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Culinary bamboo shoots in Australia: Preliminary Research Results

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by
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"Culinary Bamboo Shoots in Australia: Preliminary Research Results"

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Foreword

The funding of emerging rural industries is the key business of RIRDC, and the culinary bamboo shoot industry is one such example.

Based upon the premise of import substitution, the groundwork for establishing such an industry has evolved through the conduct of this project. Over the medium to long term, capacity to supply export markets will be developed.

Basic information that attests to the feasibility of the industry, relating to choice of species and the pivotal role of water availability and access to mineral nutrients, is one of the major outcomes of this project.

The support by RIRDC to the bamboo industry will continue, in the form of funding for a workshop to set the stage for the wider stakeholder consultation, the setting up of an Industry Body, and the refinement of research on production, post-harvest and marketing.

This evolution from collaborative links between researchers and industry representatives willing to take risks, to the reality of a fully supported Industry Body reflects one of the blueprints for success with which RIRDC wishes to be associated.

Peter Core
Managing Director
Rural Industries Research and Development Corporation

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Executive summary

Culinary bamboo shoots are an important vegetable with great market opportunities in Australia and particularly in Southeast and East Asia. However, commercial production of bamboo is virtually unknown in Australia.

This initial research was aiming at identifying the requirements for setting up a bamboo shoot industry in Australia. The major objectives were to:

1. identify species suitable for the production of culinary bamboo shoots under Australian conditions
2. gain expertise in the cultivation of bamboo species and to develop irrigation and fertiliser scheduling for optimum shoot growth
3. release trial quantities of fresh product onto the market to test its market potential
4. collate and extend information on species performance and agronomic technique.

To address these objectives, the following activities were undertaken:

(a) Installation of locally collected and imported bamboo species at a research site (Department of Primary Industry, DPIF) near Darwin in the Northern Territories, and at a commercial farm at Belli Park, Eumundi near Brisbane.

(b) Agronomic experiments superimposed on existing plantations of two bamboo species with different growth habits, *Phyllostachys pubescens* (a temperate 'runner' type also commonly known as 'Moso' and botanically as *P. heterocycla* var. *pubescens*) and *Bambusa oldhamii* (tropical 'clumping' type).

(c) Study propagation techniques for a number of different bamboo species.

(d) Monitor plant-protection requirements for bamboo cultivation.

(e) Study the agronomic practice of clump thinning for increasing productivity of the clumping-type bamboo *B. oldhamii*.

(f) Study main effects and interactions of irrigation and fertilisation on productivity of *P. pubescens* and *B. oldhamii*.

(g) Evaluate chemical composition of shoots produced in Australia.

(h) Survey the city market of Brisbane for the marketing of fresh Australian-grown bamboo shoots.

(i) Trial marketing of bamboo shoots in Melbourne.

(j) Broadcast research findings through meetings (workshops, courses and conferences), public exposure (publications and telecommunications) and interactions between research groups.

Preliminary outcomes are as follows:

1. At this stage, the number of bamboo species suitable for commercial production under Australian conditions may be reduced to the following species: ('clumpers') *B. oldhamii*, *Dendrocalamus asper*, *D. latiflorus*, and ('runner') *P. pubescens*. Commercial quantities of those species are now available in Australia and demand for bamboo planting material is steadily increasing.
2. For vegetative **propagation** of bamboo, timing (optimally at the beginning of the shooting season) seems to be crucial. Use of growth hormones (auxin) was not successful.
3. Diseases or pests did not seriously affect bamboo. However, **plant protection** for leaf rolling caterpillars may be necessary in the hot, wet season under Australian conditions.
4. There was some indication that early **thinning** (ie within the first two years of establishment) negatively affected bamboo growth in the Northern Territories. However at Belli Park, a greater number of old culms reduced the size (diameter) of new shoots.
5. 'Water' was the most important growth factor limiting growth of *P. pubescens* at Belli Park. **Irrigation** is crucial for successful bamboo production in areas of Australia where the natural water supply (eg rainfall) does not meet the high demand (approx. > 2,000 mm/year). As a shallow rooted crop, bamboo is vulnerable to soil drying. This is particularly true for the period of formation of young shoots. Therefore, timing of water supply is critical, with water required in spring, just prior to and during the shoot season of the crop when rainfall is limiting. Yield differences between bamboo grown under low and high irrigation increased over the years indicating a long-term effect of irrigation on bamboo productivity. Moreover, soil conditions in a *P. pubescens* plantation (eg soil N and C) were improved by higher irrigation. Data from a low-lying, flood-prone area indicate that bamboo is also susceptible to over-wet soil conditions.

6. Applying higher rates of **fertiliser** to bamboo cultivated at a lower rate of irrigation had no effect on growth and yield of *P. pubescens* and *B. oldhamii*. Therefore, 'nutrients' were regarded as only a secondarily important growth factor for bamboo. However, *P. pubescens* cultivated under high-irrigation conditions responded favourably to greater fertiliser rates: in contrast to the low-irrigation treatment, plant nutrient levels and yield were positively related to soil nutrient levels. Doubling the fertiliser rate doubled yields in *P. pubescens* under such conditions in 1996. In contrast to irrigation treatment, fertilisation had no 'memory' effect on bamboo performance. When the 'standard' fertiliser application rate was applied to the high-fertiliser plots in 1997, no effect of higher fertiliser rates applied in previous years on bamboo yield could be measured. Therefore, fertilisation must be regarded as a management tool to sustain bamboo productivity at a level governed by water supply and not as a practice to improve bamboo performance *per se*. Fertilisation exerted no effect on *B. oldhamii* presumably because only the 'standard' irrigation rate was applied and the plantation was younger than the *P. pubescens* stand.
7. Recorded yields (≈ 15 t/ha) with high irrigation and fertilisation are in line with published *P. pubescens* yields (10-20 t/ha) for the same species in Korea and Japan.
8. Chemical composition of Queensland-produced shoots was somewhat similar to those reported for Zhejiang Province (PRC) and Japan. Water content was within the range reported, while protein was approximately double, and carbohydrate and fat slightly less then reported elsewhere.
9. The survey of city markets in Brisbane showed a preference of owners of Asian supermarkets for minimally processed bamboo shoots. Therefore, it appears that in Brisbane there is currently no great potential for Australian fresh shoots to fetch higher prices than for the pickled product amongst Asians. Post-harvest treatments of Australian-produced shoots could open those markets. However, all bamboo shoots produced at Belli Park were readily marketed fresh at high price (according to thickness $4.50 thin to $10 thick) to Melbourne.
10. Results of this preliminary study have been broadcasted in a large number of workshops, courses and conferences. Written information is available as publications in the form of both scientific and public-press articles.

Introduction and Objectives

Most bamboo species produce edible shoots. These are the young culms harvested at the time of, or shortly after, their appearance above the soil surface. The shoots vary in size and quality and most commercially marketed shoots are derived from a small number of preferred species. Those species mainly originate from China, Taiwan, Thailand, Japan and Korea where bamboo shoots, as important constituents of stir-fry cuisine and specialised recipes, are produced and consumed in great quantities. There is a native Australian species, *B. arnhemica*. Wild stands along the Adelaide River are harvested by immigrant Vietnamese for sale into Melbourne.

More than 70 genera and 1,200 species of bamboo have been described, but only a few are grown commercially for their shoots. Those may be split into two groups: (1) the clumping types with short rhizomes (ie underground stems), botanically referred to as sympodial, and (2) the running types with long rhizomes, referred to as monopodial. The clumping types are more adapted to sub-tropical and tropical climates and produce larger shoots (up to five kilograms each) after mid-summer, while the runners are more adapted to cooler climates, and produce smaller shoots (usually not greater than 1.5 kilograms each) in spring. Given the range of bamboo species and their climatic adaptation, species from both groups may have potential to produce culinary bamboo shoots under Australia's diverse environmental conditions. These species need to be identified.

Besides selection of appropriate species, other constraints to establishment of a bamboo industry in Australia are the lack of suitably tested propagation techniques to improve availability of planting material, and the non-existence of relevant information on cultural manipulation of the crop under Australian conditions to achieve good yields of quality shoots. Varietal selection may be effective in overcoming temperature stress in bamboo (eg avoiding planting of clumping bamboo types in frost-prone areas) but other growth factors such as water and nutrients may be of overriding importance for effective shoot production. Since no local information on the agronomy of bamboo is available and information from overseas relates to production in areas differing in climate and soil, specific agronomic practices such as irrigation and fertilisation need to be developed for Australian conditions.

Development of an Australian bamboo-shoot industry offers opportunity to substitute fresh shoots for an estimated 6,000-12,000 tonnes of canned produce imported annually (MIDMORE, 1997). Until 1996, the Australian market for bamboo shoots was catered for by imported canned and preserved shoots. In 1992, those imports were estimated at 1,350 tonnes or $5.0 million value (DOLEY, 1992). However, an estimated 4,000 tones were imported annually in the 1980s. Given the increase in Asian tourists, students and residents, and the change in Australian consumption habits, this figure could have doubled by today. Besides this internal market, there is also an identified export market for Australian-grown bamboo shoots. The time of peak production in Australia (September until April) coincides with the months of scarcity for fresh shoots in Japan (November to March; Japanese market price $5-7/kg) and could make Japan a steady market for 250 tonnes per month with a monthly retail value of $1.25 million. Similar opportunities exist in countries with large Chinese communities such as Taiwan, Singapore, Malaysia and USA. Releasing trial quantities of fresh bamboo shoots onto Australian markets may be a first step to test the competitiveness of Australian-grown produce in the domestic and overseas markets.

This initial research was aiming at identifying the requirements for setting up a bamboo shoot industry in Australia. The major objectives were to:

1. identify species suitable for the production of culinary bamboo shoots under Australian conditions
2. gain expertise in the cultivation of bamboo species and to develop irrigation and fertiliser scheduling for optimum shoot growth, initially for *B. oldhamii* and *Ph. pubescens* (for which plantations exist) and planned for *D. asper* and *D. latiflorus* as plantations reach suitable age.
3. release trial quantities of fresh product onto the market to test its market potential
4. collate and extend information on species performance and agronomic technique.

1. To identify suitable species for the production of culinary bamboo shoots under Australian environmental conditions

In 1994, the Department of Primary Industry and Fisheries (DPIF) of the Northern Territory initiated research aiming at assessing the performance of different bamboo species at the Coastal Plains Research Station, south of Darwin. Soils at the station are sandy loams (10-15 % clay, 45% coarse sand and 28 % fine sand at 0-to-20-cm soil depth) with a low cation-exchange and moisture-holding capacity (pH 5.5). Meteorological data are presented in Table 1.1.

Table 1.1 ***Meteorological data from Darwin, 60 km north of the Coastal Plains Research Station (DPIF, Northern Territories)***

Month	Mean monthly precipitation (mm)	Mean monthly evaporation (mm)	Mean maximum temperature (°C)	Mean minimum temperature (°C)	Mean daily hours of sunshine (h)
Jan	414	200	31.8	24.8	5.7
Feb	345	170	31.4	24.6	5.9
Mar	309	185	31.8	24.4	6.8
Apr	101	215	32.6	23.9	8.7
May	20	225	31.9	22.1	9.5
Jun	1	210	30.5	19.9	9.9
Jul	1	225	30.4	19.3	10.0
Aug	6	235	31.2	20.6	10.2
Sep	17	245	32.4	23.1	9.8
Oct	72	260	33.1	25.0	9.5
Nov	143	245	33.1	25.3	8.4
Dec	229	230	32.6	25.2	7.2
Annual average	**1659**	**2645**	**31.9**	**23.2**	**8.5**

In a preliminary investigation, genotypes suitable for shoot production were identified for further evaluation. Those comprised 12 species gathered from around the Darwin area and 19 species (including timber, windbreak and ornamental types) purchased by DPIF funds. The latter collection included several plants of each *Dendrocalamus asper* and *D. latiflorus*, which were considered at the time to be the two preferred species for edible shoot production with *Bambusa oldhamii* for potential in Australia (Table 1.2).

Table 1.2 ***Planting of bamboo varieties at DPIF***

Bambusa arnhemica	*B. textilis*	*Gigantochloa apus*
B. arundinacea	*B. tuldoides*	*G. atter*
B. balcooa	*B. ventricosa*	*G. sp.* giant black
B. eutuldoides	*B. vulgaris*	*G. sp.* Timor Giant Black
B. glaucescens	*B. vulgaris* var. *vittata*	*G.* var. Malay dwarf variegated
B. longispiculata	*B. vulgaris* var. *wamin*	*Guadua angustifolia*
B. multiplex	*Dendrocalamus asper*	*Nastus elatus*
B. multiplex var. *riviereorum*	*D. brandisii*	*Pseudosasa japonica*
B. oldhamii	*D. latiflorus*	*Schizostachyzum brachycladum*
B. polymorpha	*D. strictus*	*Thyrostachys siamensis*

In late June 1995, Durnford Dart collected information and planting material in Thailand. Three hundred *D. asper* seedlings were returned to Brisbane, but the quarantine process destroyed all. Visits were made to the Melbourne Botanical Gardens and Zoo on 14/16 September and to Taroonga Park Zoo in Sydney on 18/19 to discuss new bamboo plantings and taxonomy.

In 1996, a non-performing variety (*Pseudosasa japonica*) under Darwin conditions was replaced by *Dendrocalamus giganteus*. The collection improved with better management practices. Several species show promise. *D. latiflorus* had impressive growth rates with production of large shoots, starting in mid-October. This species seems better adapted to local conditions. *D. asper*, although slow in production, formed good sized shoots. Observations so far indicate that *D. latiflorus* is particularly well suited to northern Australian conditions and is performing well in terms of size and vigour.

At Eumundi, six years after transplanting seedlings of *P. pubescens* to the field, yields exceeding 10 t/ha have been achieved. In this frost-prone site the performance of *D. asper* has been disappointing due to frost susceptibility. Growth of *B. oldhamii* has been very acceptable and eating quality of shoots is excellent.

2. To gain expertise in the cultivation of bamboo species and to develop agronomic practices such as irrigation and fertiliser scheduling for optimum shoot growth

Although shoots of almost any bamboo can be eaten, five principal genera are used commercially for shoots: *Arundinaria*, *Bambusa*, *Dendrocalamus*, *Gigantochloa* and *Phyllostachys*. The preferred species and variety varies across the traditional shoot-consuming populations of Southeast Asia. These species are grown as plantation crops in SE Asia and information from overseas relates to production in areas differing in climate and soil fertility. No local information on the agronomy of the crop is available. Therefore, experiments were established to quantify the influence of important agronomic practices such as propagation, thinning, irrigation and fertilisation on growth, clump form, canopy structure and shoot production of bamboo.

There are two typical types of bamboo, the temperate 'runner' or monopodial type and the tropical, sympodial 'clumper'. As representatives of these two types *Phyllostachys pubescens* (Mazel ex Houzeau de Lahaie) and *Bambusa oldhamii* (Munro), which are the most commonly consumed in Japan and China, and in Taiwan respectively, were chosen for studies on **fertilisation** and **irrigation**. *Dendrocalamus latiflorus*, a species difficult to multiply, was used for the **propagation** study as was *D. asper* and *D. latiflorus*. *B. oldhamii* in an established plantation was used for investigations on **clump thinning**. Experiments entailing fertilisation and irrigation treatments were purpose-planted at DPIF near Darwin and superimposed on an existing plantation at D. Dart's farm at Belli Park near Eumundi. Propagation and clump-thinning practices were studied at DPIF. Other agronomic results at DPIF are related to **plant protection**.

2.1 Propagation

In 1996, a bamboo mist propagation system was set up at DPIF to study propagation of *B. oldhamii*, *D. asper* and *D. latiflorus*. Bamboo cuttings were taken in mid-January 1997 from mid-culm nodes with culms 12-18 months old. A single distal branch bud was retained on each cutting and basal bud. Cuttings were drenched in fungicide ('Fongarid') and inserted into a medium consisting of equal parts of coarse sand, peat moss and pine bark. Cuttings were misted for 10 seconds per 10 minutes during daytime and for 4 seconds per 200 minutes during nights. Temperature was kept at 28-30°C. Ambient and growth medium temperature, and humidity were monitored with a datalogger.

The trial was set up in January 1997 to study the effect of growth regulators on propagation of branch cuttings of *D. latiflorus*, a species difficult to multiply. Treatments comprised one control, two rooting auxins (NAA and IBA as the two most commonly used auxins in the bamboo literature) and two auxin concentrations (100 and 500 ppm). Each treatment had three replications of eight cuttings giving a total of 24 cuttings per treatment. The hormones were dissolved in a small quantity of ethyl alcohol and then added to water. The cuttings were soaked for 24 hours in the solutions.

Results from the mist propagation systems indicate that timing is crucial for successful propagation of bamboo. Branch cuttings should be taken at the beginning of the active growth period in September/October when carbohydrate reserves are high after the long dormant phase during the dry season. When cuttings were taken too late in the season (eg in January as they were in this trial), buds may remain dormant and eventually rot. The stage of maturity of the branch may also be crucial for successful propagation.

All auxin treatments improved root initiation and development compared to the control (Table 2.1). The control treatment readily developed shoots from upper buds,

Table 2.1 ***Effect of auxin on root and shoot development in bamboo cuttings***

Treatment	Root Development		Shoot Development	
	No.	%	No.	%
NAA 100ppm	7	29.2	3	12.5
NAA 500ppm	7	29.2	0	0
IBA 100ppm	8	33.3	4	16.7
IBA 500ppm	9	37.5	1	4.2
Control	2	8.3	14	58.3

$n = 24$

whereas the auxin treatments inhibited bud development. Cuttings which developed roots but failed to form shoots from upper or basal buds eventually died. The higher concentration of both rooting auxins significantly reduced shoot development. The visible presence of root primordia at the base of harvested cuttings was not related to development of true roots (Table 2.2).

Table 2.2 ***Development of roots of bamboo cuttings as affected by presence of root primordia present on the parental stock***

Treatment	Total Cuttings	With Root primordia	Root Development	Without root primordia	Root Development
NAA 100ppm	24	13	3	11	4
NAA 500ppm	24	13	4	11	3
IBA 100ppm	24	11	5	13	3
IBA 500ppm	24	8	2	16	7
Control	24	11	0	13	2

2.2 Plant protection

Leaf rolling caterpillars appeared as a specific pest problem during the first rainy season after establishment at DPIF. This was effectively controlled by synthetic pyrethroids. A majority of trial plants were infested with a hard scale on the culms, which were reasonably controlled with spraying oils. After culm thinning its severity decreased. A soft scale on the leaves was not considered to be a problem at this early growing stage. The insect pests only appeared in the wet season after the first year of growth.

2.3 Clump thinning

Assuming that bamboo will be marketed for both edible shoots and timber, thinning of (1) new stems (ie leaving a certain number of shoots per clump for re-growth after harvest) and (2) old stems (ie cutting stems at a certain age to be marketed as timber) must be considered. A balance must be struck between leaving sufficient culms to capture available radiation for photosynthesis, and removing culms to ensure access into clumps for shoot harvest. There are some indications that by leaving many culms in each clump, numbers of new shoots may be diminished.

DPIF trials

Clump thinning trials were conducted at DPIF at the onset of the dry seasons in April 1996 and April 1997 on material transplanted April 1995. In 1996, *B. oldhamii* plants were thinned to 10-12 culms with handsaws, leaving 2-4 old (1 year or older) and 8-10 recent young culms per clump. In 1997, plants were thinned with power sabre saws to 12-14 culms, which included 3-5 old (1 year or older) culms and 9-11 recent young culms. Mechanised thinning proved to be superior to hand thinning. The thinning material was trashed with a stationary chipper/mulcher and mulched around the base of the bamboo plants.

Hand thinning proved to be a major operation with each clump taking 20-30 minutes to complete. In 1997, mechanised thinning required fewer man-hours while mulching with a power chipper required considerable time and proved uneconomic.

Some sunburn occurred on immature green culms immediately after thinning in 1996. Thinning negatively affected plant growth during the dry season of 1996 and there was no new shoot production until the onset of the rainy season in October 1996. This contrasts to growth in 1995 when shoots were continuously formed on a restricted basis through the 'dry' season. During October and November 1996, with high ambient temperatures and high relative humidity, shoot production was slow but increased with the monsoon rains in December.

The average total number of culms per clump before thinning in 1997 was 37, an increase of 25-26 culms per plant since the first thinning operation in 1996. Two months after thinning in 1997, culm sizes were variable, with many current year culms being smaller than the older material and less than 50 mm in diameter. Overcast skies during the heavy wet season may have affected culm size and maturity although the total culm number was high.

Trials at D. Dart's farm, Belli Park

In June 1996, thinning treatments were imposed on an existing 4-year-old stand of *B. oldhamii*. During 1996 and 1997, 4 old stems (> 1 year) and a certain number of new stems (2, 3, 4, 5, 6 and 7) were left for each clump after thinning. At the end of 1997 these treatments were modified to include thinning of older stems for timber. The experiment is now a 1-factorial (4 levels) with four replications (16 plots) and 3 clumps per plot (48 clumps). The thinning treatment has four levels:

Table 2.3 ***Treatments in the thinning trial at Belli Park***

Number of 1-year-old stems	Number of 2-year-old stems	Number of 3-year-old stems
1	1	1
2	2	2
3	3	3
4	4	4

After each year's harvest, 1 to 4 stems will be allowed to re-grow, and all stems older than 3 years will be removed and sold for timber. Shoot yield (numbers, size and weight) will be recorded.

2.4 Irrigation and fertilisation

DPIF trials

Agronomic experiments in the Northern Territories were laid out as a randomised split-block design including 'irrigation' with three levels (low, medium, high) as the main-plot factor and 'fertilisation' with three levels (low, medium, high) as the sub-plot factor in three replications. *B. oldhamii* bamboo was established in February 1995 by transplanting seedlings at seven-meter intervals along rows eight meters apart, giving 18 plants per plot (total 162 plants in each block).

Irrigation rates were calculated using the 'evaporation replacement method', re-plenishing 90% (CF 0.9) of the area's evaporation. Based on an estimated canopy area of 19.6 m^2 and a maximum daily evaporation of 8.0 mm, the irrigation rate is 140 l/clump/day. This is supplied in the dry season from April until November. Irrigation treatments included (Table 2.3):

Table 2.3 ***Irrigation treatments at DPIF***

Evaporation Replacement (%)	Irrigation Volume (l/week/plant)
90 (CF 0.9)	987
70 (CF 0.7)	768
30 (CF 0.3)	329

Soil moisture tensiometers were installed in the three irrigation treatments with three replications. Installation depth was 20, 40 and 80 cm. Sprinkler outputs and lateral flow rates were tested, with pressure control units installed to ensure uniform irrigation distribution over the trial area. Tensiometer readings were recorded twice per week. Irrigation treatments will be imposed at the end of the 1997/98 wet season and will continue until the onset of the wet season in November/December 1999.

During 1995, fertiliser was applied at monthly intervals with alternately 150 g NPK (as 'Nitrophoska Blue Special'; 12:5:14 N:P:K) and 150 g urea per plant. From the beginning of 1996 until mid 1997, the rate was increased to 200 g/plant of each fertiliser type which corresponds to a rate of 198:16:43 kg N:P:K per hectare per year. Subsequent treatments were based on a 4:1:3 ratio of N:P:K which was derived according to reports in the literature on bamboo and other perennial grasses.

Before superimposing fertiliser treatments after mid 1997, soil and leaf (youngest fully expanded) samples were analysed. Leaf data were compared with standards for sugarcane as a preliminary guide until optimal values for bamboo have been developed (Table 2.4).

Table 2.4 ***Analysis of soil and leaf in bamboo over three dates at DPIF, Northern Territories, and standards for sugarcane leaf nutrient concentrations***

Soil Analysis				Leaf Analysis			
	Oct 1996	Jan 1997	Aug 1997		standard (sugarcane)	Oct 1996	Aug 1997
pH (1:5 water)	6.1	5.8	5.8	N (%)	1.8-2.5	2.43	2.86
EC (dS/m)	0.05	0.04	0.05	P (%)	0.19-0.25	0.21	0.20
P (ppm)	7	9	6	K (%)	1.11-2.50	1.64	1.55
K (ppm)	70	30	50	Ca (%)	0.20-0.50	0.18	0.17
Ca (ppm)	270	270	420	Mg (%)	0.20-1.0	0.21	0.19
Mg (ppm)	160	150	220	Zn (ppm)	10-50	19	16
Zn (ppm)	0.3	0.2	0.6	Mn (ppm)	15-400	168	208
S (ppm)	12	8.1	7.9	Fe (ppm)	50-200	77	91
				B (ppm)	1-30	14	9

Experimental fertiliser application rates are presented in Table 2.5 and schedules in Table 2.6.

Table 2.5 ***Fertiliser treatments at DPIF, Northern Territories (installed mid-1997)***

Treatment	N	P	K
		(kg/ha)	
low	100	25	75
medium	200	50	150
high	300	75	225

Table 2.6 ***Fertiliser schedules at DPIF, Northern territories***

50 % before harvest period

- 40 days before shoot emergence (25 %)
- 20 days before shoot emergence (25 %)

30 % after harvest period

- immediately after harvest (15 %)
- 20 days after harvest (15 %)

20 % after thinning

There is some indication that leaf nutrient concentrations of bamboo before applying different fertiliser rates were in line with optimal sugarcane levels although calcium levels seemed to be low and potassium levels probably marginal.

Trials at D. Dart's farm, Belli Park

Representative meteorological and soil data for the site are presented in Table 2.7 and 2.8.

Table 2.7 ***Meteorological data (twenty-five year averages) from Nambour, 25 km south of Belli Park***

Month	Mean monthly precipitation (mm)	Mean monthly evaporation (mm)	Mean maximum temperature (°C)	Mean minimum temperature (°C)	Mean daily hours of sunshine (h)
Jan	293	176	28.5	19.1	6.5
Feb	276	133	28.1	19.3	6.0
Mar	260	129	27.4	18.1	6.2
Apr	137	115	25.8	15.0	7.0
May	111	87	23.1	11.4	6.4
Jun	84	77	21.4	9.2	6.5
Jul	93	83	20.7	6.9	7.3
Aug	48	101	22.1	7.5	7.6
Sep	48	123	24.1	10.0	7.7
Oct	114	153	26.0	13.4	7.7
Nov	155	164	27.4	16.1	8.0
Dec	178	185	28.6	17.8	7.4
Annual average	**1797**	**1524**	**25.3**	**13.7**	**7.0**

Table 2.8 ***Soil chemical attributes at Belli Park in 1990***

Attribute	Value	Attribute	Value
pH ($CaCl_2$)	4.3	Ca (meq/100g)	1.50
CEC (meq/100g)	4.7	Mg (meq/100g)	1.05
P (Bray-mg/kg)	3.0	Al (meq/100g)	1.30

Experimental plots were superimposed in October 1994 on established *P. pubescens* and *B. oldhamii* stands. In November 1990, 18-month-old seedlings of *P. pubes-*

cens were planted at six-metre intervals along rows seven meters apart. The *B. oldhamii* stand, established in March 1991, was planted in rows six metres apart with five metres between plants. Plants of *B. oldhamii* were derived from cuttings. Clumps were thinned in 1994 by removing three-year-old stems, thus maintaining an open habit and encouraging radial spread of the plant along and out from the planting row.

Blood and bone fertiliser was applied at planting and N:P:K (25:5:14.1) fertiliser at 1,000 kg/ha at six-month intervals prior to the beginning of the *P. pubescens* experiment. The *P. pubescens* stand was irrigated by overhead impact sprinklers along lines placed between rows. Water flow to the treatment areas was monitored with in line flow meters. Microjet sprinklers, one placed in the middle of each clump, were used to irrigate the *B. oldhamii* stand.

Phyllostachys pubescens

Four years after planting of the 'runner' bamboo, the experimental area was split into two irrigation blocks. Both high-irrigation and low-irrigation blocks were fed by the same main line. They had regular (ie farmer determined) irrigation rate, but the high irrigation block had an additional irrigation line of rotary sprinklers along each row. Approximately 50 % more water was applied to plots in the high-irrigation treatment, beginning 1994. Figure 2.1 shows water application rates in both irrigation rates in 1996.

Each irrigation block was split into four replicate rows, with three plots along each row randomly assigned one of three fertiliser treatments: the farmer's rate

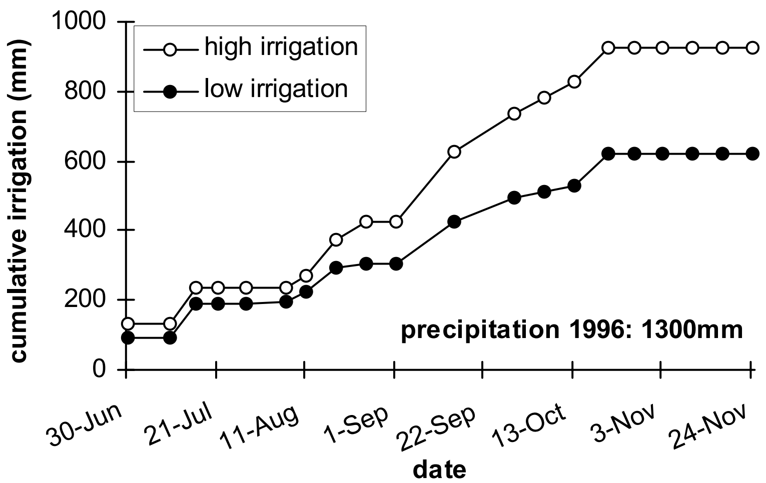

Fig. 2.1 ***Irrigation rates and precipitation in the* P. pubescens *irrigation-and-fertiliser trial at Belli Park in 1996***

(250:50:141 kg/ha N:P:K), 1.5 and 2 times the farmer's rate. Fertiliser treatments were applied in 1995 and 1996, but in 1997 the low (farmer’s) rate was used for all treatments. Tensiometers at 30 cm and 60 cm depths were installed in two plots (the highest fertiliser rates in both high and low irrigation) and were read periodically from November 1994. Water-stress indexes were calculated as an average of the 30-cm soil depth tensiometer data using the formula:

$$T_m = \frac{\sum_{i=0}^{m}((d_{i+1} - d_i)t_i)}{\sum_{i=0}^{m}(d_{i+1} - d_i)} \qquad \text{[kPa]}$$

where: T_m is the water-stress index (kPa), i represents a single time of tension measurement, m represents the total number of readings, d represents the Julian day of the year when a reading was made, (d_{i+1}-d_i) is the time interval in days between successive readings, and t_i is the moisture tension at a single time.

Leaf samples (youngest fully expanded) from each plot were analysed for mineral nutrient content at the start of the experiment in 1994, and in 1995 and 1996. Soil samples (30-cm depth) were analysed in 1994 and 1996. Weekly counts of new shoots that emerged during the shooting season (late winter to early spring in 1994 and 1995) and their diameters (at soil level) were taken in a 1-meter-wide transect within the center of each plot. Shoots were not removed for weighing, but they were left in the field for the development of new culms. Yield was recorded in 1996 and 1997 as number of shoots, shoot weight and shoot diameter in each plot. Main effects of fertiliser and irrigation and their interaction were analysed with ANOVA techniques.

In 1994, the number of new culms emerging during the shooting season tended to be greater (statistically not significant, P = 0.26) in the high-irrigation treatment (Figure 2.2, top). No influence of fertilisation on shoot emergence could be determined in that season (Figure 2.2, bottom), neither across irrigation rates (error bars), nor within individual irrigation treatments (P values).

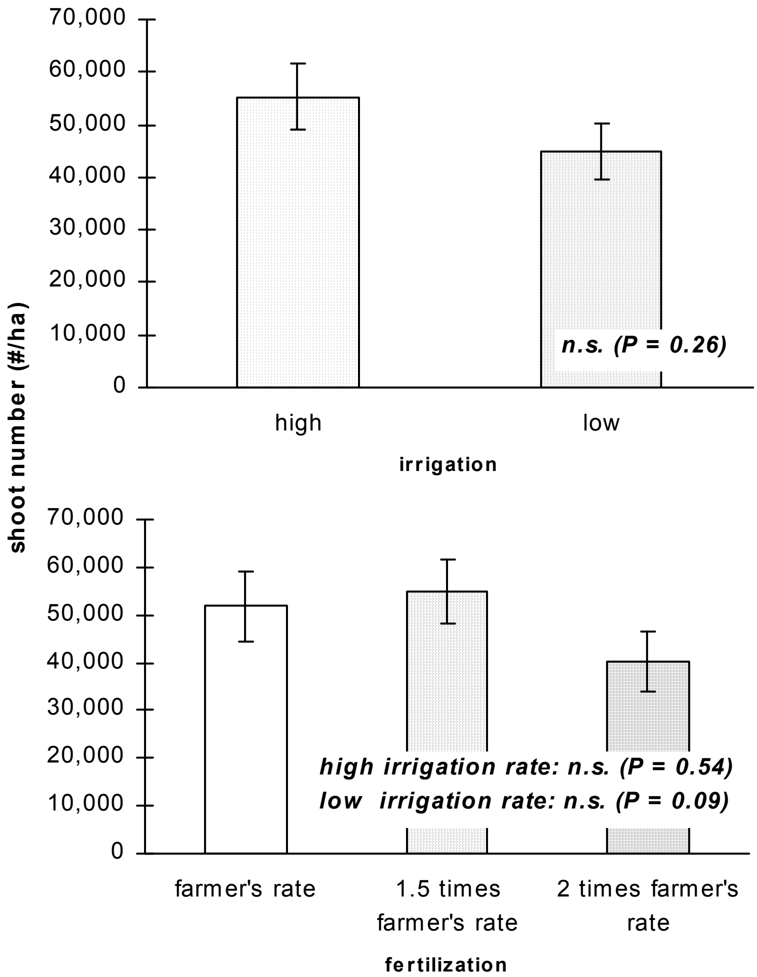

Fig. 2.2 ***Effect of (top) irrigation and (bottom) fertilisation on shoot numbers of* P. pubescens *at Belli Park in 1994 (error bars indicate standard errors, P-values indicate significance levels of mean separation tests)***

In 1995, significantly more shoots were produced in the low irrigation treatment (Figure 2.3, top), but fertilisation exerted no effect on shoot production in that year (Figure 2.3, bottom). However, the fertiliser effect was greater in the high-irrigation treatment compared with the low-irrigation treatment as indicated by a lower *P* value (0.32 cf. 0.68). While a lower number of shoots was produced in the high-irrigation treatment (Figure 2.4, top), each shoot with high-irrigation treatment was significantly larger, as indicated by their average shoot diameter (Figure 2.4, bottom). The effect of irrigation on shoot-size was stronger than that on shoot-count (*P* values: 0.01 cf.0.04).

A few fresh shoots of *P. pubescens* were removed for chemical analysis (Table 2.9). While water content was within the range of published figures, protein at five percent fresh weight was approximately double and carbohydrate and fat slightly less than reported in other studies.

Table 2.9 ***Chemical composition of* P. pubescens *shoots harvested at Eumundi in 1995***

Moisture	Fat	Protein	Ash	Carbo-hydrates	Crude fibre	Sugars	(Glucose	Fructose	Sucrose)
					(%)				
89.1	0.2	4.6	1.2	5.0	1.4	0.5	0.2	0.3	0.0

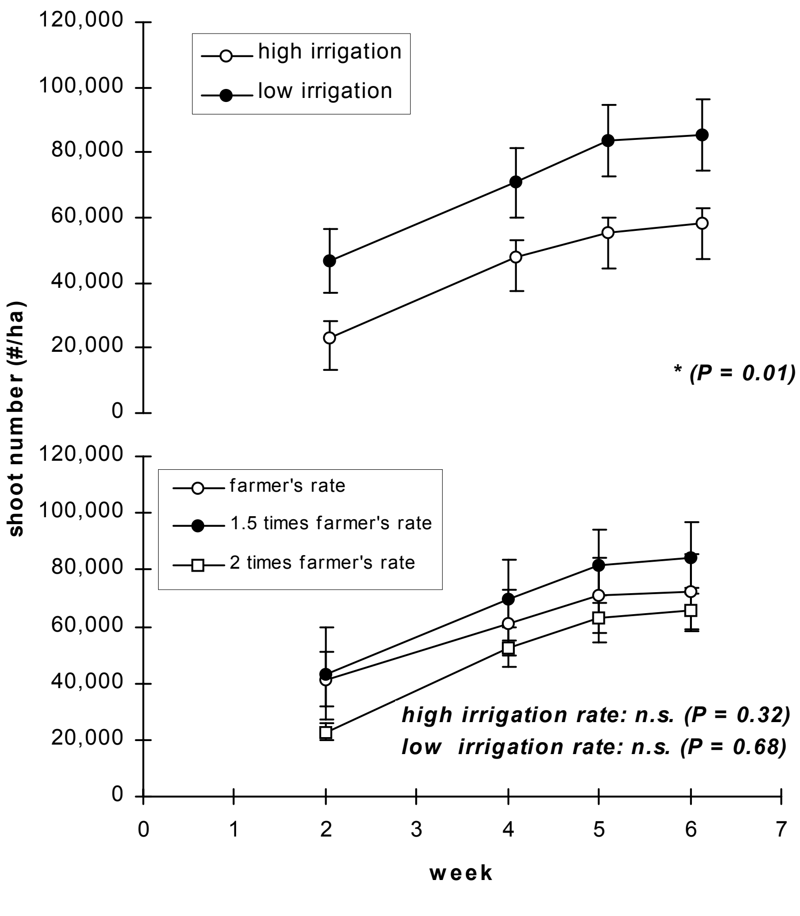

Fig. 2.3 ***Effect of (top) irrigation and (bottom) fertilisation on shoot production of* P. pubescens *at Belli Park in 1995 (Error bars represent standard errors, P values indicate significance levels of mean separation tests for the final data)***

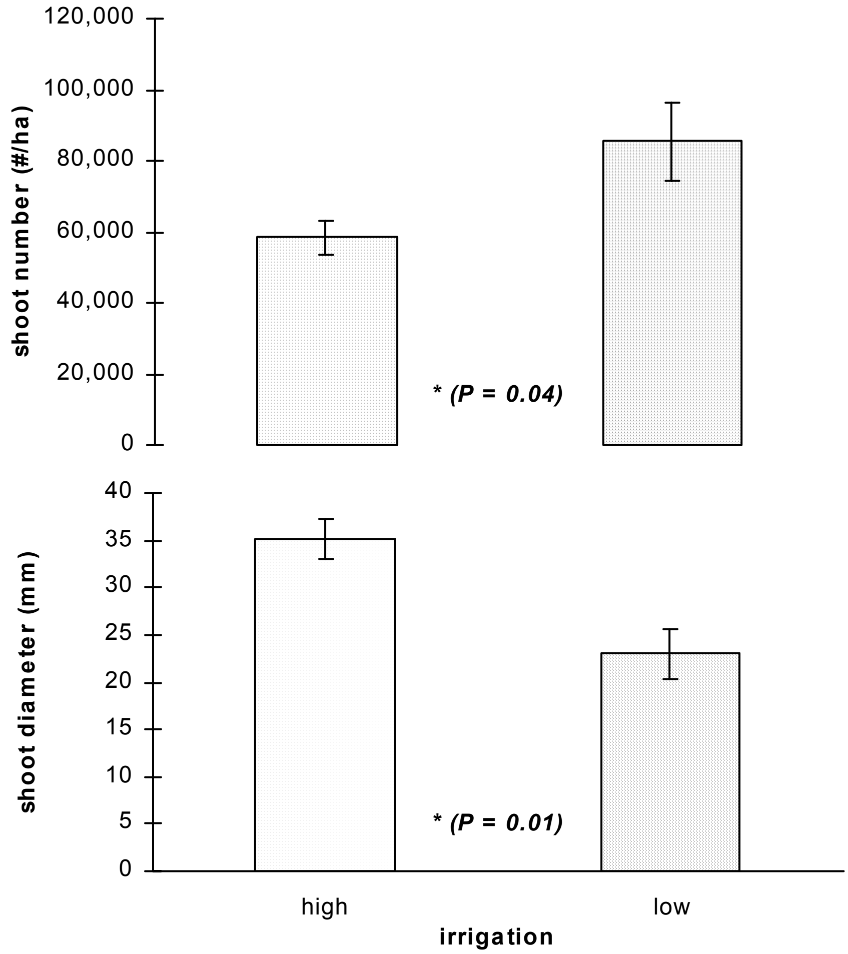

Fig. 2.4 ***Effect of high irrigation on (top) total shoot number and (bottom) shoot diameter of*** **P. pubescens** ***at Belli Park in 1995***

In 1996, shoots were harvested commercially for the first time. Cumulative yield was greater in the high-irrigation treatment (Figure 2.5, top). Although more yield was produced when the fertiliser rate was doubled, this effect was statistically not significant as indicated by *P* values (Figure 2.5, bottom). However, the influence of fertiliser rate on yields was greater under the high irrigation rate ($P = 0.17$; figure 2.6, top) than under the low irrigation rate ($P = 0.91$; figure 2.6, bottom). Figure 2.7 emphasises this observation: there was no response to fertilisation when irrigation rates were low but the greater fertiliser rate almost doubled the total shoot yields when additional irrigation was applied.

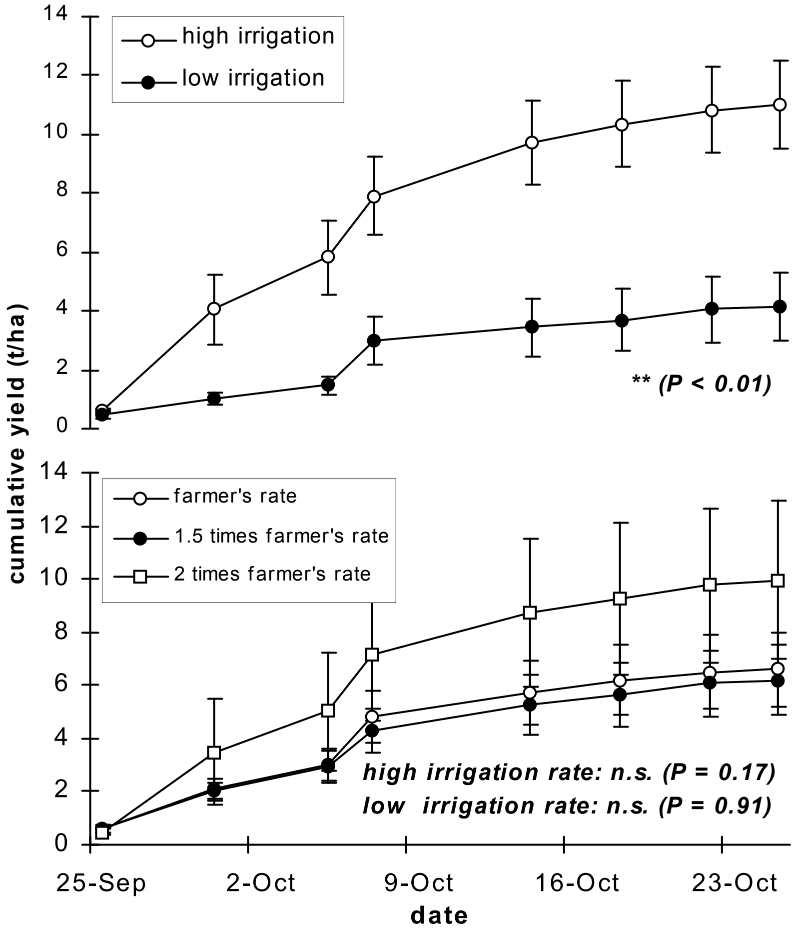

Fig. 2.5 ***Effect of (top) irrigation and (bottom) fertilisation on cumulative yield of* P. pubescens *at Belli Park in 1996***

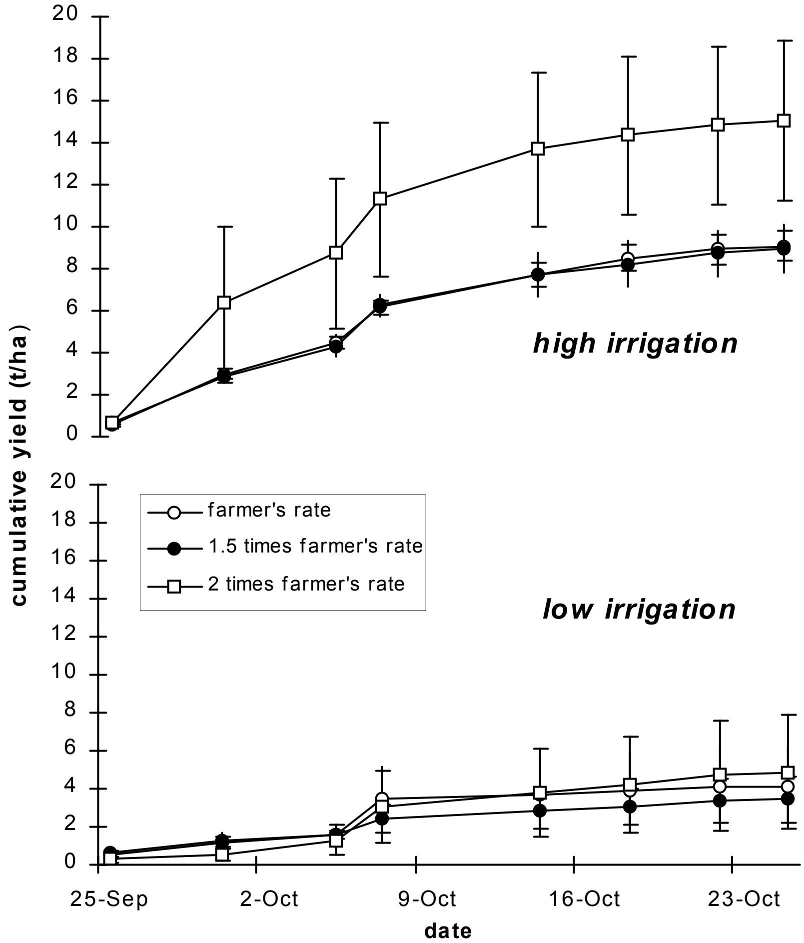

Fig. 2.6 ***Effect of fertilisation under (top) high irrigation and (bottom) low irrigation on cumulative yield of*** **P. pubescens** ***at Belli Park in 1996***

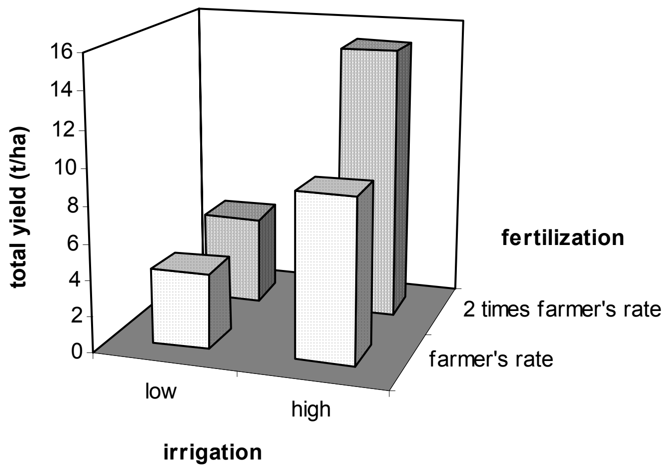

Fig. 2.7 ***Effect of irrigation and fertilisation on total yields of*** **P. pubescens** ***at Belli Park in 1996***

In 1996, higher irrigation improved all yield parameters in bamboo (Figure 2.8): shoot number was significantly greater (top). Shoot diameter (middle) and shoot weight (bottom) tended to be greater (not significant).

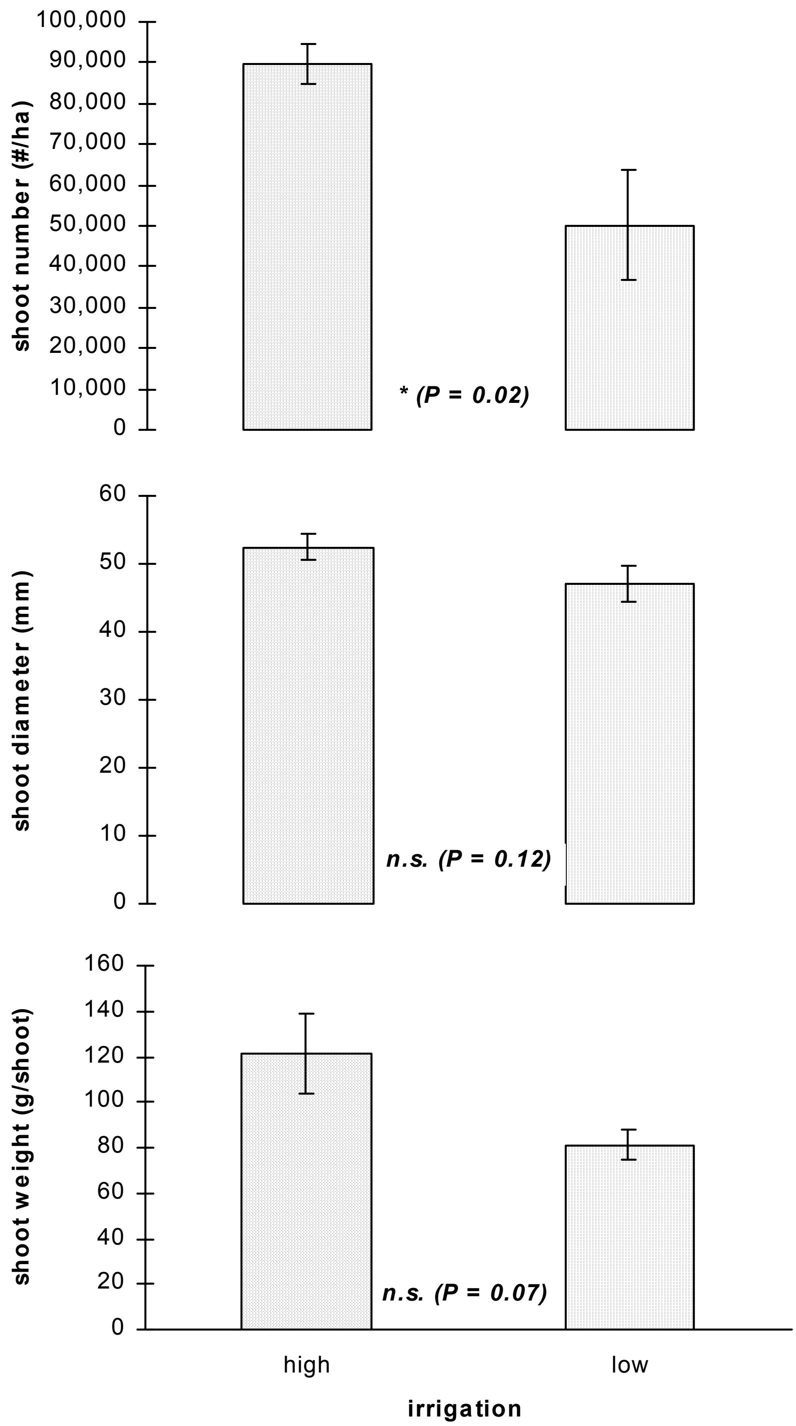

Fig. 2.8 ***Effect of irrigation on (top) number, (middle) diameter and (bottom) weight of harvested shoots of*** **P. pubescens** ***at Belli Park in 1996***

The influence of irrigation on bamboo performance was highly significant in 1997 (Figure 2.9, top). The standard (farmer's) fertiliser rate was applied to all plots and no residual treatment effects from previous years of fertilisation could be measured (Figure 2.9, bottom).

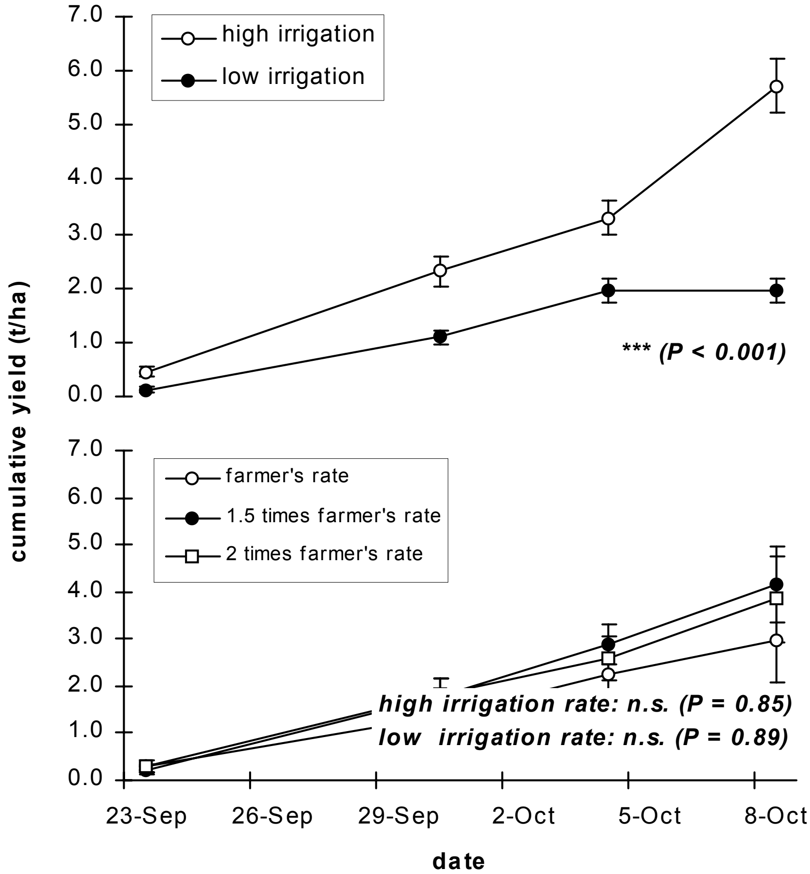

Fig. 2.9 *Effect of (top) irrigation and (bottom) fertilisation on cumulative yield of* **P. pubescens** *at Belli Park in 1997*

All yield parameters were significantly improved by the greater irrigation rate (Figure 2.10).

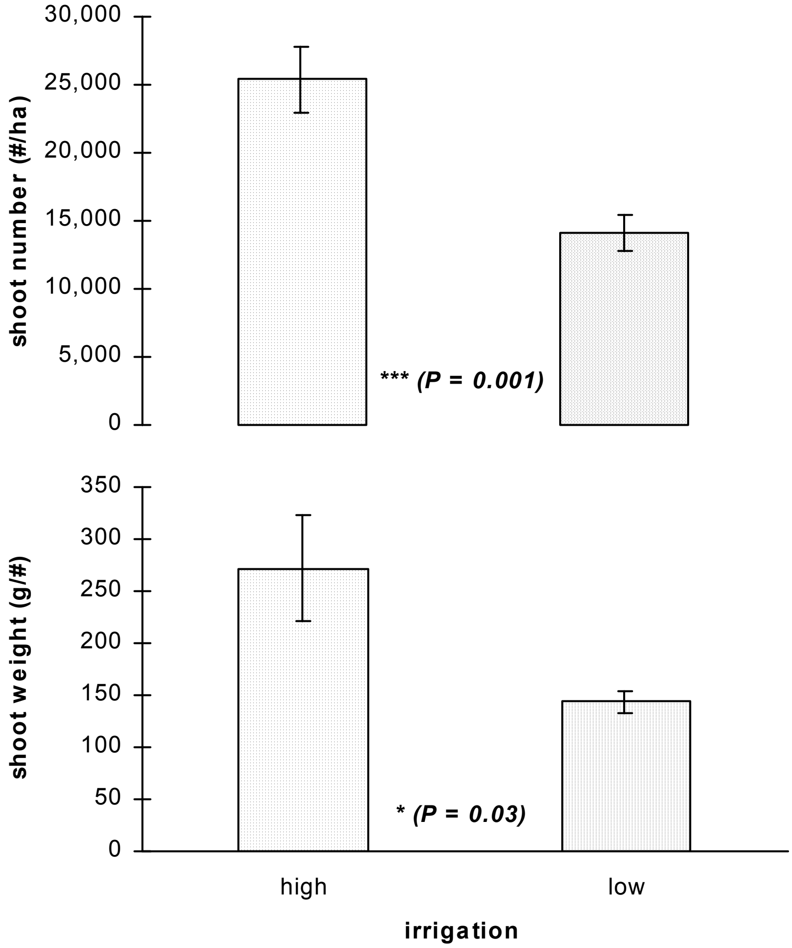

Fig. 2.10 ***Effect of irrigation on (top) number and (bottom) weight of harvested shoots of* P. pubescens *at Belli Park in 1997***

To explain treatment effects on bamboo performance, a simple growth model was applied to the data collected (Figure 2.11).

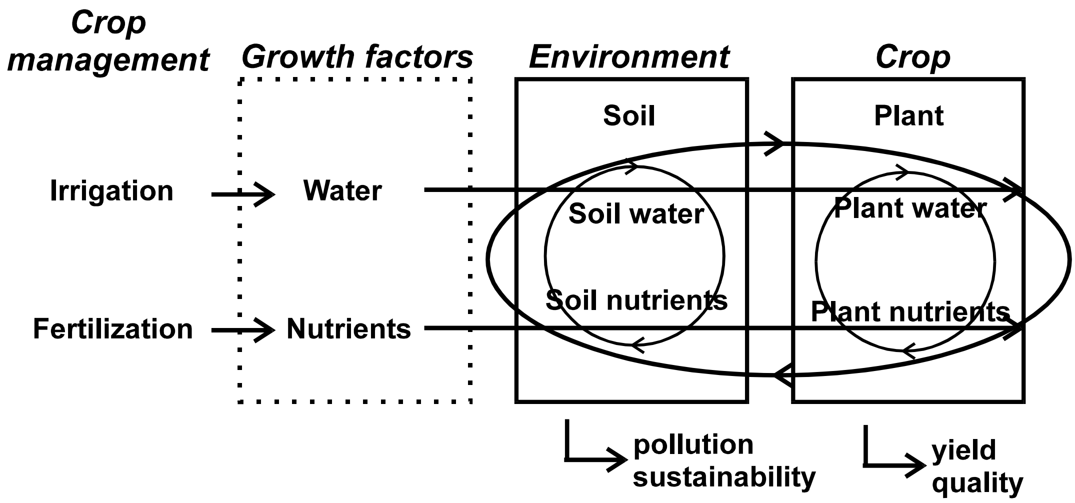

Fig. 2.11 ***Growth model for bamboo production***

By applying crop-management techniques of irrigation and fertilisation, the growth factors 'water' and 'nutrients' are modified. This affects their intensity in the environment and in the crop. The intensity of individual growth factors and their interactions determine growth of plants (the so-called '*Mitscherlich*-model'). To measure the effects of irrigation and fertilisation on crop productivity and the environment, quantitative measures for water and nutrients in the soil-plant system were developed. Within the current experiments, 'soil water' was measured as soil moisture tension by tensiometers and 'plant water' as leaf water potential by a *Scholander* pressure bomb. The effects of soil-water availability on plant growth were estimated by calculating water stress indices and relating them to bamboo yield. 'Soil and plant nutrients' were measured by soil and plant analyses.

Soil moisture tension was usually greater in the low-irrigation treatment throughout the season in 1997 (Figure 2.12, top). Since soil moisture was better controlled under high irrigation, 'water stress' was lower in this treatment (Figure 2.12, bottom). Water-stress indices at the end of the season were significantly related to crop yield (Figure 2.13).

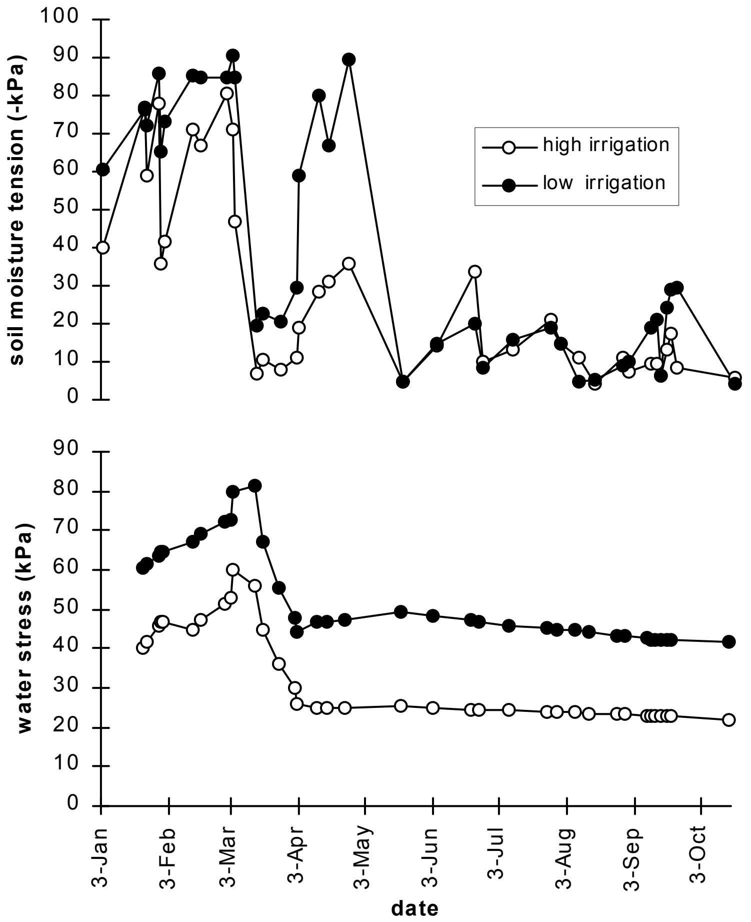

Fig. 2.12 ***Effect of irrigation levels on soil moisture tension (top) and calculated water stress indices (bottom) in*** **P. pubescens** ***at Belli Park in 1997***

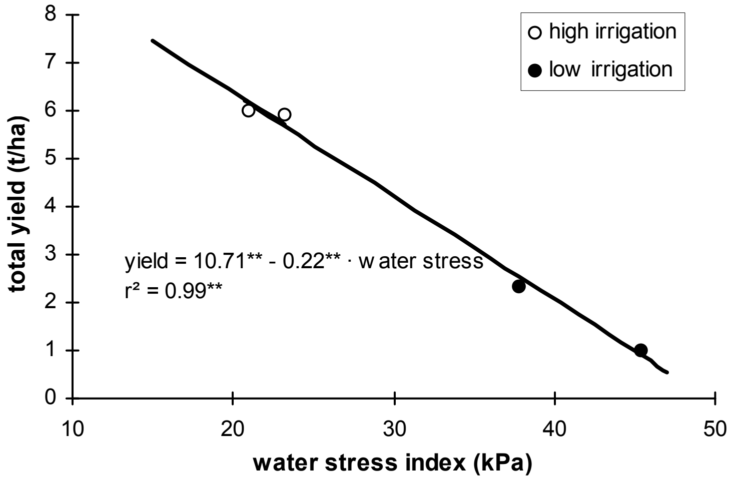

Fig. 2.13 ***Regression of water-stress indices on yields of*** **P. pubescens** ***at Belli Park in 1997***

Better supply of soil water was reflected in plant water status: although statistically not significant, leaf water potential tended to be lower in the high-irrigation plots (Figure 2.14).

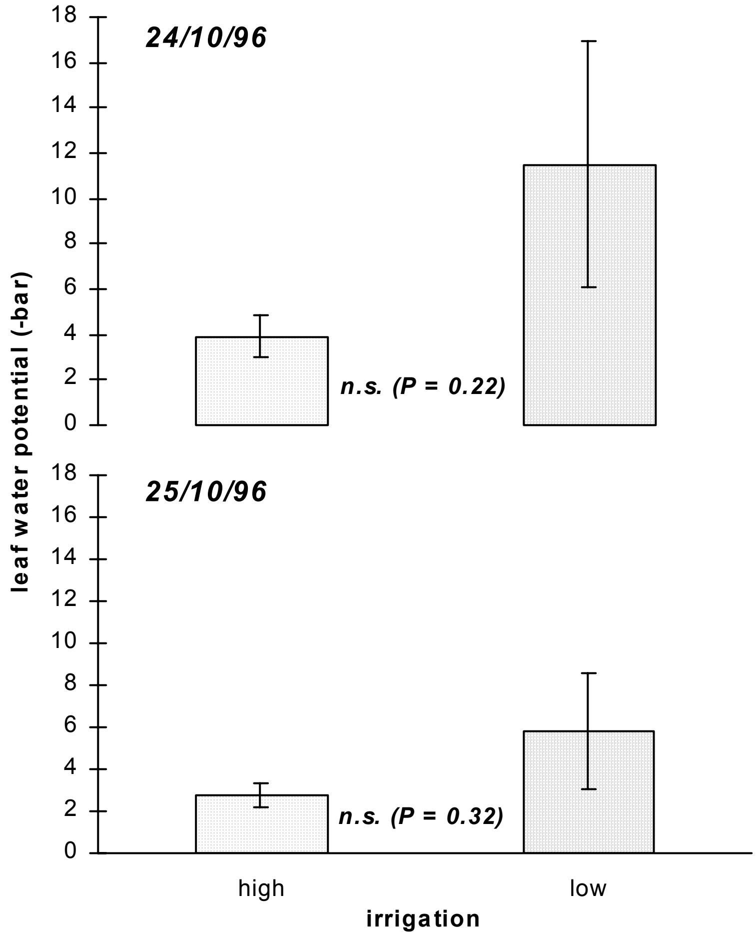

Fig. 2.14 ***Effect of irrigation levels on leaf water potential on two occasions in* P. pubescens *at Belli Park in 1996***

Prior to application of the fertiliser treatments in 1994, leaf and soil samples from areas of the established plantation (Table 2.10) revealed high levels of manganese most likely associated with the low soil pH (4.9-5.3) and seasonal waterlogging. Young leaves (standardised among treatments as the most recently fully expanded) are most commonly used to indicate plant nutrient status, especially of elements that are relatively mobile in the plant. Leaf samples from green *P. pubescens* were low in P, K and B. Yellow leaves from plants in a waterlogged area showed slightly lower levels of these elements and high manganese. Soil sampled from around those plants showed adequate inorganic N, but low P and B levels. Lime at the rate of 600 kg/ha was applied uniformly over the whole experimental area for *P. pubescens* in August 1995. By April 1996 treatment averages for pH ranged from 4.82 to 5.35.

Table 2.10 ***Leaf and soil characteristics of*** **P. pubescens** ***at Belli Park in 1994***

Attribute	Green plant	Yellow plant
<u>Soil</u>		
Organic C (%)	2.7	1.8
NO_3-N (ppm)	20.0	33.3
S (ppm)	18	11
P (ppm)	18	36
Mn (ppm)	46	41
K (meq/100g)	0.30	0.42
Ca (meq/100g)	5.50	1.84
pH	5.3	4.9
EC (dS/m)	1.0	0.9
<u>Leaf</u>		
N (%)	2.60	2.24
S (%)	0.24	0.20
P (%)	0.14	0.12
K (%)	0.72	0.57
Mn (ppm)	1423	1520
B (ppm)	10	13

Total soil N and C were not significantly influenced by fertiliser rates in 1996 (Figure 2.15, top). Leaf samples collected in 1995 in the high-irrigation plots showed an increase in total nitrogen and carbon with greater fertiliser rates (Figure 2.15, bottom). In 1996, this trend was statistically significant for N, but not for C.

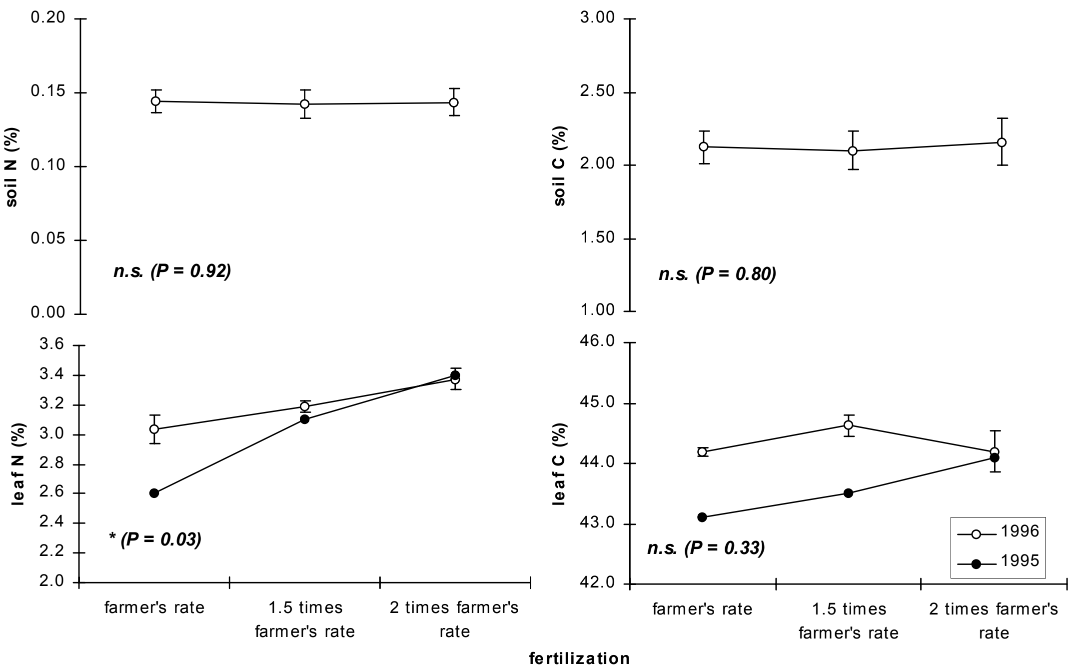

Fig. 2.15 ***Effect of fertilisation on (left) nitrogen and (right) carbon in (top) soil and (bottom) plant in*** **P. pubescens** ***(high irrigation) at Belli Park in 1995/96***

At the higher irrigation rate, soil nitrogen and carbon were significantly improved, whereas pH and electric conductivity were not significantly affected (Figure 2.16).

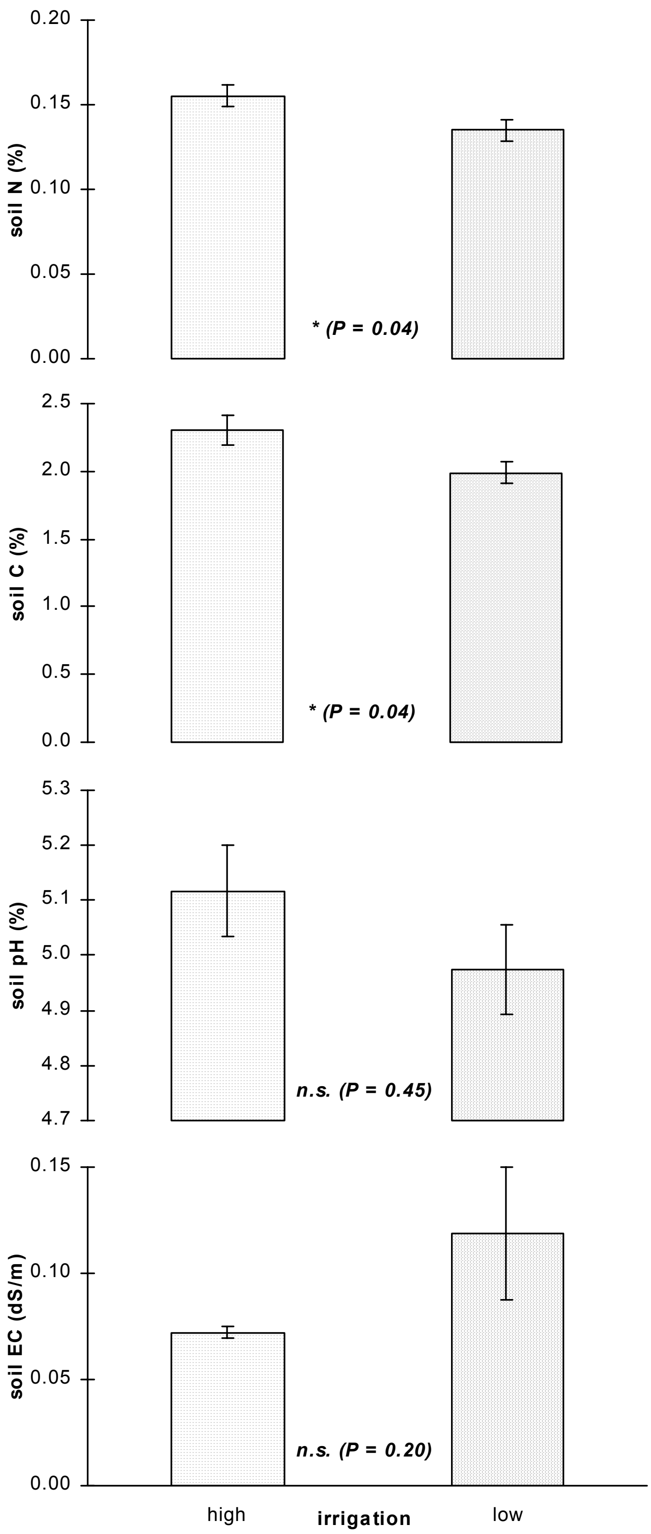

Fig. 2.16 ***Effect of irrigation on soil parameters in***
P. pubescens ***at Belli Park in 1996***

There was no relationship between total soil nitrogen and bamboo yield for P. pubescens cultivated with low irrigation (Fig. 2.17). However, bamboo yields tended to be greater with more soil nitrogen under high-irrigation conditions.

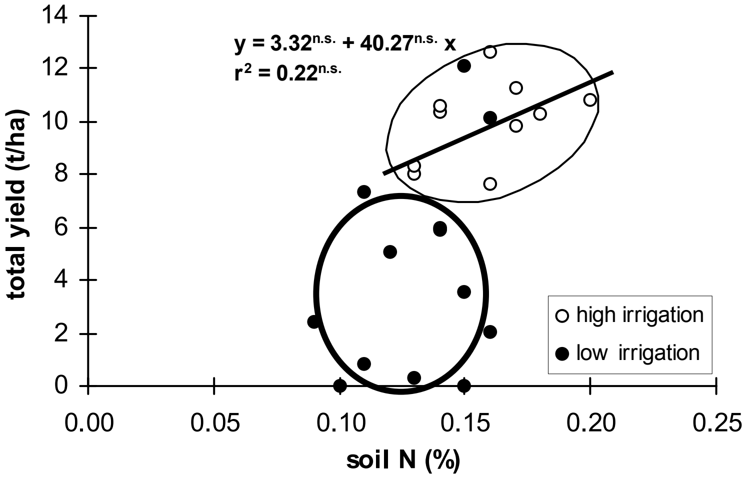

Fig. 2.17 ***Effect of total soil nitrogen on* P. pubescens *yield at Belli Park in 1996***

According to *Mitscherlich*, a growth factor which is below its critical level determines the growth of a plant. Only by moving this ‘minimum-factor’ further towards its optimum can growth be improved. Managing growth factors other than the limiting minimum-factor will have no effect on growth. However, if one growth factor is optimised, another factor may become the minimising element for growth and so on.

‘Water’ appeared to be the most important growth factor for bamboo in this experiment. In the first year of irrigation supplementation, there was only a tendency for above ground bamboo growth to be improved by the high-irrigation treatment. However, this effect gained importance with plantation age. In 1994, slightly more shoots were developed under high-irrigation conditions. In 1995, significantly fewer shoots emerged, but their greater size overcompensated for the smaller number. High irrigation improved yields in 1996 and 1997 with increasing distinctness ($P < 0.01$ and $P < 0.001$). The same was true for the effect of irrigation on yield parameters (number and size of shoots). Irrigation in one year would be expected not only to enhance shoot number and weight in that year, but also the number of shoots initiated in readiness for the following year. Water stress caused by deficient soil water conditions explained the greater part of variations in bamboo yield in 1997 (Figure

2.13). In contrast, table 2.9 shows the detrimental effect of excessive soil water (periodic waterlogging) on nutrient uptake of bamboo (the yellow plant in Table 2.10). Bamboo thus requires water in frequent small applications. Higher irrigation improved some soil parameters (Figure 2.16). This could be due to greater nutrient cycling under those conditions: irrigation improved crop growth and thereby increased return of organic material to the soil via leaf litter.

'Nutrients' were only of secondary importance as a growth factor for bamboo, for fertiliser application was without effect on bamboo growth unless irrigation was applied at the higher rate. This one-side interaction was particularly pronounced in 1996: under low irrigation the greater fertiliser rate did not improve yield, but under high irrigation yields were almost doubled (Figure 2.7). Figure 2.17 illustrates that bamboo responded favourably to greater soil-nutrient contents only under high-irrigation conditions. Under those conditions, fertiliser application significantly increased the plant nutrient status (plant N) but had no effect on the soil nutrient level (soil N, figure 2.15). This suggests that available nutrients were effectively absorbed by bamboo under high-irrigation conditions. On the other hand, excessive soil water hindered uptake of soil nutrients as stated above. Since rates of biomass production were much lower when less water was applied, it can be assumed that the extra nutrients applied in the high-fertiliser treatment could not be absorbed by bamboo and were consequently lost, perhaps through leaching and/or volatilisation. While irrigation had a 'multiplying' long-term, ie increasingly important, effect on bamboo growth, effects of fertiliser over the current duration of the experiment were only short-lived: different fertiliser rates in 1994, 1995 and 1996 exerted no effect on yields in 1997 when only the standard fertiliser rate was applied to all plots.

To sum up, successful cultivation of *P. pubescens* bamboo in the studied environment primarily depends on frequent 'shallow' irrigations (approximately > 2000 mm per year) with attention given to water supply just before shoot production, when rainfall is less than evaporation (Table 2.7). In areas where the natural supply of water (ie precipitation, underground supply) does not match the high demand of bamboo, the extra quantities must be supplied by irrigation. This will have a multiplying effect on yield over time and associated improvements in soil C and N. Under such optimal water management, the yield potential of *Moso* bamboo may be 15 tons per hectare and year or even higher. This potential requires close to or more than 400 to 500 kg N per hectare and year. Fertiliser application in one season seems to have no residual effect on crop growth in subsequent years. Therefore, fertiliser must be continuously applied to bamboo at a rate sufficiently high to sustain a yield potential that is governed by water availability. The greater productivity of bamboo under high-input conditions (high irrigation and fertiliser) may also curb pollution of the environment and thereby maintain, or even improve, sustainability of the cultivation area.

Bambusa oldhamii

Similar to the *P. pubescens* trial, the experimental area was split into a (1) low and a (2) high-irrigation block. Each irrigation block was split into 12 plots (five clumps, ie. 25 m of row, per plot). Those plots were randomly allocated one of three fertiliser rates (four replications). The fertiliser treatments were the same as for the *P. pubescens* experiment (farmer's rate, 250:50:141 kg/ha N:P:K; and 1.5 and 2 times the farmer's rate). Only the fertiliser treatment was applied to the tropical 'clumper' from 1994 to 1997. From the next (1998) season, an additional high-irrigation treatment will be imposed. In 1995 and 1996 no shoots were harvested.

Soil and leaf analyses were made as for *P. pubescens*. Numbers of old culms (> 1 year) and young, emerging shoots were recorded during the shooting seasons in 1995 and 1996 (mid-summer to early autumn). Additionally, the diameter of new but fully developed shoots was measured at the seventh internode in 1996. For two clumps from each of the high and low fertiliser treatments, one leaf on each of five branches of one and two year old culms were tagged in December 1995, and the appearance of new leaves recorded at approximate monthly intervals until March 1997. Leaf appearance was also measured for non-irrigated clumps close to the trial area. The number of branches appearing from young culms was measured for four young stems per clump in 1996 (one replication). Shoots were first harvested in 1997. Cumulative yield, shoot number and shoot diameter were recorded for each plot. Main effects of fertiliser on shoot counts, shoot diameter, leaf and branch appearance, and yield were analysed with ANOVA.

Soil samples of *B. oldhamii* collected from green and yellow clumps (Table 2.11) showed characteristics similar to those of *P. pubescens* (Table 2.10) although electrical conductivity was overall lower. Leaf samples collected from those clumps showed similar nutrient levels, with the difference in leaf N being marked. The effect of greater fertiliser application rates on leaf N in *B. oldhamii* was not as pronounced as in *P. pubescens* (Table 2.12).

Table 2.11 ***Leaf and soil characteristics of*** **B. oldhamii** ***at Belli Park in 1994***

Attribute	Green plant	Yellow plant
Soil		
Organic C (%)	2.7	2.4
$N0_3$-N (ppm)	1.7	0.8
S (ppm)	14	11
P (ppm)	7	14
Mn (ppm)	34	24
K (meq/100g)	0.36	0.41
Ca (meq/100g)	1.58	1.26
pH	5.3	5.3
EC (dS/m)	0.5	0.5
Leaf		
N (%)	2.76	1.92
S (%)	0.24	0.39
P (%)	0.14	0.13
K (%)	1.12	0.79
Mn (ppm)	650	908
B (ppm)	23	13

Table 2.12 ***Effect of fertilisation on leaf nitrogen in*** **B. oldhamii** ***at Belli Park in 1995 and 1996***

Year	Fertiliser rate		
	Farmer's rate	1.5 times farmer's rate	2 times farmer's rate
1995	2.600	2.572	2.779
1996	2.126	—	2.199

During the 1995/96 shooting season, differences in rates of leaf emergence between irrigation and fertilisation treatments were statistically not significant. However, irrigated clumps and clumps which received double rates of fertiliser produced slightly more leaves (Figure 2.18). The same was true for the number of new leaf branches in 1996: although statistically not significant, more branches expanded on shoots of culms that received the higher fertiliser rates (Figure 2.19).

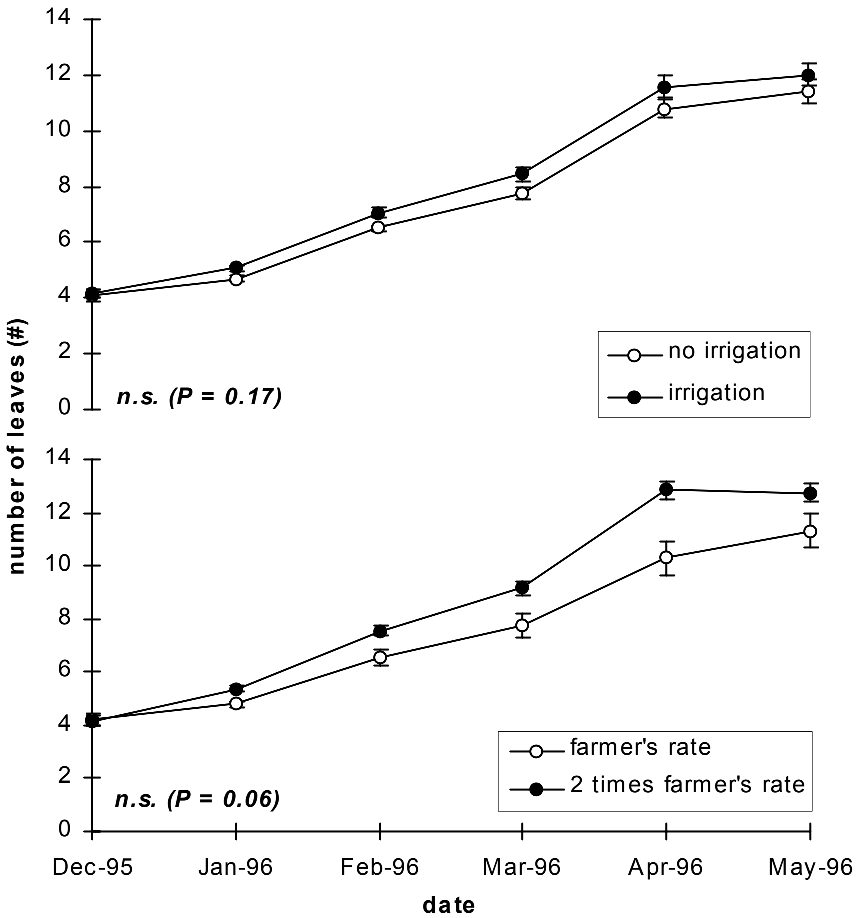

Fig. 2.18 ***Effect of (top) irrigation and (bottom) fertilisation on leaf emergence of*** **B. oldhamii** ***at Belli Park in 1996***

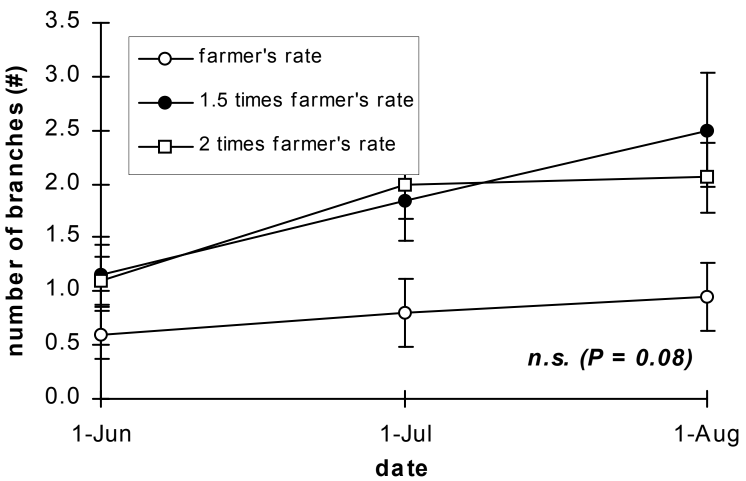

Fig. 2.19 ***Effect of fertilisation on branch emergence of*** **B. oldhamii** ***at Belli Park in 1996***

In 1995 and 1996, the number of emerging shoots was not affected by the number of old (> 1 year) culms per clump ($P = 0.81$ and $P = 0.72$). However, the diameter of new shoots was reduced by a greater number of old culms (Figure 2.20).

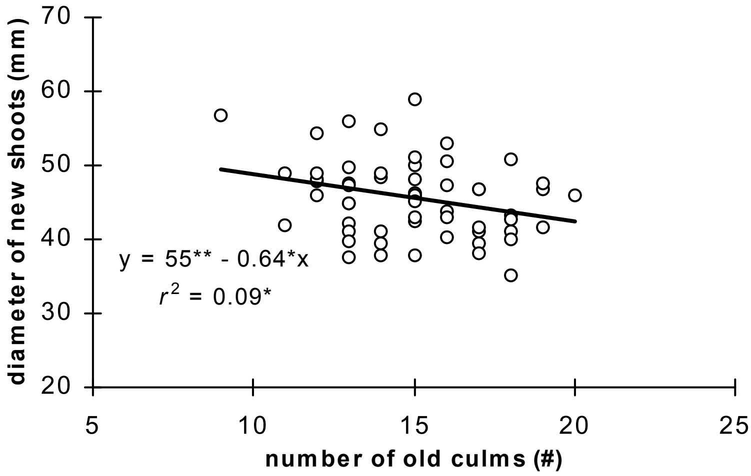

Fig. 2.20 ***Effect of old (> 1 year) culms on shoot production of*** **B. oldhamii** ***at Belli Park in 1996***

The total number of new shoots produced during the shooting season increased from 1995 to 1997 (Figure 2.21). However, the influence of fertilisation on productivity of *B. oldhamii* decreased with season ('significance' decreases as P values increase).

When harvested for the first time in 1997, yields were not affected by fertiliser rate (Figure 2.22); neither were shoot weight (average: 246 g/shoot) nor shoot diameter (average: 58.6 mm).

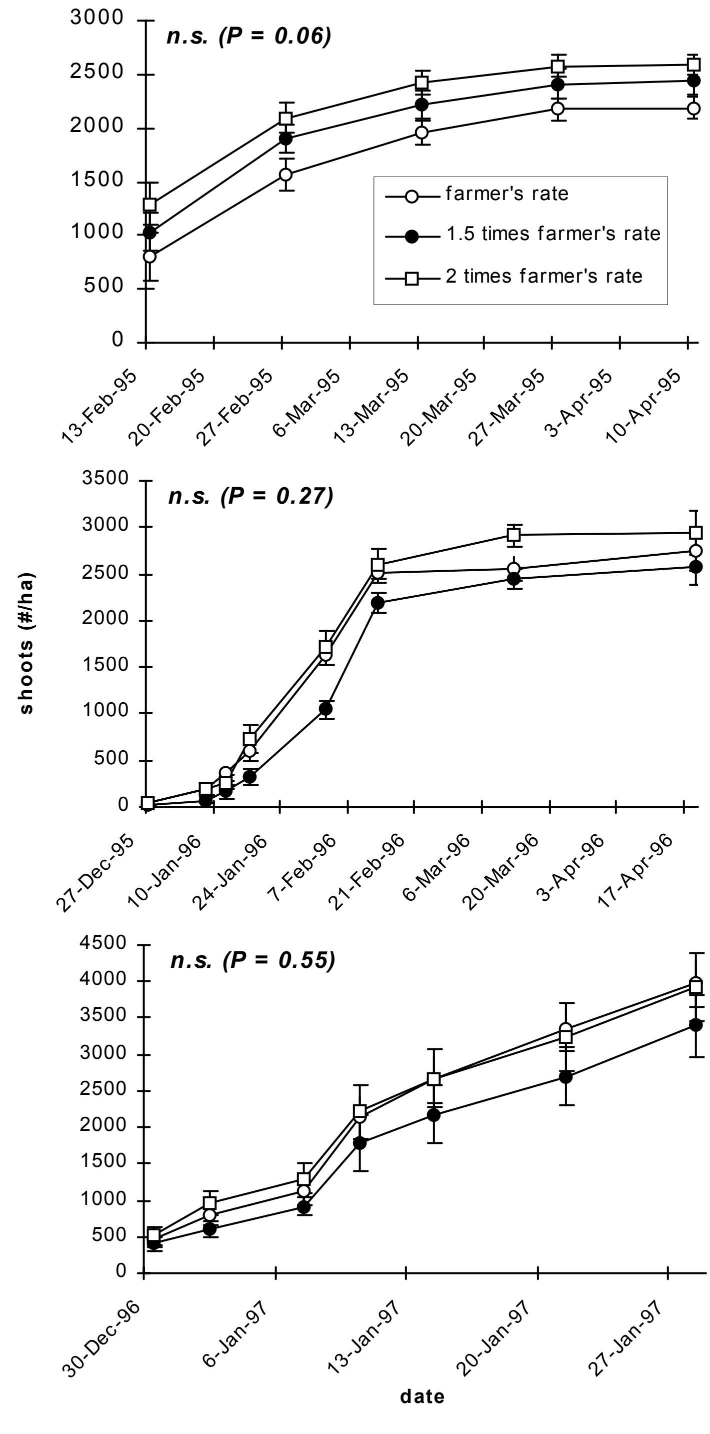

Fig. 2.21 ***Effect of fertilisation on shoot production of*** **B. oldhamii** ***at Belli Park during the shooting seasons (top) 1994/95, (middle) 1995/96 and (bottom) 1996/97***

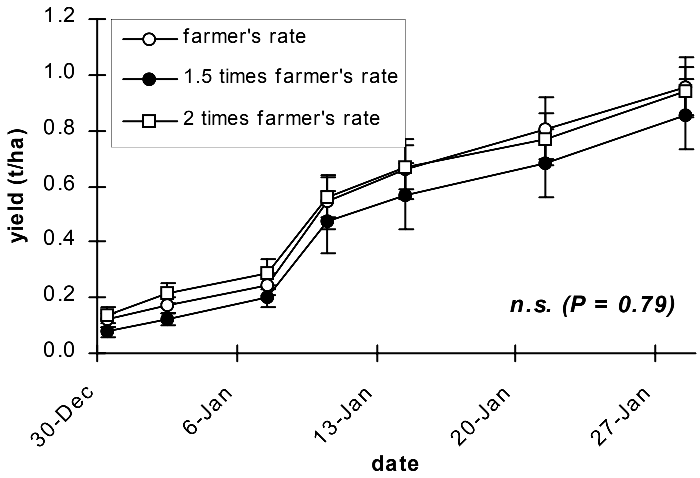

Fig. 2.22 ***Effect of fertilisation on cumulative yield of*** **B. oldhamii** ***at Belli Park in 1996/97***

In contrast to the data for 'running' type of bamboo (*P. pubescens*) presented preliminary results in the 'clumper' *B. oldhamii* show no effect of fertiliser rates on growth parameters. This may be due to genetic differences, but more likely to water supply. Leaf appearance was slightly faster under irrigated than under non-irrigated conditions. In this irrigation treatment, water was applied at a rate similar to the "farmer's rate" in the *P. pubescens* experiment. Although not statistically analysed, a two-fold increase in shoot numbers was evident in the irrigated experimental plots compared to the average of 20 clumps in an adjacent non-irrigated area (2493 shoots/ha vs. 1067 shoots/ha in 1995). Fertilisation had no effect on growth parameters in *P. pubescens* when only the standard rate of irrigation was applied. This may also be true for *B. oldhamii*: fertilisation may only improve bamboo growth under conditions of high water supply.

The number of old culms had no effect on shoot-emergence rates, but reduced shoot sizes in 1996. This stresses the need to identify optimal numbers of shoots to be left behind after harvest of the fresh produce. Those will be determined in the ongoing thinning trials.

These preliminary data illustrate the feasibility of producing a commercial crop of bamboo shoots in Australia. Although the *B. oldhamii* plantation was only five years old when initial yield assessments were made, the number of harvestable shoots increased to about 4,000 shoots/ha in 1997. The plantation has yet to form a complete canopy (in April 1996 ground cover was approximately 20%) hence yield (≈ 1 t/ha) is still low. Yields of *P. pubescens* were more in line with reported yields of 10-20 t/ha for Korea and Japan.

The importance of adequate water supply is illustrated by the increasing differences in yield parameters between irrigated and non-irrigated *P. pubescens* from 1994 to 1997. There is some indication that the same is true for *B. oldhamii*. Differences may become more obvious when stands become mature and a high-irrigation treatment is included in the experiments with the latter species.

Fertiliser application had significant effects on growth parameters of *P. pubescens* only when high irrigation rates were applied. Under those conditions, yields were double compared with the low-irrigation treatment. In *B. oldhamii*, only the standard irrigation rate was applied and, similar to *P. pubescens*, fertilisation had only little effect on growth.

It can be expected that shoot yields will continue to increase for *P. pubescens,* while yields of *B. oldhamii* may dramatically increase in the future as the plantation matures. The influence of irrigation on growth parameters will likely increase from year to year and greater fertiliser rates may be necessary to support the yield potential of the bamboo. Clump thinning may be another suitable management practice to optimise production of both culinary shoots and timber.

3. To release trial quantities of fresh product onto the market to test its market potential

3.1 City market survey

In 1996, eight stores were surveyed in Brisbane. The survey revealed that a great number of markets selling bamboo shoots are run by ethnic Vietnamese or Chinese. Of eight surveyed Asian supermarkets in Brisbane, five were owned by Vietnamese at Darra and three by Chinese in Chinatown. Cheap imported preserved shoots ($2.50 to 3.00 per kg) were common shelf items in those shops; almost none of them were selling fresh produce.

Four of the five Vietnamese stores were selling bamboo shoots that had only been minimally processed, ie sheaths removed, boiled, preserved in some liquid and stored cold. The type of bamboo was unknown. One type was a short (approx. 10 cm), large, thick (10 cm at base) shoot, which may have been *Bambusa oldhamii* or *Phyllostachys pubescens*. The other was a long (approx. 20 cm) thin (approx. 3.5 cm) shoot comprised of up to 15 nodes, perhaps *P. praecox*. The shoots were selling at between $2.00 and $3.00 per kg. The shoots were imported from Thailand in drums containing 20 kg of shoots. Packaging before selling was done by shop owners. The owners indicated that occasionally, locally grown, fresh bamboo shoots were available at wholesale markets. They were not regarded as popular. Customers seemed to prefer slightly processed shoots. Furthermore, the fresh produce was not (according to them) expected to fetch a higher price than the processed shoots.

Most surveyed Chinese supermarkets had the same minimally processed shoots selling for about the same price as the Vietnamese. However, one store sold frozen bamboo shoots in plastic bags. The shoots had their sheaths removed, were not boiled or pickled, but probably snap-frozen. They were imported from Taiwan and sold for about $8-9 per kg. A visit to a factory of Taiyan Products Corporation in Lin Ying Hsing revealed that the company M&M imports into Australia quantities of frozen bamboo shoots from Taiwan. Occasionally, fresh bamboo shoots, grown locally at Morningside, are available for about $7 per kg.

These results from Brisbane indicate that there may be a consumer preference for minimally processed bamboo shoots and possibly less potential for fresh shoots to fetch higher prices. Simple on-farm or off-farm **post-harvest** treatments could expand the demand for bamboo shoots grown in Australia.

3.2 Trial marketing

Before the harvest season in 1996, **distribution agents** were found for the Sydney and Brisbane fresh produce markets. One small-scale farmer received $18 per kg on a retail sale (restaurant) for impeccable produce. D. Dart attended a meeting at the Mary Valley Plantation regarding the establishment of a **farmers' cooperative marketing body** called the Bunya Co-Op. He discussed the marketing of fresh shoots with various **wholesalers** in Sydney including Masahiro Murai of Jun Pacific Corp., Chatswood. The overall response was that a commitment could only be made after sampling the product. It was agreed that shoots should be packed in 15-kg cardboard cartons. D. Dart has canvassed local restaurants for trialing fresh *B. oldhamii* shoots. Several restauranteurs have responded favourably to his invitation.

In 1996, local endemic (*B. arnhemica*) bamboo shoots gathered from wild stands (Adelaide River) received $5.00 per kg on the local market and $3.50-4.50 per kg at southern markets. *Phyllostachys pubescens* bamboo shoots from D. Dart's farm were placed on the Melbourne market for the first time. Shoots were graded into premium, thick and thin, and priced accordingly (Table 3.1). When not sorted after harvest, they were classified as mixed grades. Data for shoot supply and monetary returns were taken from D. Dart's invoices.

Table 3.1 ***Grading and pricing of bamboo shoots at Melbourne market in 1996***

Grade	Description	Market Price ($/kg)
Thin	tall, thin - these shoots were bitter	4.50
Thick	thick (20-40mm base by 100-150mm tall) with high water content - these shoots were more palatable than the thin grade	8.00
Premium	very large (approx. 75mm base and up to 250mm tall)	10.00
Mixed	Unsorted	6.50

All shoots were sold at the market. Market supply and returns are shown in Figure 3.1. Other bamboo species produced shoots of good taste (*Semiarundinaria fastuosa viridis*, *P. bambusoides*) and one (*P. bambusoides*) was marketed ($5.50 per kg).

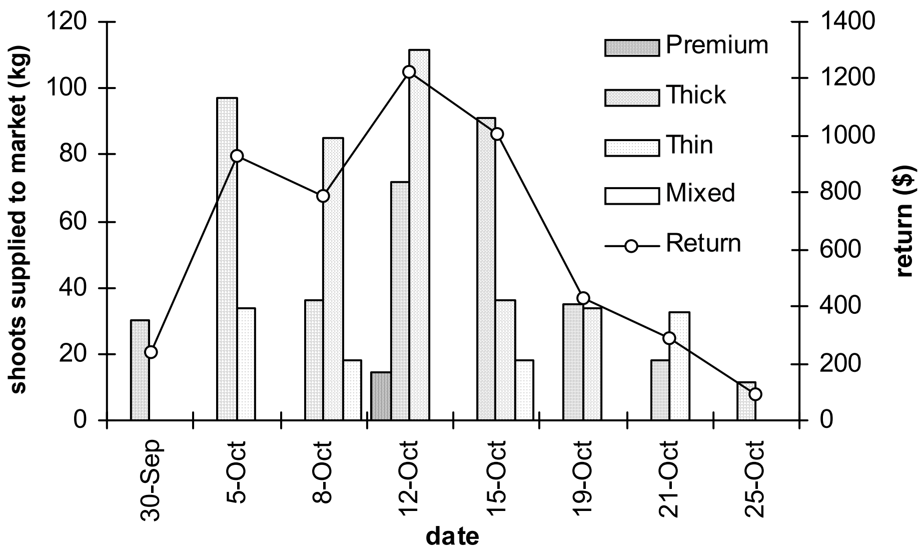

Fig. 3.1 ***Supplies of, and returns from, marketed bamboo shoots in October 1996***

The ready sale of all grades of shoots indicated that small shoots, which predominate early in the development of a bamboo plantation, might also generate income for the commencing producer. An economic analysis was initiated to establish viability of enterprises and to identify areas in the production process that may be become more efficient with greater technological input.

In contrast to the Brisbane market analysis, the popularity of the fresh produce on the Melbourne market and the high prices that were gained by D. Dart show that there may indeed be a market potential for higher-priced fresh shoots. This is further supported by steadily increasing demand for bamboo planting material in Southeast Queensland and Northeast New South Wales. D. Dart plant sales to growers reached approximately $44,000 in 1995/1996 that represent a 50% increase compared with the previous financial year (Fig. 3.2). The data indicate that sales in the current financial year will surpass that of 1995/1996. Prices per plant range from $25 to $100, depending on species, and this high cost will continue to limit short-term expansion of the industry.

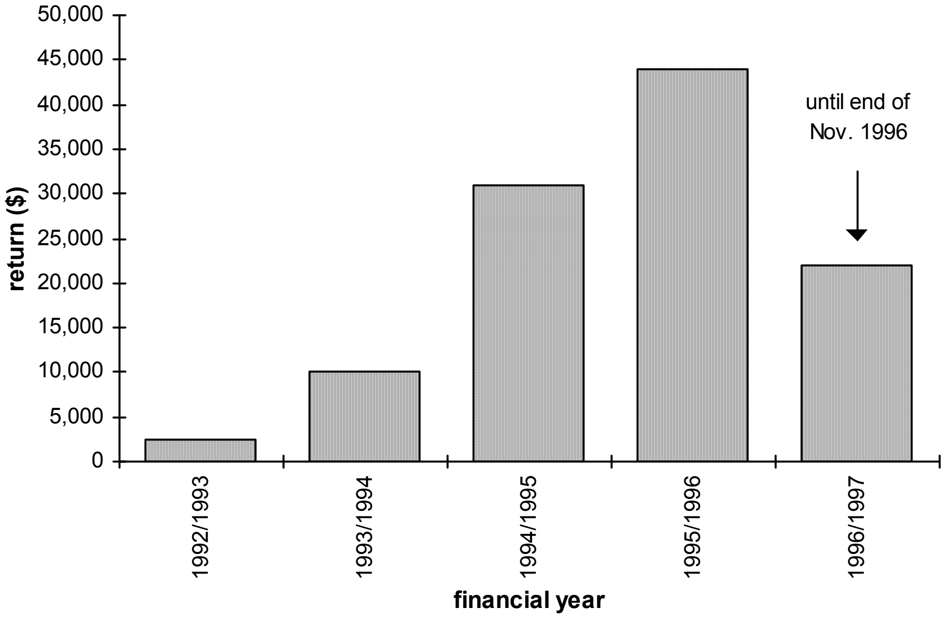

Fig. 3.2 ***Yearly plant sales by D. Dart***

The differences between farmers' and traders' expectations of sale of fresh bamboo shoots are obvious. A further survey of Asian supermarket managers was initiated to gauge interest in locally produced fresh bamboo shoots. It appears necessary to translate the survey into Chinese and Vietnamese before distributing to city supermarket managers. This activity will be undertaken as a part of the follow-up research project to develop a business plan for the bamboo industry.

4. To collate and extend information on species performance and agronomic technique

4.1 Workshops, courses and conferences

An introduction to the potential of edible bamboo shoot production in Australia and the aims of the research project was delivered at the **Introductory Workshop** held at the Belli Park plantation in 1994. Organised by D. Dart, the workshop was attended by 15 people. Presentations included those by K. Blackburn (Northern Territory DPIF) and P. Bindon (Australian Bamboo Network).

A **Course on Tropical Bamboo** at the Subtropical Research Institute in Guangzhou (Canton province, China) was attended by D. Dart. The course dealt with tropical, clumping bamboo types, which are more likely to be commercially cultivated in Queensland and the Northern Territory. A valuable outcome was the opportunity to network with bamboo professionals particularly from Southeast Asia.

On 24 February 1995, D. Dart conducted a **Bamboo Seminar** in Darwin which was attended by 20 bamboo growers, native bamboo harvesters and interested people. The seminar, hosted by DPIF, aimed at generating interest in bamboo locally.

The **Fourth International Bamboo Conference**, held in Bali from 19-22 June, was attended by D. Dart (not RIRDC funded). Contact with the established bamboo industry in SE Asia may be essential for the development of an industry in Australia. D. Midmore gave presentations to the **Fitzroy Water 2000 Conference** (5 February 1996) and the **Bundaberg Agricultural and Trading Exposition** (10 April 1996) which focused on current and future research on Asian vegetables, including bamboo shoots. Presentations to the **Bundaberg Advisory Committee** and to the **Miriamvale Council** focused on the potential for increasing investment in Asian vegetables.

A first scientific paper, featuring agronomic results from the field trials at D. Dart's farm, was presented to the **First Australian New Crops Conference**, Gatton in July 1996. The work presents the first two-year's results of fertiliser and irrigation management. Another manuscript is in preparation, which expands upon the data in the conference paper (fertiliser and irrigation effects), and incorporates new subjects (photosynthesis and water potential).

D. Dart conducted **Bamboo Workshops** on 12th August 1995 with 20 attendees, and in July and September with the Noosa permaculture group attended by 90 people each. The workshops demonstrated the practical use of bamboo in the rural environment. Another workshop was held at Belli Park on 10th February 1996 with 39 attendees. The workshops encouraged participants to purchase plants to trial on their farms. One participant had purchased and planted out two hectares of Moso. Two workshops and one **Field Day** at D. Dart's farm followed, respectively, on 13th August, 14 December and 23 November, attended by 29, 17 and 30 interested people. J. Leonardi, J. Milne and K. Walsh supported the field days through presentations and field demonstrations. Two field days on Asian vegetables were run in Bundaberg (QDPI, CQU) and Rockhampton (CQU). Approximately 60 people attended each field day.

4.2 Publications and public exposure

Publications in **Bambooroo**, the quarterly **Journal of the Australian Bamboo Industry Association** (ABIAB) regularly reported project results on agronomic practice and shoot production. The journal, which is partially funded by RIRDC, covers a diversity of subjects related to bamboo.

In 1995, about 25 **popular press** exposures included coverage by radio (particularly *ABC*), daily papers, magazines and some TV. In 1996, a three-page article by B. Culver (an employee at Bamboo Australia) was published in *Soft Technology* magazine. Responses came in from mostly alternative life stylers and business people from as far as the Marshall Islands, Nauru and Fiji. A two-part story appeared in the gardening section of *The Sunshine Coast Daily*, which attracted response from some gardeners and farmers. A comprehensive article on bamboo shoot production by P. Bindon (Australian Bamboo Network) mentioned the project's commercial plantation in the *Grass Roots* magazine. Many inquiries were received. On 9 June 1996, *ABC Television* covered bamboo research at Belli Park and Bamboo World, Wadeville, NSW. More than 30 inquiries about agronomic results and economic viability have been answered with many interested persons visiting the farms. The most interested groups were early retirees and Aboriginal communities. Other public exposure included a published article in *Business Review Weekly* on 10 June, speeches by D. Dart to several local View and Probus Clubs, and interviews on *ABC radio*, *4QR Brisbane* and *Coast FM Maroochydore*. D. Dart has continued promoting bamboo through major media outlets. Television coverage included the programs: The *ABC's 'Landline'*, *Channel 7 Brisbane News*, *Channel 7 Sunshine Coast News*, *Network 7 11 am Sunday Show* and '*Totally Wild*'. Radio interviews were conducted on the *ABC's 4QR Brisbane*, *The Sunshine Coast's 4GY FM* and some of the local community stations. Print media outlets included *Queensland Country Life*, *Australian Country Journal*, *Leisuretime*, *Brisbane Courier Mail*, *Sunshine Coast Daily* and *Noosa News*. The field days in Bundaberg and Rockhampton were covered by *Country News*.

4.3 Liaison between research groups

The foundations for coordination of research activities were laid by a meeting hosted by the Bundaberg Research Station in 1994. This was a planning session for allying work between the commercial grower D. Dart, and the research organisations CQU and QDPI. A representative of the Australian Bamboo Network was also present.

In 1995, the CQU Research Officer maintained good contact with the commercial grower D. Dart at Eumundi and the DPI trial site in Bundaberg. D. Dart was frequently visited for designing and maintaining the field experiments, and for training a research worker. Procedures were developed on the bamboo trial design, sampling methods, leaf and soil analysis, and irrigation monitoring. The need to standardise methods between the sites was emphasised. Researchers from CQU visited the trials at Bundaberg, Darwin and Belli Park.

D. Dart visited DPIF for the delivery of plants for the DPIF trial and to advise on management practice (eg thinning clumps, bamboo nutrition and propagation). He frequently inspected the trial area and cultivar collections. In addition, he has been asked by various groups in the Marshall Islands, on Cook Island and in Lae in Papua New Guinea to advise them on the feasibility of growing bamboo for timber.

Implications and Recommendations

Yields of 15 tons per hectare and one ton per hectare were achieved for *P. pubescens* and *B. oldhamii,* respectively. With changes to agronomic practice (frequent shallow irrigations and improved nutrition) yields comparable to that reported overseas (10-25 t/ha and 10 t/ha, respectively) should be possible. At a modest five tonnes per hectare, a farm gate price of $5/kg will provide a gross return of $25,000/ha. The industry should be viable, at least up to a national planting area of 250 ha, supplying 1,250-2,500 tons per annum during the shoot season to the Australian market.

Data generated within this project highlight the feasibility of growing bamboo in Australia for edible shoots, but also points to the current difficulties in multiplication that will be experienced by growers unwilling to pay the current prices ($25-100 per plant) for plants of some of the desirable species. Australian produce is acceptable to markets within Australia.

To accelerate the development of an industry in Australia, further research is essential on the following fronts:

- streamlining vegetative propagation protocols
- evaluation of irrigation/water requirement in the non-shoot season, and for species other than those listed in this project
- development of post-harvest practices to maintain shoots in a high quality condition
- extend temporal supply of fresh shoots within Australia
- investigate market potential for shoots and timber
- validate culm thinning rates for optimum shoot, or a balanced shoot:timber, output

It is proposed that the relevance of these topics be discussed at a workshop convened to gauge the producer-interest in bamboo shoot production, and that an Industry Body be formed to oversee the development of a Bamboo Industry.

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