CHAPTER VI

SUMMARY

Bamboo is considered to be the fastest growing, highest yielding renewable natural resource. Bamboo is not only an ideal economic investment with multifarious uses but also has enormous potential for alleviating many environmental and social problems. Besides its utility in furniture, construction, agriculture, baskets, handicrafts etc., juvenile shoots are used as food in many parts across the globe. China has a long tradition of cultivating, processing and preserving bamboo shoots as food. Bamboo shoots are eaten as vegetable mostly in South-East and East Asian countries. Bamboo shoots are now processed into many kinds of food, including fresh shoots, dry shoots, and canned shoots, that are sold around the world. The health benefits of bamboo shoots were little understood until recently. Except in North East India and few parts of peninsular India where bamboo shoots have been consumed traditionally, the prevailing myth that bamboo shoots are poisonous and ignorance on the choice of edible species has so far restricted its utility for edible purposes. In Peninsular India, the exploitation of bamboo shoots of *B. bambos* and *D. strictus*, in traditional cuisines has been confined to Coorg and Malnad area in Karnataka and Waynad in Kerala. However, the availability of fresh edible bamboo shoots is very limited for much of the year and in many places of peninsular India it generally lasts for only one to four months (June – September) during the rainy season. The usage of shoots in food in other regions has not gained much popularity primarily due to lack of awareness about the nutritional value of the shoots and also the non-availability of choice of species of bamboo. This may primarily be due to lack of awareness regarding the edible characteristics of the shoots and lacunae in research on the subject. Though extensive study has been reported in major bamboo growing areas in the North-eastern parts of India, not much work has been reported on edible shoots and the sustainable management aspects of bamboo in peninsular India. A study in this dimension would be beneficial in promoting bamboo as an alternative source of dietary supplement in semi-arid regions as well where the consumption of bamboo is highly limited. The essential requirement for successful exploitation of shoot production technology is the availability of bamboo bioresource and technical and entrepreneurial
skills in managing shoot-producing bamboo plantation. Also the industrially important species if cultivated with appropriate inputs will aid in the exploitation of the shoots for other industrial purposes as well as a potential nutrient source. The study was aimed to throw light on nutritional composition of edible bamboo species in different agroclimatic zones, and also emphasize on the importance of managing bamboo shoots for maximising sustainable production which will address the issues of income generation and nutrition in poverty stricken areas and undernourished population especially in rainfed agriculture dependent areas.

Six industrially important species were taken up for the present study viz. Bambusa bambos, Bambusa balcooa, Dendrocalamus strictus, Dendrocalamus asper, Dendrocalamus stocksii and Guadua angustifolia, two different agroclimatic zones viz. tropical humid (Koppa, Chickmagalur, Karnataka, India) and semiarid conditions (Gottipura, Hosakote, Karnataka, India). Of the six species, B. bambos and D. strictus are two multifarious bamboo species largely distributed across the Indian subcontinent. B. balcooa, is a species commonly found in North-east India which has been found to have good calorific value and hence the most preferred species across India for captive plantations for bioenergy. D. stocksii, a species endemic to Central Western Ghats, is commonly cultivated by farmers in the Konkan region and increasingly being seen as a replacement for cane in the furniture industry. D. asper and G. angustifolia are two species introduced in India by NMBA and NBM for the commercial utility value. Four separate experiments were undertaken to (1) the assess the six species for nutritional composition, to see if there is any variation in the nutritional composition if the same species is cultivated in two different growth conditions (2) to evaluate and identify less time consuming processing methods for quick removal of HCN content in the shoots to promote increased consumption in the region (3) to standardize silvicultural management of these six species in semiarid conditions to promote plantations of bamboo (4) to assess the biomass and productivity by means of physiological evaluation of these six species in both the locations to scientifically validate which species is better suited for a particular location. All these experiments were conducted at IWST field station in Gottipura, Nallal, Hosakote, Bangalore and Devon plantation and estate, Koppa, Chickmagalur on 5-6 years old clumps of the six species from the plantation with spacing 5X5m
established by IWST in 2006 and lab experiments at Institute of Wood Science and Technology, Bangalore and Department of Processing and Food Engineering, UAS, Raichur during the years 2012 to 2014.

**Summary of Salient Findings**

The main nutrients in bamboo shoots are protein, carbohydrates, amino acids, minerals, fat, sugar, fiber, and inorganic salts. The shoots have been reported to have a good profile of minerals, consisting mainly of potassium (K), calcium (Ca), manganese (Mn), zinc (Zn), chromium (Ch), copper (Cu), iron (Fe), and lower amounts of phosphorus (P), and selenium (Se). Fresh shoots are a good source of thiamine, niacin, vitamin A, vitamin B6, vitamin C and vitamin E. The fresh shoots of all the six species for analysis were collected from IWST field station at Gottipura, Hosakote (semiarid condition) and from the trial established by IWST at Devon estate, Koppa, Chickmagalur (Tropical humid conditions). The inner tender creamy white portion was used for analysis of macro and micronutrients following standard procedures. Composition of nutrients like carbohydrates, proteins, vitamins and dietary fibers may vary considerably among different species and also on conditions of growth. Thus it becomes imperative to understand the nutrient composition of a particular bamboo species growing in a particular region to exploit its edible potential. The highest ash content was observed in *D. stocksii* (1.47g/100g) in Koppa and in *G. angustifolia* (1.33 g/100g) in Hosakote. The highest protein content in Koppa was observed in *B. bambos* (3.46 g/100g) and in *G. angustifolia* (2.39 g/100g) in Hosakote. *D. asper* was found to contain highest amount of carbohydrates (8.6 g/100g, 7.6 g/100g) in both Koppa and Hosakote. Highest fiber content was observed in *B. bambos* (3.7 g/100g) and lowest in *D. asper* (2.15 g/100g) in Koppa. *D. asper* was found to contain the highest levels of Sodium (15.04 mg/100g, 14.15mg/100g), Potassium (515.67 mg/100g, 416.67mg/100g) and Calcium (6.4 mg/100g, 7.1 mg/100g) in both Koppa and Hosakote and highest Iron content (2.92 mg/100g) in Hosakote. Copper and Zinc content was found to be highest in *D. strictus* (0.580 mg/100g, 0.88 mg/100g), *G. angustifolia* (0.87 mg/100g, 0.92 mg/100g) and *B. bambos* (0.94 mg/100g, 0.88 mg/100g) were found to contain high levels of Manganese in Koppa and Hosakote. It was observed that macro and micronutrient composition of the
same species grown at different locations varied significantly upon statistical analysis and was observed to be on par with the nutritional composition of shoots reported from North-east India. *D.asper* could be a potential species with rich nutritional composition for consumption in the tropical humid conditions. *D.stocksi*, a species endemic to Central Western Ghats, not considered edible in the region, was found to nutritionally on par with other species which are commonly consumed.

It was observed that the hydrogen cyanide content also varied significantly between species in both locations. Maximum variation was observed in *D.asper* shoots with 80% more HCN content in Hosakote as compared to Koppa. Bamboo shoots contain very high concentration of cyanogenic glucosides, which on endogenic hydrolysis, yield hydrocyanic acid lending a bitter taste to the bamboo shoots. Two methods of processing were tested for their efficiency in removing the bitterness - Pressure cooking of shoots and traditional method of soaking in water but for a shorter duration were employed for reduction of cyanide content. The macronutrient (carbohydrates, proteins, fat, fibre and ash) composition and the amount of HCN were estimated before and after treatment for both the species. Except for total ash content and crude fiber content, there was significant variation in the macronutrient composition of both the species after overnight soaking and pressure cooking. The hydrogen cyanide content reduced in both the species after processing. However, pressure cooking was found to be more effective and less time consuming as compared to soaking since in 15 minutes the hydrogen cyanide content was reduced around 80% as compared to fresh shoots whereas, soaking for 12 hours reduced around 30-45% as compared to fresh shoots in both the species. To validate if the processing methods are effective in removal of hydrogen cyanide content, they were tested on all the six species. It was observed that the hydrogen cyanide content consistently decreased in all the species after processing. However, pressure cooking was found to effectively reduce the hydrogen cyanide content as compared to soaking in water and also much less time consuming in

Previous studies on these six species by IWST, Bangalore revealed that their growth performance in tropical humid conditions is better as compared to semiarid conditions. However the present study has shed more light on the response of various bamboo
species in terms of emerging shoot behaviour to precise management inputs. The site at Hosakote (semiarid) was selected for studying the effect of management inputs on shoot emergence. The study was undertaken to assess the impact of scientific management for maximising sustainable production of shoots in semiarid conditions. For studying the effect of management on shoot emergence, organic and inorganic inputs, separately and in combination, were applied on 6 year old clumps established at IWST field station at Gottipura, Hosakote, Karnataka, India. Organic and inorganic inputs were applied as eight combinations on clumps of all the six species in triplicates for two consecutive years (2013 & 2014) during May-June. The shoot emergence was recorded monthly till December. The shoot emergence was found to significantly vary between treatments in all the six species. A combination of fertilizers, compost and biochar (T7) was found to be performing better in *B. balcooa*, *B. bambos*, *D. asper* and *D. strictus*. Whereas, application of inorganic fertilizers alone was found to be most effective for *D. stocksii* and *G. angustifolia*. Fertilizers have been reported to increase shoot production in various bamboo species. It was observed that in most species there was maximum shoot emergence during the rainy period between August and October. Observations on the average number of new shoots emerging annually in *D. stocksii* clumps at IWST field station, Hoskote indicated that around 18-20 new shoots emerged as compared to 10-15 shoots in *B. bambos* and *D. strictus* and 8-10 shoots in *D. asper*. This indicates that after scientifically harvesting 20-30% of the emerging shoots for edible purposes, the mature culms can still be exploited for other commercial uses. Based on nutritional composition, processing, growth, shoots emergence, number of shoots and volume of edible portion, *D. asper* was found ideal for cultivation in tropical humid conditions and *D. stocksii* was found to be ideally suited for semiarid conditions. Over a 40 year period of the plantation, an equated annual income of 7 to 9 lakhs can be obtained from *D. asper* and an equated annual income of around 2.9 to 3.7 lakhs (Table 4.8) can be reasonably expected from *D. stocksii* plantation at different discount rates. Hence these two species were found to be ideal for recommendation for commercial cultivation for exploitation of edible shoots.

The biomass studies were conducted on full-grown 8 years old clumps of the six species (*Bambusa bambos*, *B. balcooa*, *Dendrocalamus asper*, *D. strictus*, *D. stocksii* and *Guadua angustifolia*) in 2014 at IWST field station, Gottipura, Hosakote (semiarid condition) and
from the same age field trial of the six established by IWST at Devon estate, Koppa, Chickmagalur (tropical humid conditions). Five representative clumps were selected randomly in each species. Biomass allocation to components viz. culms, twigs, leaves and its per cent contribution to the total biomass were estimated for both the locations for all the six species. The growth and biomass in *D. asper*, *G. angustifolia* and *B. balcooa* in Koppa were found to be better as compared to their growth in Hosakote where growth and biomass of *B. bambos* and *D. stricus* was almost same in both the locations and *D. stocksii* performed better under semiarid conditions as compared to tropical humid conditions. The above ground biomass extrapolated for plantations of six species in tropical humid conditions and semiarid conditions are consistent with the reports on biomass accumulation. The highest biomass accumulation was found to be *B. balcooa* (206.64 Mg ha$^{-1}$) which works out to 27.30 Mg ha$^{-1}$yr$^{-1}$ in terms of annual above ground productivity of this species in Koppa and in *D. strictus* (91.5 Mg ha$^{-1}$) which works out to 12.40 Mg ha$^{-1}$yr$^{-1}$ in terms of annual above ground productivity of this species in Hosakote. Also, in contradiction to the general trend of per cent contribution of various components to the total biomass – culms > twigs > leaves observed in other species in both the locations, *B. bambos* followed a trend of twigs > culms > leaves and *D. strictus* followed a leaves > culms > twigs trend in Koppa.

The variation in the physiology (photosynthetic rate, intracellular CO$_2$ concentration, stomatal conductance, transpiration rates and water use efficiency) was studied using a Portable Photosynthetic system LI 6400 XT (Li-cor Inc., USA). Observations were recorded from full-grown 8 years old clump grown at IWST field station at Gottipura, Hosakote (semiarid condition) and from the trial established by IWST at Devon estate, Koppa, Chickmagalur (Tropical humid conditions). Significant difference was observed between the photosynthetic rate, intracellular CO$_2$ concentration, stomatal conductance and transpiration rates of all the six species between locations. Transpiration and photosynthesis are two major gas exchange parameters which determine WUE of plants. The conditions of growth in Koppa favoured leaf expansion which was indicated by the high total leaf area in all the species in Koppa as compared to Hosakote except in *D. stocksii*. The highest WUE in *D. strictus* (7.26) could be indicative that the species is more ideally suited for dry conditions which was also substantiated by the high culm
biomass accumulation in the species in Hosakote as compared to Koppa. The growth rates and biomass accumulation in Koppa was higher than Hosakote indicating favourable conditions for growth in Koppa. *D. strictus* recorded highest WUE compared to any other spp in Hosakote and Koppa indicating that the species is ideal for growth in dry semiarid conditions.