoots and inflorescences produced from Phoenix dactylifera L. plantlets in vitro. Bull. Torrey Bot. Club 112: 35-42.

Uchimura, E. 1984. Site condition of growth and methods of multiplication of bamboo.: 23-26. In Higuchi, T. (ed) Bamboo Production and Utilization. Wood Research Inst. Kyoto Univ. Uji, Kyoto, Japan.

Vasil, I.K. 1986. Advantages of embryogenic cell cultures of Gramineae.: 7 l-75. In Nuclear Techniques and In Vitro Culture for Plant Improvement. Proc. Inter. Symp. Inter Atomic Energy Agency and the Food Agric. Orgn. United Nations (August, 19-24, 1985.) Internatational Atomic Energy Agency IAEA-8M- 282/4 1, Vienna.

Vasil, I.K. 1988. Progress in the regeneration and genetic manipulation of cereal crops, Bio/Tech. 6: 397-402.

Venketraman, T.S. 1926. Studies in sugarcane germination. Agricultural J. India 21: 101-106.

Wang, B.-L. 1981. Method of vegetative propagation in *Phyllostachys pubescens* Maze1 ex H. De Langhe. Lin yueh k'o hsueh Scientia Silvae Sinica (Beijing) 17: 287-290 (in Chinese with English abstract).

Yamada, Y. & Loh, W.H. 1984. Rice : 151-170. In Ammirato, P.V.; Evans, D.A.; Sharp, W.R. & Yamada, Y. (eds). Handbook of Plant Cell Culture 3. Crop Species Macmillan Publ. New York.

Yao, D.-Y. & Krikorian, A.D. 1981. Multiplication of rice (Oryza sativa L.) from aseptically cultured nodes. Ann. Bot. 48: 255-259.

Yeh, M.-L. & Chang, W.-C. 1986. Plant regeneration through somatic embryogenesis in callus culture of green bamboo *(Bambusa oldhamii* Mum-o). Theor & Appl. Genet. 73: 161-163.

Yeh, M.-L. & Chang W.-C. 1987. Plant regeneration via somatic embryogenesis in mature embryo-derived callus of ***Sinocalamus latiflora*** (Munro) McClure. Pl. Sci. 51: 93-96.

Appendix 1. Quarantine regulations as they relate to bamboo in the U.S.A. (Anonymous 1967)

United States Department of Agriculture
Agricultural Research Service
Plant Quarantine Division

Bamboo Quarantine 34 As published in 7 CFR
Revised January 1, 1967

Title 7--AGRICULTURE

Chapter III--Agricultural Research Service, Department of Agriculture Part 319 - FOREIGN QUARANTINE NOTICES

Subpart - Bamboo

§ 319.34 Notice of quartine.

(a) The fact has been determined by the Secretary of Agriculture, and notice is hereby given. that dangerous plant diseases, including the bamboo smut *(Ustilago shiraiana),* new to and not heretofore widely prevalent or distributed within and throughout the United States, occur in Japan, China, India, Philippine Islands. Australia, New Zealand, Oceania, Africa, Europe, South America, British West Indies. Cuba, and Central America.

(b) On and after October I,19 18, and until further notice, by virtue of the act of Congress approved August 20. 1912, known as "The Plant Quarantine Act" (37 Stat. 3 15; 7 U.S.C. 15 l-l 67), the importation into the United States for any purpose of any variety of bamboo seed, and species of the tribe Bambuseae, from the above-named and all other foreign countries and localities, is prohibited, except for experimental or scientific purposes by the Department of Agriculture: *Provided.* that the entry for immediate export, or for immediate transportation and exportation in bond, of bamboo seed, plants, or cuttings thereof capable of propagation, including all genera and species of the tribe Bambuseae, may be permitted in accordance with §§ 352.2-352.8 of this chapter: *Provided, further,* that this prohibition shall not apply to importations into Guam of the bamboo seeds, plants, or cuttings designated in this paragraph but such importations are subject to the requirements of §§ 3 19.37-4(b) and 3 19.376.

(c) This notice of quarantine does not apply to bamboo timber consisting of the mature dried culms or canes which are imported for fishing-rod, furniture-making, or other purposes, or to any kind of article manufactured from bamboo, or to bamboo shoots cooked or otherwise preserved.

(d) As used in this subpart, unless the context otherwise requires, the term "United States" means the States, the District of Columbia, Guam, Puerto Rico, and the Virgin Islands of the United States.

Table 1. List of bamboo genera covered by the U.S. Department of Agriculture Notice of Quarantine (Revised, June 1977). (From Anonymous 1976).

3 19.34 BAMBOO

M319.34. *Notice of quarantine* II. a. Plants, seeds and propagable cuttings of the following bamboos are prohibited entry from all foreign sources:

Apoclada	*Greslania*	*Pseudocoix*
Arthrostylidium	*Guadua*	*Pseudosasa*
Arundinaria	*Guaduella*	*Pseudostachpum*
Athroostachys	*Hickelia*	*Puelia*
Athr-actantha	*Hitchcockella*	*Racemobambos*
Aulonemia	*indocalamus*	*Rettbergia*
Bambusa	*Indosasa*	*Rhipidocladum*
Bonia	*Klemachloa*	*Sasa*
Brachystachyum	*Lingnania*	*Sasaella*
Cephalostachyum	*Melocalamus*	*Sasamorpha*
Chimonobambusa	*Melocanna*	*Schirostachyum*
Chloothamnus	*Merostachys*	*Semiarundinaria*
Chusquea	*Myriocladus*	*Shibataea*
Colanthelia	*Nastus*	*Sinarundinaria*
Decaryochloa	*Neohouzeaua*	*Sillobambusa*
Dendrocalamus	*Neurolepis*	*Sinocalamus*
Dendrochloa	*Och Iandra*	*Swallenochloa*
Dinochloa	*Oreobambus*	*Teinostachyum*
Elytrostachys	*Oxytenanthera*	*Thamnocalamus*
Fargesia	*Perrierbambus*	*Thyrsostachys*
Gigantochloa	*Phyllostachys*	*Yushania*
Glaziophyton	*Pleioblastus*	

b. The above articles may be entered for export, either for direct exportation or transportation and exportation, under the provisions of Sections 352.2 - 352.8.

c. Dried bamboo canes and articles made thereof, cooked frozen, or otherwise preserved bamboo shoots, and dried bamboo leaves for cooking purposes, or articles made thereof, are consideredoutside the scope of quarantine regulations and may be imported without restriction other than verification and inspection.

As a guideline for bamboo canes, if the canes show any green, they may be considered as capable of propagation and entry will be denied.

II Importations into Guam extempt from this quarantine but subject to quarantine 37. (Rev. June 1977)

PROCEEDINGS OF
THE INTERNATIONAL
BAMBOO WORKSHOP,
NOVEMBER 14-18, 1988

BAMBOO INFORMATION SYSTEM

Bamboo Information Centre (China)

Zhu Shilin

Institute of Scientech Information,
Chinese Academy of Forestry,
100091 Wan Shou Shan, Beijing, China.

Abstract

This paper describes the activities of the Bamboo Information Centre (BIG), established by the Chinese Academy of Forestry (CAF) and supported by the International Development Research Centre (IDRC) of Canada. The objectives of BIC are given in detail. The organization of a national bamboo information network, the training of personnel, the establishment of a computerized database, the preparation of bamboo publications and the compilation of a micro-thesaurus of bamboo terminology are discussed. The BIG intends developing cooperation with bamboo-related institutions in all countries.

Objectives of BIG

The Bamboo Information Centre (BIC) was established towards the end of 1987 by the Chinese Academy of Forestry (CAF) in cooperation with the International Development Research Centre (IDRC) of Canada, at the Institute of Scientech Information of CAF. The Institute is a national centre of scientific and technological information on forestry and employs more than 160 persons and publishes seven information periodicals; its library has 300 000 volumes of books and subscribes to some 1600 periodicals. The deputy director of the Institute is acting as the project leader of BIC. Therefore, the BIC enjoys full support from the Institute and has among other things, a computer room and a printing house.

The long-term objective of BIC is to promote the sharing of knowledge and experience about bamboo research, development and utilization in Asia. Its short-term objectives are to organize and disseminate information regarding Chinese bamboos to users in China and abroad, and to selectively collect and organize information on bamboos of other Asian countries for the benefit of bamboo users in Asia.

Activities of BIG

Organization of a National Bamboo Information Network

In China, most southern provinces engage in the cultivation, utilization, research and development of bamboo. In recent years. due to the serious shortage of ordinary wood and rapid development of a commodity economy, new forms and new technologies of bamboo utilization have been developed, and workshops on bamboo research are being held in many provinces. It is impossible to collect all this information in time without an efficient national network. For this purpose, the BIC has formed a bamboo information network, consisting of about 30 persons from almost all the southern provinces of China. They are employees of universities, research institutions, governmental bodies and enterprises. As a result of the network, BIC receives all important information on bamboo from all bamboo cultivating provinces.

Training Network Members and BIC Personnel

A workshop was organized in January 1988 in Nanjing and another one in October in Fujian for training the members of the network. In these workshops, the structure of the classification system of forestry literature, the thesaurus of forestry terminology, the principles of indexing, the rules of abstract compilation and the input sheet form for computer storing were explained. Members also discussed the proper distribution of work amongst themselves. Consequently, the information comes to BIC without overlap, in the right format and in time.

BIC is a small-sized information centre, with international contacts. The working team consists of seven members. To ensure high efficiency and accuracy, the project assistant was deputed to the Rattan Information Centre in Malaysia to study

Development of Printing Facilities

BIC prints a maximum of 1000 copies of all its publications. In Beijing, all commercial printing houses do not accept orders less than 2000 copies. The Institute's printing house lacks facilities for English publications. For this reason, BIC had to develop its own printing facilities. We purchased a Laser Jet printer HP II, a mini-offset printer, some font cartridges and some printing software. As a result, the capability for printing publications has been built up besides reducing the production cost of the publications.

Compilation of a Micro-thesaurus of Bamboo Science and Technology (English-Chinese/ Chinese-English)

Since international exchange of bamboo knowledge and experience is becoming very frequent, the translation and indexing of bamboo literature requires a unique thesaurus of bamboo terminology. We have decided to compile such a thesaurus and it is due to be completed in 1990. The senior editor of BIC, having taken part in the compilation of the Chinese thesaurus of forestry science and technology, is making all necessary preparations for the job.

As a newly set-up information institution, BIC looks forward to developing links with all individuals and institutions dealing with bamboo cultivation, processing, utilization and research, and welcomes candid criticism and suggestions for the improvement of its work.

modern management methods and the routine working of a well-run small information institution. At the same time, a computer engineer was sent to Singapore and Thailand to observe the application of computers in information and bibliographic services. In addition, the project leader and senior editor of BIC will visit information institutions of some ASEAN countries to get acquainted with the policies and trends in modern scientific and technological information management.

As the main products of BIC are its publications in English and Chinese, it is very important for its personnel to master English. To improve competency in English language, two BIC employees have been attending an intensive course in English language. In addition, a consultant visits BIC once a year to edit the English version of its publications.

Establishment of a Database of Bamboo Literature

The bamboo literature is scattered in various periodicals devoted to forestry, agriculture, light industry, civil engineering and mining industry. Besides, there are several other publications such as proceedings, papers and monographs devoted to bamboo research. For professionals to identify and locate them, a computerized database is needed. Since the amount of bamboo literature is not very large, it is possible to establish a database on a microcomputer system, Thanks to the financial support from IDRC, a North Star NS 1200 computer complete with three terminals has been obtained. The computer division of the Institute compiled a programme for document retrieval, called FORES, which can be run on medium-sized computers, minicomputers and microcomputers (mainly IBM PC series), both in Chinese and English. Since the beginning of this year, we have been inputting bamboo abstracts and titles into our database. At present, it contains around 2000 references. In time, however, it will grow into a useful database, capable of offering retrieval services to information users.

Publication of Bamboo Literature

The most important activities of BIC are to collect, process and disseminate bamboo information through its publications.

BIC issues Bamboo Abstracts twice a year with both English and Chinese versions containing 150 titles per issue. One hundred titles are taken from Chinese sources and the other fifty from foreign sources. The first English issue was completed and delivered to users in August 1988.

A Retrospective Catalogue of Chinese Bamboo Literature has been edited its Chinese version containing 1200 titles and the English version, 600 titles. All the titles, taken from Chinese bamboo literature, were published during 1975-86. This catalogue has also been delivered to the users. If financial resources permit, catalogues of Chinese bamboo literature published before 1975 will also be compiled.

All the titles in the first issue of Bamboo Abstracts and the Catalogue of Chinese Bamboo Literature Abstracts were arranged according to the Chinese bibliographic classification system which differs greatly from the international UDC system. In order to suit foreign users, an international system will be used in the future.

The library of the Institute maintains all the Chinese bamboo literature cited in the Bamboo Abstracts and the Catalogue of Chinese Bamboo Literature. Any foreign user, wishing to obtain the full text of the paper he is interested in, may contact the BIC and get the Chinese original or its English translation.

As China has a history of about 3000 years in the cultivation and utilization of bamboo, much information is available on this plant. BIC is going to edit a collection of selected Chinese bamboo literature. This collection will include one hundred of the most important key documents that benchmark the progress of bamboo research, development and utilization. Each document will carry an English abstract or a full translation. This task is tremendous, for it takes much time and labour to find these out from a vast sea of bamboo literature, most of which is written in classical Chinese, much different from modem Chinese. The experts, who undertake this task need to master not only the bamboo sciences, but also the Chinese language and, if possible, English as well. At present, very few bamboo researchers know classical Chinese. We plan to form an editing committee, consisting of five members, well-versed in bamboo science and the languages. Professor A.N. Rao from the National University of Singapore and Professor Hsiung Wenyue from the Nanjing Forestry University have agreed to take part in the work of the committee. The Collection will be issued in 1990.

A Bamboo Newsletter in English is being issued twice a year from the Nanjing Forestry University with financial support from IDRC. It reports recent developments in work connected with bamboo. The Newsletter carries the name of the Bamboo Information Centre on its front cover and is issued under the editorship of Professor Hsiung Wenyue.

An English-cum-Chinese information brochure about the Bamboo Information Centre will be prepared and distributed in 1989.

Development of Printing Facilities

BIC prints a maximum of 1000 copies of all its publications. In Beijing, all commercial printing houses do not accept orders less than 2000 copies. The Institute's printing house lacks facilities for English publications. For this reason, BIC had to develop its own printing facilities. We purchased a Laser Jet printer HP II, a mini-offset printer, some font cartridges and some printing software. As a result, the capability for printing publications has been built up besides reducing the production cost of the publications.

Compilation of a Micro-thesaurus of Bamboo Science and Technology (English-Chinese/ Chinese-English)

Since international exehange of bamboo knowledge and experience is becoming very frequent, the translation and indexing of bamboo literature requires a unique thesaurus of bamboo terminology. We have decided to compile such a thesaurus and it is due to be completed in 1990. The senior editor of BIC, having taken part in the compilation of the Chinese thesaurus of forestry science and technology, is making all necessary preparations for the job.

As a newly set-up information institution, BIC looks forward to developing links with all individuals and institutions dealing with bamboo cultivation, processing, utilization and research, and welcomes candid criticism and suggestions for the improvement of its work.

Bamboo Information Centre (India)*

K. Ravindran

Kerala Forest Research Institute, Peechi 680 653, Kerala, India.

Abstract

Information is an essential input for research and effective implementation of research results. It is also vital for framing natural resource policies. A Bamboo Information Centre (BIG) has been set up at the Kerala Forest Research lnstitute (KFRI) with IDRC funding for disseminating information on bamboo. The main functions of the BIC will be (a) to develop and manage an integrated database comprising Indian bamboo literature, specialists and current research programmes; (bj to provide search services from the database backed with a document delivery service; (cj to publish a half-yearly bulletin containing abstracts and research news; (d) to prepare a compendium on bamboos describing the 137 species found in India; (e) to popularise research results by producing extension bulletins and slide sets; and(f) to publish a directory of bamboo scientists and current research programmes.

Introduction

Shrinkage of the forest area, coupled with increasing demand and over-exploitation is depleting the bamboo wealth of India, This is a matter of serious concern, particularly for the poorer folk who depend solely on bamboo for their livelihood and who cannot compete with large organized industries for their raw material. Efforts are on, therefore, to research into cultural and agronomic techniques which will boost bamboo production so that raw material in sufficient quantity can be made available to farmers, rural households and large industries.

For the research programmes being carried out on the bamboos at KFRI and in the country as a whole, access to information (especially that produced in India itself) is desirable. At present, this information, especially that in the older literature, is scattered in several institutions. What is needed is the collection and organization of the existing and emerging literature on bamboo under one roof and facilitation of easy access by means of appropriate documentation and reprography services.

For effective documentation and dissemination of bamboo literature, a Bamboo Information Centre has been set up at the KFRI with financial and technical assistance from the IDRC.

Objectives

The following are the objectives of the BIC (India): (i) to develop and manage an integrated database comprising Indian bamboo literature, scientists engaged in bamboo research and current research programmes; (ii) to provide search services from the database backed up with a document delivery service; (iii) to publish a half-yearly bulletin containing abstracts and research news; (iv) to prepare a compendium on bamboos describing all the species of bamboos found in India; (v) to popularise research results by producing extension bulletins and slide sets; and (vi) to publish a directory of bamboo scientists and current research programmes.

Accomplishment of these objectives will complement and support indigenous research, avoid duplication of past research, facilitate contact between scientists, promote the use of research results in the field and enable scientists to identify new research problems. The Bamboo Information Centre will serve scientists doing research on bamboo, personnel from bamboo-based industries, officials and research staff of forest departments, staff and research students of agricultural universities, as well as the agriculture and forestry extension services of Kerala.

**KFRI scientific paper- no. I91*

Methodology

An Advisory Committee will be constituted by the Director of KFRI to guide and advise the work of BIC. All categories of BIC users will have representation in the Committee. The KFRI Director and Project Leader will also be members of the committee which will meet twice a year. The present KFRI Librarian will function as the Project Leader, who will supervise and manage the Centre. One existing Librarian will be deputed to work full time for the Centre. She will implement and coordinate the programme of work. In addition, a keyboard operator and a technical assistant will also be recruited by the project. All other KFRI library staff will contribute their part-time services to the project.

The Library has a IBM PC AT microcomputer on which it is running the Micro ISIS software. This machine will be used to create the BIC database and publications. To facilitate data entry a PC will be purchased for the Centre. A UPS will also be purchased.

The BIC database will be an integrated one in which data concerning documents, scientists and research programmes will be incorporated using the Common Communication Format, using Micro ISIS and the Cabvoc thesaurus. This protocol will generate the major outputs of this project. It is expected that in the first year some 1000 annotated references to the literature will be inputted into the database. In succeeding years 300 references each will be inputted. For the directory of scientists it is estimated to have at least 100 entries and for their research programmes up to 300 items.

The Library has a good collection of conventional bamboo literature published since 1978. To acquire older published and unpublished material, BIC staff will visit up to ten libraries to collect information dating back to the colonial era. This will include the Forest Research Institute, Dehradun; the Indian Agricultural Research Institute, New Delhi; the Agricultural University, Coimbatore; and the Indian National Scientific Documentation Centre, New Delhi. Documents will be procured in paper and microform. To facilitate use of the latter, a microfilm/fiche plain paper reader-printer will be purchased. While visiting these institutions, BIC staff will collect data on scientists and research programmes using predetermined worksheets. Institutions which cannot be visited will be asked to complete the worksheets themselves.

During the first year of operation it is hoped to provide current and retrospective services and SD1 from the BIC database. To ensure a responsive document delivery service a photocopier will be purchased. All published outputs will be prepared using desktop publishing techniques facilitated by the Ventura software which runs on IBM microcomputers. Camera-ready copy will be provided to local presses who will print it in offset.

Two issues of the BIC Bulletin will be published annually. In addition to abstracts and the author, subject and species indices, the Bulletin will also contain news concerning meetings and events, short notes on current research and so on. Five hundred copies will be distributed to scientists, forestry officers, industries and selected extension services. At the end of the third year the abstracts and indices will be cumulated into a single bibliography for distribution to BIC Bulletin recipients.

In the second year of the project, 500 copies of the directory of scientists and research programmes will be published. BIC staff will ensure that the database is kept current. Updates will appear in the BIC Bulletin. Also during the second year, the project will begin to produce extension materials to popularise the results of in-house and IDRC-supported bamboo research at KFRI. In conjunction with the Kerala agriculture and forestry extension services, five booklets in the Information Bulletin series will be written by KFRI scientists. Topics can include: harvesting, seed collection, intercropping, use, propagation, diseases and control, preservation and treatment. Malayalam (local language) versions will be prepared for the local extension services and English versions for wider distribution within India. All the publications and services offered by the Bamboo Information Centre will be outlined in a booklet to be published in the second year of operation.

The same topics mentioned above will be considered for the production of five slide sets which aim to propagate sound cultural practices. These will be prepared by the scientists and photographer of KFRI during the field experimentation period. The scientists will prepare English and Malayalam scripts to accompany the slides. Twenty duplicate sets of each will be provided to local extension and protection services and similar agencies in the bamboo-growing areas of North-east India.

Todate, there exists no single publication describing all the bamboos found in India. Literature is scattered throughout a wide variety of sources including files and publications dating back to the colonial times. In addition to the desirability of having comprehensive information about bamboos in one source, a bamboo compendium would also help in the field identification of species and their properties along with their commercial applications. The KFRI Bamboo Research Group will compile a compendium of Indian bamboos describing their appearance, habitat, characteristics, use, nomenclature and so on. This will be achieved by reference to the collections of BIC and by consulting the files and personnel of key agencies. The scientists will visit the Forest Research Institute, Dehradun, the Botanical Survey of India, Calcutta; the Department of Forests, Gauhati (Assam); and the Department of Forests, Andaman Islands. Whenever possible, plants will be collected for adding to the live bamboo collection at KFRI. Work will start in the first year and the publication of the Compendium is expected in the third year. It will be written by KFRI scientists and illustrated with line drawings. Five hundred copies will be produced. A scanner will be purchased to transfer the artist's drawings to the microcomputer to ease formatting when producing the camera-ready copy.

To promote contact with the Chinese Bamboo Information Centre, all BIC publications and the database will be exchanged with China. In addition, the Project Leader will visit Beijing to determine ways in which his Centre can use the resources of the Chinese Centre. It is expected that the Chinese will provide BIC with their database and publications. This would prove useful because even though Chinese bamboos tend to be temperate and Indian bamboos tropical, there is an overlap of species. It is also hoped that the project leader of the BIC (China) will pay a visit to the BIC (India).

Provision has also been made in the project to translate Indian language publications into English and to microfiche rare and old bamboo literature.

Training

Two practical training courses will be provided by the project. In the first place, three BIC indexers will visit ICRISAT for a two week abstracting and indexing training. Secondly, one staff member will visit the International Centre for Development Policy Modelling, Pune, for two weeks training on the Ventura desktop publishing software. In addition, two staff members will be supported to take the Master in Library and Information Science degree at an Indian University. This will bring to the Bamboo Information Centre enhanced skills and knowledge especially on modem information handling techniques.

Using the Scientific Information System

F.S.P. Ng

Forest Research Institute Malaysia (FRIM),
Kepong, 52109 Kuala Lumpur, Malaysia.

Abstract

The number- of scientific periodicals has doubled in the past 20 years. English has become the dominant language of science and is used in over 80 percent of scientific publications. In spite of the rapidly increasing number of publications, the volume of useful information remains manageable. This is because with the passage of time, information has been rationalized, simplified and condensed. Papers for- publication should tell a simple and logical story. The abstract, being the representative part of the paper that gets into most information databases should summarize all important facts in the paper To use the scientific information system effectively, both for retrieving and inputting information, one should understand and adapt to the peculiarities of the system.

Introduction: History of Scientific Publication

The scientific information system consists primarily of information published in books, periodicals and patents. Historically, books came first, and until the establishment of periodicals, the supreme achievement for a scientist or any learned person was to write a book. The book format gives ample room for the author to develop the subject matter in a complete manner, starting from the first principles and answering all anticipated questions, thereby displaying his mastery of the subject.

One of the most famous of all scientific books is Isaac Newton's *Philosphiae Naturalis Principia Mathematica* or *Pr-incipia* in short, which was published in 1687 and covered almost a lifetime of Newton's discoveries in mathematics and physics. In this monumental book there was a section devoted to calculus. Newton is thought to have discovered the principles of calculus around 1666, but delayed publishing it by 20 years because he was saving it for his book. In the meantime, Gottfried Lebnitz independently discovered the principles of calculus, by a different approach, sometime between 1673 and 1676. The bitter controversy over who first discovered calculus blighted the last years of the lives of these two great men of science.

Nowadays, a scientist does not save up a lifetime of work for the sake of a book. Work is published in segments as and when a segment is ready and acceptable for publication in a periodical. This change from book form to the periodical format for the publication of original works, has several advantages. It provides a means for knowledge to be saved in small segments, otherwise much knowledge would be lost because of failure to write books. Publication in a periodical also disseminates knowledge rapidly thereby catalysing further thought and development with minimum delay. Finally, but perhaps most importantly, for the individual scientist, publication in a periodical is a means for claiming priority and honour for each unit of personal achievement.

The earliest scientific periodical was the Philosophical Transactions of the Royal Society. first published in 1665. Initially this resembled a newsletter. The practice of using the periodical to publish original research, supported by references to previous work, took about 200 years to get firmly established (Price, 1963) because scientists took a long time to appreciate the advantages of publishing in a periodical, as compared to publishing a book.

For those scientists involved with discoveries or inventions of commercial potential, there is another means of establishing priority and that is through the process of patenting. Patent laws have their origin in the Statute of Monopolies passed in 1624 by the British Parliament, which allowed monopolies to be granted for "the sole working or making in any manner of inventor or inventors thereof ". In other words, the "true and first" inventor would be granted a monopoly for the commercialization of the invention. At first, a new invention was defined by a title, but by about 1710 it became a condition for the patentee to file a written description of the invention. Eventually, the written description became a legal and technical specification that could be tested in a court of law.

Looking back, we can appreciate the fact that the Statute of Monopolies in 1624 and the first scientific periodical in 1665, were by a happy coincidence and parallel development, to exert the most profound influence on science.

The ancient civilizations, of Egypt, India and China made remarkable progress in science and technology; but such progress was erratic because they had no system for recognizing the people who contributed segments to scientific and technological development, and knew no dependable method for systematically saving and disseminating such segments. The periodical and the patent solved this problem, thereby allowing science and technology to grow at an exponential rate. There is therefore much justification for considering that the modem age of science and technology started in about the mid- 1600s.

Characteristics of Scientific Information

Rate of Publication has Doubled in 20 Years:

An idea of the growth of scientific information can be obtained from the rate of increase in periodicals. A comparison between the 12th and 25th editions of Ulrich's International Periodicals Directory, for various sciences, is given in Table 1.

Table 1. Number of periodicals in print

Subject	2nd Edn (1967- 1968)	25th Edn (19861987)
Biology*	788	1592
Chemistry	380	588
Earth Sciences	266	575
Mathematics	225	428
Physics	282	524

**Basic biology, not including medicine, agriculture, forestry, horticlture, etc.*

The doubling time for periodicals in biology is about 20 years, but different sciences have developed at slightly different rates. It has been suggested (Price, 1963) that there is one periodical for every 100 scientists and that the increase in periodicals in each discipline reflects the increase in number of scientists in that particular discipline.

English as the Language of Science

Until about 1970, young scientists were advised to learn English and one or two other "languages of science", e.g., German, French or Russian. Nowadays, the emphasis is almost entirely on English. The reason is because English has become the dominant language of science. The degree of dominance is apparent from the contents of periodicals indexed in ISI's Science Citation Index. In an analysis of 700 000 papers indexed in 1986, Garfield (1987) produced the figures given in Table 2.

Table 2: Analysis of 700 000 papers in 1986 Science Citation Index, by language (%)

English	87.8
Russian	4.0
German	3.7
French	2.5
Japanese	0.8
Spanish	0.6
Others	0.6

Scientific Information Gets Devalued

Science does not have classics in the manner of religion or literature. If there are any classics in science they are considered only for archival reasons, as noteworthy episodes in the history of science. Newton's *Principia* is not used in the training of modem physicists. Biologists do not need to read Darwin's *Origin of Species (1859).* One can be a taxonomist without ever seeing a copy of Linnaeus' *Species Plantarum* (1753). Each of these scientific classics, which generated intense interest and enthusiasm at one time are now dealt with in college textbooks in the passing pages.

The development of science is very much the development of the concepts by which we interpret natural phenomena. The birth of an interesting new concept is accompanied by new observations, experiments, arguments, and by a deluge of scientific papers. Eventually, the whole issue gets condensed into one chapter of a textbook, later still into one page, or it may eventually even disappear. With the benefit of hindsight, all complicated issues can be rationalized, simplified and condensed, and this is what happens in science.

Even papers that deal with facts go through the same process. For example, a paper describing the properties of a newly discovered element may be important for some time but gets superseded by a review that summarizes and places this element in its proper place within the chemical system. The description of a new species of plant is soon absorbed into a regional flora,a forestry experiment into a forestry textbook, and so on.

Modern genetics acknowledges Gregor Mendel (1822-1884) as its founder, but reinterprets genetics according to the most recent concepts, not from Mendel's perspective, because although Mendel's discoveries were a big breakthrough in his time, they are rudimentary by present standards, and will become more so as genetics develops.

The process of reinterpretation, rationalization, simplification and condensation, from hindsight, ensures that science will never be overwhelmed by the rate at which scientific publications increase. The teaching of science also remains manageable because of this. Indeed, most topics in science get easier to teach as the topic matures because it is easier to teach something that is well understood than something that is poorly understood.

Getting Information from the System

Because scientific information is continuously generated, evaluated, and ultimately devalued by new developments, a scientist needs to adopt a dynamic attitude towards information. Information is to be scanned critically, used selectively, and discarded when no longer found useful. The best introduction to a topic in science is still a book, because a book would discuss the topic from first principles and gradually lead into the more complicated matters. However, books vastly differ in quality, content and style.

The content of a book becomes obsolete with age, but the rate of obsolescence varies with the topic. Given the current rates of development, books on biotechnology are obsolete if more than a few years old. On the other hand, taxonomic books are still cited (but not necessarily read) after 200 years because taxonomy has a strong archival component in its methodology, self-imposed by the rule of priority in nomenclature. We have to develop a feel for the rate of obsolescence in our own areas of interest. In general, we should be wary of any science book which is more than 20 years old.

Writing and presentation styles vary greatly, and the difference between a well-produced and a badly-produced book can be enormous. If we make a bad selection, we may waste a lot of time struggling through a bad book. Scientists are, on the whole, quite conditioned to reading badly written books, but it is unfortunate when librarians use up tight budgets on bad books when better ones are available. We cannot leave it to the librarians to assess the quality of books in specialized subjects.

Ideally, there should be, in science, a system of comparative reviews. Instead of reviewing a book in isolation, a reviewer should deal with a range of current books on the same subject at the same time, draw attention to the differences in content and presentation, and rate them accordingly. The current review system, based on complimentary books by publishers, which get to be reviewed singly and haphazardly, is quite unscientific. It is time for scientific book reviewing to be organized on a professional basis.

After getting a good introduction to a subject from a good book, we will need to refer to periodicals for more information, so as to keep up to date. Papers published in periodicals are usually very narrow in scope and are aimed at the author's peer group. Finding the papers relevant to one's own needs requires the approach of a prospector who quickly sorts through the dirt to find the gold. The task has become easier because of the development of electronic databases in which titles of articles and abstracts are stored for easy retrieval and selection. As the cost of subscribing to such databases comes down it should become possible within the next few years for even small, new and isolated research institutes to obtain this service, and thus, for the first time in history, to have a chance to narrow the information gap between themselves and the established scientific centres of the world.

Most papers can be scanned on the basis of the title. Scanning the titles of periodicals is an important activity for scientists because that is the best way to develop a feel for the speed and direction in which various topics are developing. Those titles that sound useful may be evaluated on the basis of the abstract. Of these, only the most promising ones, perhaps one in a hundred will warrant the trouble of requesting for a reprint, or a photocopy.

Established and competent scientists need to spend only a small proportion of their time reading articles in order to keep on top. They do this by scanning titles, reading selected abstracts and studying papers that are of real value.

At the beginning of our scientific careers, we need to spend a large amount of time reading, because we do not know enough to make value judgements. This is an unavoidable phase of the learning process, but we should try to get through this phase as quickly as possible.

In countries where English is not popularly used in daily communication, poor command of the language figures as a major drawback slowing down the development of young scientists. Anyone who has to stop and refer to a dictionary once in each paragraph already runs a high risk of wasting a lot of time labouring on articles that turn out to be of low value. A good command of English has become essential for scientists. Translation services are expensive and cannot keep up with the exponential increase in scientific publications. Moreover, the rate of devaluation of scientific information makes it futile to organize any systematic translation service at all.

Putting Information into the System: Writing for Publication

The main rule in scientific writing for publication is to keep the story simple and logical. For our own records, we need to write down exactly what happened during an investigation but we cannot publish what actually happened because few original investigations ever proceed along a straight and logical pathway. The original hypothesis gets modified along the way, the methodology is changed to cater to unforeseen problems and finally the results can be interpreted in more ways than one. In writing for publication, we have to apply the hindsight rule: choose the interpretations, then rationalize, simplify and condense the story, as if the whole investigation was planned and executed in a brilliantly logical manner. This is the only way to present work without dragging others through the same twists and turns that we may have gone through. The researcher is like an explorer who, after scouting out an unknown territory is able to take others across with the minimum of trouble.

One minor disadvantage of this approach is that administrators of science and the general public get fooled into thinking that science is completely logical and plannable. Partly because of this, we are all obliged to write detailed and logical proposals in order to get funds for research. However, there is a larger reason, which is to ensure that all of us have the ability to plan and communicate clearly. The main thing that could go wrong with a logical plan of investigation is when such a plan is carried out blindly.

The title is the part of the paper that will be most widely read. It must be short, yet contain the right words to attract the right kind of readers to go one step further, into the abstract.

The abstract is the representative part of the paper that will get into information databases. Therefore, it must say all the important things that are said in the paper. Do not say “this paper will describe the properties of x”. Say “the properties of x were found to be: a, b, c . . . . . " If there are no important things to say, then we must ask ourselves why we want to publish the paper at all.

Finally, the list of references should only contain those references that provide a necessary basis for our own paper. A paper to be published in a periodical is not a proposal for funding nor a thesis for examiners to vet. An unnecessarily long citation list wastes a lot of space and will not impress the edi tor

References

Garfield, E. 1987. English spoken here. The Scientist (Sept 7).

Price, D.J. deSolla 1963. Little Science, Big Science. Columbia Univ. Press , N.Y. pp 119.

Recommendations of the Third International Bamboo Workshop

Preamble

The Third International Bamboo Workshop was the largest gathering of scientific and technical experts of its kind in the world. Together, these experts represent much of the combined talent and current wisdom that currently exists on the bamboos.

The forum recognized the cardinal role that the sustained support, principally from the IDRC, has played in the promotion of bamboo research and in the bringing together of people working on this very important plant group, The increasing national support to bamboo research as well as the increasing interest of other donors in the bamboos was also recognized. Research on the bamboos is in many ways research for the upliftment of the poor as the resource is largely utilized by them.

International Cooperation in Bamboo Research

The forum unanimously agreed that greater international cooperation in different fields of bamboo research was imperative. Greater collaborative research and interaction among scientists was essential in order to make a significant headway in the gathering of information and the overcoming of problems related to various aspects of bamboo production and its utilization.

Three mechanisms were identified in the concluding session for greater international cooperation in bamboo research:

1. There was near unanimous support for the establishment of an International Centre for Bamboo Research (INBRI). This was deemed essential in order to bring greater focus on the plant and to bring together a critical mass of researchers to enable effective solution of research problems. In this context, attention was drawn to the vast progress in the agricultural crops through the establishment of research centres all over the world, with different institutes for different crops. While many favoured a centralized set up, some felt a decentralized INBRI would serve the needs better. Another suggestion was to have two centres, one for the monopodial and the other for the sympodial bamboos. Mention was also made of the possibility of having regional centres and sub-contracting the work to national laboratories.
2. The prime role of meetings such as the International Bamboo Workshop in promoting information exchange and interaction was emphasized. As agreed by all the participants, the role of this meeting in furthering international cooperation was self-evident and would have a lasting effect. It was, therefore, proposed that the meeting be further institutionalized. This would help in increasing coordination in research efforts. The setting up of national coordinating bodies was also suggested.
3. A program for exchange of scholars and scientists for a meaningful period of time for the learning of technical skills, furtherance of research and to facilitate greater exchange of information was also proposed.

Bamboo Society of India

During the concluding session, one of the members proposed the setting up of a Bamboo Society of India. There was all-round support for this proposal and Mr Karim Oka announced a grant of CAD 500 from the IDRC for supporting its activities.

Research Recommendations

The forum having recognized the work that has been accomplished in the last decade through the efforts of international agencies such as the IDRC, national agencies and other donors, drew attention to the following areas in which research needs to be continued or initiated. The wide range of research fields indicated is a reflection of the actual current need for research on the bamboos. The increase in the fields of research and overall interest in bamboo is also evident from the number of papers submitted to the Workshop. From a small number in 1980 to 52 in 1985 and to 69 in 1988 in successive Workshops represents a significant increase both in research interests and in the diversity of problems being investigated. Under each area of research, specific topics are given which the delegates felt required the attention of all concerned.

1. Propagation of bamboos

Development of methods for collection, storage and exchange of bamboo seeds; increasing the efficiency of conventional vegetative propagation methods including the use of growth regulators, better containers, etc.; use of tissue culture methods for the mass propagation of bamboos.

2. Conservation of the bamboo resource and its improvement

Collection of gene-pools in germplasm banks both in the regional and national contexts; germplasm exchange: the use of plant tissue culture methods to facilitate germplasm exchange was emphasized; collection of data on the flowering cycles of bamboo; work on the reproductive physiology of bamboos; research on the induction of flowering by both in vivo and in vitro methods; breeding and all items related to bamboo breeding for the improvement in quality; generation of variants through tissue culture.

3. Estimation of the present resource base

Documentation of the existing stock through remote sensing and field surveys; development of a field-guide for the identification of the bamboos.

4. Management of bamboo forests

Intensive management of monocultural stands; examination of the question of monoclonal versus polyclonal plantations; effect of spacing on productivity; management practices for maximizing production in a unit area; effect of fertilization on productivity; intercropping of bamboos with other plants; work on the allelopathic characteristics of bamboo.

5. Physiology, ecology and cytology of bamboos

Basic studies such as plant nutrition, plant-soil relationships, growth studies, water use efficiencies, photosynthetic efficiencies; matching of bamboos to soil conditions; effect of flooding on survival of bamboos; cytology of bamboos.

6. Diseases and pests of bamboos

Protection from pests and diseases especially in plantations.

7. Bamboo as a construction/housing material

Investigation into joints with bamboo to facilitate construction; strength properties as affected by specific applications; development of a design code for bamboo; establishment of an engineering database to facilitate the use of bamboo in the construction and building industry: biodeterioration management and alternative architectural strategies.

8. Ultilization of bamboos

Continuous product development to ensure that bamboo remains in vogue including engineering products for urban and rural use; documentation and dissemination of cottage industry technologies.

9. Economics of bamboo

Assessment of the employment generation potential of the bamboos; cultural-anthropological impact on product development; market surveys and development of marketing strategies: socio-economic implications of the depletion of the bamboo resource.

10. Bamboo information system

The BICs should be able to complement each other in compiling and disseminating all available information on the monopodial and sympodial bamboos.

Report on the Meeting of the Sub-group on 'Building and Engineering with Bamboo'

A meeting on Building and Engineering with Bamboo was organized on 15 November 1988 under the auspices of the Third International Bamboo Workshop at Cochin, Kerala, India, with Dr Jules Janssen as Chairman and Dr Geoff Boughton as Secretary. Twenty-seven other participants of the Bamboo Workshop were present.

The Chairman highlighted the status of the meeting as the first one of the Sub-group on Building and Engineering with Bamboo. Professor Hsuing, Chairman of IUFRO-P.5.04 as well as Dr R. Youngs, the Coordinator of P.5, had agreed to the convening of the meeting. The IUFRO Vice-President, Dr Salleh Mohd Nor, was also being informed.

The activities for the group (which appear in detail in the paper by Jules Janssen) deal with durability, properties, housing, larger buildings, bridges, roads, reinforced concrete, woven bamboos, plybamboo, chipped bamboo panels and piles. Publications on these topics will be prepared for researchers, designers and for education. The group will also take care of construction manuals, and standards for testing and building regulations.

The need for a grading system for bamboo and the development of a simple building code was emphasized by the participants. The generally felt need for information exchange and retrieval was also voiced. It was mentioned that the BICs in China and India could be of help in information exchange. Dr Cherla B. Sastry said IDRC would be willing to make CAD 5000 available for printing and distributing a small booklet on this subject. This booklet should contain an annotated bibliography. Volunteers for an editorial board were: Adkoli, Boughton, Chavez, Ghavami, Gutierrez, Janssen, Mukewar, Ranjan and Sastry (ex officio).

It was decided that the editiors would determine whether to include architects'opinions or to restrict the scope to physical and mechanical properties. The target group would in the first place be the scientists and in the second, the practitioners and users. The bibliography would be a State of the Art Report and would deal with the world situation. Dr Sastry offered the help of a computer search on the subject. The subjects "roads" and "piles" will be included in "bamboo and soil aspects" and Dr Douglas agreed to contribute on this point.

It was agreed that building codes for bamboo will have to be developed at three levels: the real scientific level (like CIB and ISO), on the second level, appropriate codes would be needed for individual countries and on the third level, many different codes for village levels. Dr Ghavami, Dr Low and Dr Janssen would participate in this work. The group was also informed that Dr Boughton is Chairman of the CIB-W. 18B group on a bamboo building code. During the discussion several aspects such as that of fire retardant treatments were considered. It was also pointed out that several countries have a bamboo building code which could be useful material. Even in North-eastern India, engineers have a bamboo handbook. The fact that over five to ten years would be required for the development of such a code was recognized by all.

A code is essential for the use of bamboo by governments. Nevertheless, simplified documents are also needed. One suggestion was that the code should try to reserve the construction techniques that have been used traditionally, while adding the necessary safety features. Another was of producing a code of building and philosophy in parallel.

It was decided that work on a bamboo building code would be carried out over the next three years. The next meeting of the sub-group was also scheduled (in all probability) for the next bamboo workshop.

Participants in the Third International Bamboo Workshop

Australia

MS CLAIRE HICKS
P.O. Box 252
Richmond NSW 2753

Dr GEOFF BOUGHTON
Senior Lecturer in Civil Engineering
Cur-tin University of Technology
GPO Box U1987
Perth WA 6001

Brazil

Prof K. GHAVAMI
Pontificia Univ.Catolica do Rio de Janerio
Department of Civil Engg.
Rua Marqves de Sao Vincente 225
Rio de Janeiro CEP 22433

Canada

Dr ROBERT A. DOUGLAS
Associate Professor
University of New Brunswick
P.O. Box 4400, Fredericton NB
Canada E3B 5A3

Costa Rica

Ms ANA CECILIA CHAVES
Director
Bamboo National Project
P.O. Box 4540
San Jose

Dr JORGE A. GUTIERREZ
Head, Dept of Res & Dev
Bamboo National Project
P.0, Box 4540
San Jose

Germany

Mr W. KIRCHHOF
Research Institute for Water
Technology at the Technical
University of Aac hen
Mies-van-der-Rohe-Strasse 17
D-5 100 Aachen

Prof W. LIESE
University of Hamburg
Leuschnerstr. 9 1
D Hamburg 80

ZDRC

Mr AK. OKA
Program Officer (Forestry)
International Development Research Centre
11 Jor Bagh
New Delhi 110 003, India

Dr CHERLA B. SASTRY
Senior Program Officer (Forestry)
International Development Research Centre
Tanglin, P.O. Box 101
Singapore 9 124
Republic of Singapore

India

Mr ABHAY M. GANDHE
Bharatiya Agro Industries Foundation
Uruli Kanchan
Pune412202

Mr A. ACHUTHAN
Conservator of Forests
Northern Circle
Calicut 673020

Mr N.S. ADKOLI
Joint Managing Director
Kamataka Pulpwood Ltd
No. 6/6/l 1, Crescent Road
High Grounds, Bangalore 560 00 1

Mr C.K. ANTONY
Working Plan Officer
Kerala Forest Department
Near Bishop Palace
Trichur 680 005

Mr K. BALACHANDRAN THAMPI
Conservator of Forests (Wildlife)
Forest Headquarters
Trivandrum 695 014

Prof N. BALAKRISHNAN NAIR
Chairman
State Committee on Science
Technology and Environment
TC/400, General Hospital Road
Trivandrum 695 037

Dr B BALAKRISHNAN
Regional Agricultural Research Station
Kerala Agricultural University
Kumarakom
Kottayam 686 566

Mr K.C. CHACKO
Silviculturist
Division of Silviculture
Kerala Forest Research Institute
Peechi 680 653

Mr M.C. DAS
Managing Director
Orissa Forest Development
Corporation, Satyanagar
Bhubaneswar 75 1 007

Dr P.M. GANAPATHY
Director
Indian Plywood Industries
Research Institute
Post Box No. 2273
Bangalore 560 022

Dr GEORGE MATHEW
Scientist .
Division of Entomology
Kerala Forest Research Institute
Peechi 680 653

Dr R. GNANAHARAN
Head
Division of Wood Science
Kerala Forest Research Institute
Peechi 680 653

Mr S. GOPALAKRISHNAN NAIR
Managing Director
Kerala State Bamboo Corporation Ltd
Angamaly

Mr M. GOVINDANKUTTY
Conservator of Forests
High Range Circle
Kottayam

Prof T. HARINATH BABU
Faculty of Ecosystem Management
Indian Institute of Forest Management
P.B. No. 357, Bhopa1462 003

Mr N.G. HEGDE
Vice President
Bharatiya Agro Industries
Foundation 'Kamadhenu',
Senapathy Bapat Marg
Pune411016

Prof U.C. JINDAL
Professor in Mechanical Engineering
Delhi College of Engineering
Kashmere Gate
Delhi 110 006

Mr JOHN KOILPARAMPIL
Conservator of Forests
Central Circle
Chempukavu
Trichur 680 020

Prof N.M. JOSEPH
Minister for Forests
Government of Kerala
Secretariat
Trivandrum 695 001

Mr KHARMUJAI
Meghalaya Forest Department
Shillong

Dr K.C. KOSHY
Tropical Botanic Garden & Research
Institute
Palode 695 562
Trivandrum

Mr C.N. KRISHNANKUTTY
Scientist
Division of Management
Kerala Forest Research Institute
Peechi 680 653

Mr A.K. KURIAN
Works Manager
Bamboo Board Factory
Angamaly

Mr A.C. LAKSHMANA
Conservator of Forests
Bellary Circle
Bellary 583 101

Mr LALRAM THANGA
DFO, Extension Division
Mizoram Forest Department
Aizwal, Mizoram

Dr LUCKINS C. BABU
Associate Professor
College of Forestry
Vellanikkara
Trichur 680 654

Mr MAMMEN CHUNDAMANNIL
Scientist
Management Division
Kerala Forest Research Institute
Peechi 680 653

Dr A.F. MASCARENHAS
Division of Biochemical Science
National Chemical Laboratory
Pune 411008

Mr MATHEW
Forest Department
Kerala

Dr A.R.R. MENON
Scientist
Division of Ecology
Kerala Forest Research Institute
Peechi 680 653

Mr H.N. MISHRA
Officer-in-Charge
Timber Engineering Branch
Forest Research Institute
New Forest PO.
Dehradun 248 006

Mr C. MOHANAN
Scientist
Division of Pathology
Kerala Forest Research
Institute
Peechi 680 653

Dr A.M. MUKEWAR
Associate Professor
Department of Forestry
College of Agriculture
Akola 444 00 1

Mr MUKTESH KUMAR
Scientist
Division of Botany (Taxonomy)
Kerala Forest Research Institute
Peechi 680 653

Dr P.K. MURALEEDHARAN
Scientist
Management Division
Kerala Forest Research Institute
Peechi 680 653

Mr K.K. NAIR
Komath House
Cannanore Road
Calicut 673 011

Dr K.S.S. NAIR
Director
Kerala Forest Research Institute
Peechi 680 653

Dr S. NARENDRA PRASAD
Wildlife Institute of India
New Forest PO.
Dehradun 248 006

Mr R.M. RAY
Conservator of Forests
Karnataka Forest Development Corpn. Limited
No. 6, Kumara Park East
Bangalore 560 00 1

Dr V.C. PATIL
Associate Professor of Agronomy
University of Agricultural
Sciences
Dharwad 580 005

Dr PRATAP SINGH
Officer in Charge
Entomology Branch
Forest Research Institute
New Forest PO.
Dehradun 248 006

Mr T. RAGHAVAN NAIR
Conservator of Forests
Southern Circle
Quilon

Dr I.V. RAMANUJA RAO
Research Scientist B
Department of Botany
University of Delhi
Delhi 110 007

Mr M.P. RANJAN
Chairman
Furniture Design
National Institute of Design
Paldi, Ahmedabad 380 007

Mr K. RAVINDRAN
Librarian
Kerala Forest Research Institute
Peechi 680 653

Mr SANJAY SAXENA
Tata Energy Research Institute
90 Jor Bagh
New Delhi 110 003

Dr SATISH KUMAR
Officer In-charge
Wood Preservation Branch
Forest Research Institute
New Forest PO.
Dehradun 248 006

Dr K.K. SEETHLAKSHMI
Scientist
Division of Plant Physiology
Kerala Forest Research Institute
Peechi 680 653

Mr K. SHANMUGHANATHAN
H 130/4 34th Cross Street
Basant Nagar
Madras 600 090

Mr SHYAM SUNDER
Principal Chief Conservator of Forests
Karnataka Forest Department
Bangalore 560 003

Mr SIDDHAPPA
Silvicultural Research Officer
Forest Department
Vazhuthacadu
Trivandrum 695 014

Mr M. SIVARAJAN
Principal Chief Conservator of Forestry
Forests Headquarters
Trivandrum 695 014

Mr C.K. SOMAN
Field Assistant
Kerala Forest Research Institute
Peechi 680 653

Mr V.R. SONTI
President
Ascu India Ltd
7A Elgin Road
Calcutta 700 020

Dr K. SREENIVASA RAO
SRA
CSR & Tl
Berhampore 742 10 1

Mr G.V. SUNDARAM
Manager (Forestry)
Hindustan Newsprint Ltd
Newsprint Nagar PO.
Kottayam 686 616

Mr T. SURENDRAN
Scientist
Division of Plant Physiology
Kerala Forest Research Institute
Peechi 680 653

Mr THOMAS P THOMAS
Scientist
Division of Soil Science
Kerala Forest Research Institute
Peechi 680 653

Mr D.S. TIPRE
Assistant General Manager-RM
Ballarpur Industries Ltd
Ballarpur 442 901

Dr I. USHA RAO
Reader
Department of Botany
University of Delhi
Delhi 110 007

Dr R. V. VARMA
Scientist
Division of Entomology
Kerala Forest Research Institute
Peechi 680 653

Mr S.S. ZOOLAGUD
Indian Plywood Industries
Research Institute
Post Box 2273, Tumkur Road
Bangalore 560 022

Indonesia

Prof ACHMAD SULTHONI
Faculty of Forestry
Gadjah Mada University
Bulaksumur, Yogyakarat

Dr ELIZABATH A WIDJAJA
Herbarium Bogoriense
Jl. Raya Juanda 22-24
Bogor 16122

Dr SOENARDI PRAWIROHATMODJO
Faculty of Forestry
Gadjah Mada University
Balaksumur, Yogyakarta

Kenya

Dr ANWAR-UL-HAQ
Ag. Dean
Faculty of Forest Resources and
Wildlife Management
MOI University, P.O. Box 3900
Eldore t

Mr JAMES MAINA WERE
Kenya Forestry Research Institute
P.O. Box 20412
Nairobi

Mr B.N. KIGOMO
Project Leader (Bamboo)
Kenya Forestry Research Institute
P.O. Box 204 12
Nairobi

Malaysia

Mr ABDUL LATIF MOHMOD
Forest Research Institute Malaysia
Kepong, Selangor
52109 Kuala Lumpur

Dr K. S. LOW
Forest Research Institute Malaysia
Kepong 52109, Kuala Lumpur

Dr RAZAK WAHAB
Forest Research Institute Malaysia
Kepong, Selangor
52 109, Kuala Lumpur

Nepal

Mr ANNAPURNA NANDA DAS
Research Officer
Forest Research & Information Centre
Department of Forests
Babar Mahal, Kathmandu

People 's Republic Of China

Mr FANG MINGYU
Subtropical Forestry Research Institute
The Chinese Academy of Forestry
Fuyang, Zhejiang

Mr FU MAOYI
Subtropical Forestry Research Institute
The Chinese Academy of Forestry
Fuyang, Zhejiang

Prof WENYUE HSIUNG
Nanjing Forestry University
Nanj ing

Mr ZHU SHI-LIN
Project Leader, BIC
Deputy Director
Institute of Scientech Information
Chinese Academy of Forestry
100091 Wan Shou Shan, Beijing

Philippines

Ms ZENITA B. ESPILOY
Forest Products Research and
Development Institute
College, Laguna 403 1

Singapore

Prof A. N. RAO
Secretary/ Treasurer, ANBS
Department of Botany
National University of Singapore
Lower Kent Ridge Road
Singapore 05 11

Tanzania

Dr T.N. LIPANGILE
Director
Wood-Bamboo Division
Ministry of Water
P.O. Box 570, Iringa

The Netherlands

Dr JULES JANSSEN
Eindhoven University
P.O. Box 513
5600 MB Eindhoven

United Kingdom

Ms NEELA DE ZOYSA
Oxford Forestry Institute
South Parks Road
Oxford OX1 3RB

Thailand

Dr ANAN ANANTACHOTE
Department of Forest Management
Faculty of Forestry
Kasetsart University
Bangkok 10903

Mr BOONCHOOB BOONTAWEE
Royal Forest Department
Phaholythin Road
Bangken
Bangkok 10900

Ms RUNGNAPAR VONGVIJITRA
Royal Forest Department
Phaholythin Road
Bangkhen
Bangkok 10900

Mr SAKONSAK RAMYARANGSI
Royal Forest Department
Phaholyothin Road
Bangkhen
Bangkok 10900

Dr SONGKRAM THAMMINCHA
Faculty of Forestry
Kasetsart University
Bangkok 10903

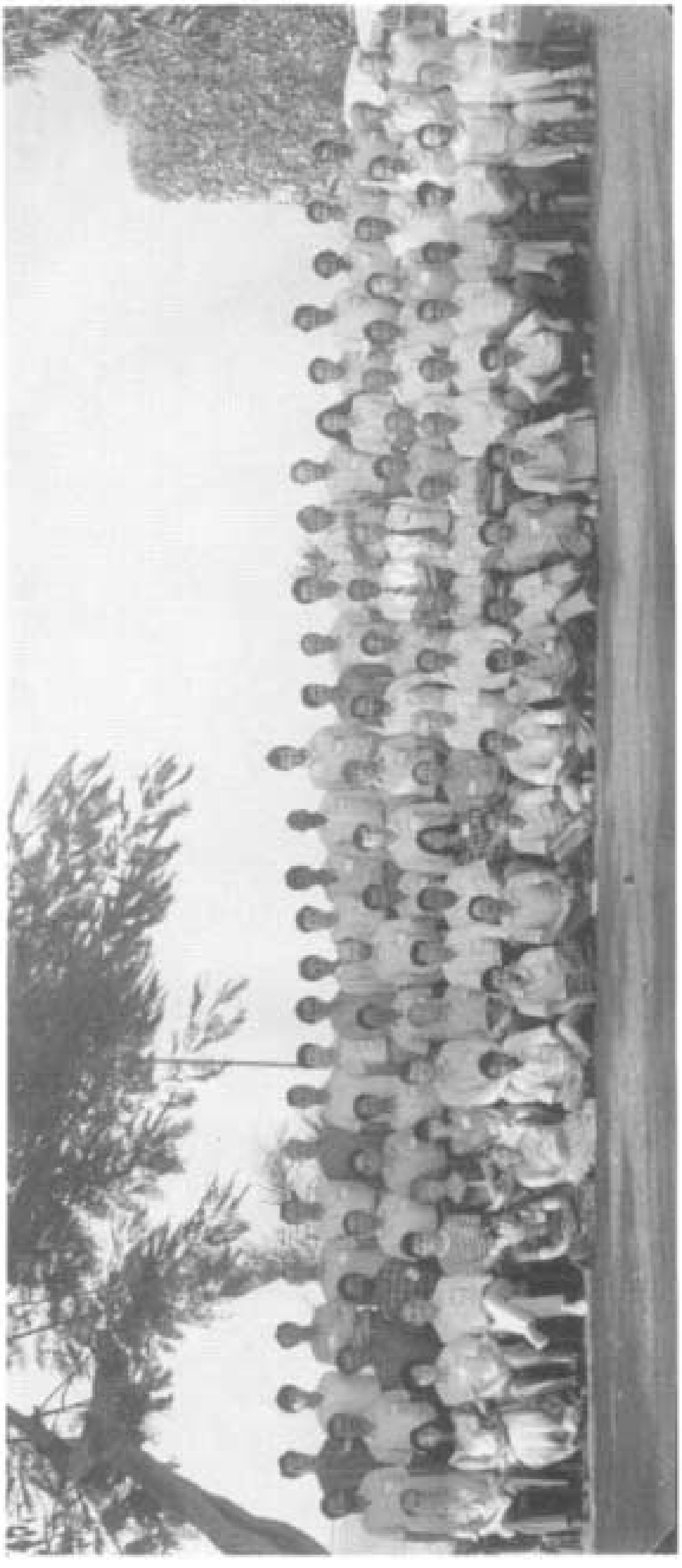
Opening session

Some of the distinguished participants

Coffee-time discussions!

Two of the sessions in progress

Two views of the field trip



Participants in the third International Bamboo Workshop

Typesetting and Page Layout by
Compubllshing Services
Blk 3026, Ubi Road I #O3- 180, Singapore 1440
Tel; 7433856 Fax: 7491595
Printed in Singapore

ISBN 98 100