Impact of Tissue Culture on Agriculture in India

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ABSTRACT

Biotechnology has been globally accepted as one of the important tools for direct application in agriculture. It has a strong and positive influence on the agricultural sector worldwide. Agricultural biotechnology includes plant tissue culture (PTC), applied microbiology, and applied molecular biology contributing to the production of crops with improved food, feed, fiber and fuel. The technique of PTC is well translated from ‘concept’ to ‘commercialization’. As an industry, PTC is no more a nascent industry in India. It is flourishing with multidirectional growth and multimillion dollar turn over. Several crop plants are routinely propagated (anthuriums, bananas, strawberries, sugarcane, orchids etc.) by tissue culture technique and are being traded domestically and internationally for nearly three decades. Since PTC is a powerful technique for mass production in many crops, it has become an important tool in the nursery and farming industry. PTC technique has been responsible for bringing about the second green revolution in our country. The growth of PTC industry in India, its impact on the growing needs of the market, its business potential and the challenges this industry is facing are discussed in the review article.

Keywords: plant tissue culture, in vitro propagation, new varieties, industry, agriculture

INTRODUCTION

Plant tissue culture can be defined as the culture of all types of plant cells, tissues and organs under aseptic conditions. This definition also extends to the culture of excised embryos and protoplast culture. There are many articles that discuss in detail the basic procedures and methods involved in plant tissue culture [1-3]. Plant tissue culture has an important role to play in the manipulation of plants for improved agronomic performance. Plant tissue culture is an integral part of molecular approaches to plant improvement and acts as an intermediary whereby advances made by the molecular biologists in gene isolation and modification are transferred to plant cells. Some of the simpler techniques that are more approachable and have been found to be applied directly in plant propagation and genetic improvement of plants are (i) micropropagation, (ii) meristem culture, (iii) somatic embryogenesis, (iv) somaclonal variation, (v) embryo culture, (vi) in vitro selection, (vii) anther culture, and (viii) protoplast culture [4]. The details of each of these techniques and their applications are listed in table 1. Most applied and well translated among these is the technique of micropropagation, which has revolutionized the modern agriculture industry.

MICROPROPAGATION INDUSTRY IN INDIA

Micropropagation is the application of tissue culture technique to the propagation of plants starting with very small parts grown aseptically in a test tube or other suitable containers [21]. Micropropagation is one of the key tools of plant biotechnology that has been extensively exploited to meet the growing demands for elite planting material in the current century. There exists a large demand for disease free clones of superior quality plants in ornamental, horticultural, floricultural
Table 1. Techniques of tissue culture and their various applications.

<table>
<thead>
<tr>
<th>Technique*</th>
<th>Application</th>
<th>Comments and References</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>- Rapid propagation of a superior plant while maintaining the genetic make up - To maintain stock under controlled conditions - Germplasm storage</td>
<td>1. Immediate application; however, the ease with which plants can be micropropagated varies from species to species and even certain genotypes within a species can prove to be more recalcitrant than others. In general, herbaceous species are more amenable to tissue culture techniques than woody perennials. 2. Somaclonal variation can be a problem with some micropropagation techniques. Field evaluation of plants is required to verify trueness-to-type and to check for genetic variants [5-7].</td>
</tr>
<tr>
<td>II</td>
<td>Elimination of diseases (particularly viral diseases) from plant propagative material</td>
<td>1. Immediate application if plants amenable to tissue culture. 2. Heat treatment/meristem culture does not ensure that the material has been freed of virus. Quarantine and virus indexing are still recommended to verify that the material is in fact disease-free [8].</td>
</tr>
<tr>
<td>III</td>
<td>To rapidly increase desirable plants while maintaining the genotype of the original plant</td>
<td>1. Involves regeneration from callus and cell suspensions and as such is more difficult to achieve than micropropagation. More research and development is needed to successfully develop the technique and a time frame that may involve years of trial and error with a recalcitrant species. 2. Orbital shakers centrifuge and microscopes are needed when working with cell suspensions. 3. Because regeneration is from undifferentiated cells the chances of somaclonal variations increase [9].</td>
</tr>
<tr>
<td>IV</td>
<td>To induce desirable, heritable changes in regenerated plants</td>
<td>1. Involves regeneration from callus and cell suspensions, therefore the constraints and limitations are the same as those above. 2. Not all changes are desirable; in fact most are deleterious or of no agronomic use. 3. Not recommended if suitable genetic diversity is already present in the species; better application in vegetatively propagated material with a limited gene base. 4. Screening the many thousands of plants for those with useful characters is expensive and time-consuming. If a selection pressure can be applied at the cellular level then better use can be made of somaclonal variation and <em>in vitro</em> selection [10,11].</td>
</tr>
<tr>
<td>V</td>
<td>To ‘rescue’ embryos during attempts at wide hybridization by sexual crosses between distantly related plants and culture them to maturity</td>
<td>1. Relatively easy to culture. 2. Immediate application. 3. Chances of success are good; but difficulty increases with more immature embryos. Hormone and growth factor requirements are more specific with early-stage embryos [12-14].</td>
</tr>
<tr>
<td>Technique*</td>
<td>Application</td>
<td>Comments and References</td>
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</table>
| VI | To induce desirable, heritable changes in regenerated plants by subjecting a population of cells to a selection pressure | 1. Involves regeneration from callus and cell suspension. Constraints and limitation as mentioned in embryo culture.  
2. Important to have a reproducible system for the regeneration of large numbers of plants from stressed cells as the selecting agent may lower the ability to regenerate plants.  
3. Important that tolerance to the stress operates at both the cellular and whole plant levels so that there is a greater chance of recovering desirable plant. Unfortunately, many of the agriculturally important traits are multigenic and depend on the structural and physiological integrity of the whole plant [15,16]. |
| VII - | To produce homozygous, pure-breeding lines of plants for hybrid production and genetic studies | 1. Involves regeneration from callus, cell suspension and pollen. Constraints and limitation as mentioned in embryo culture.  
2. Important to have the frequency of regeneration and to be able to distinguish between plants regenerated from haploid somatic tissue found in the anther.  
3. The use of colchicines may be needed to double the chromosome number of haploid plants [17,18]. |
| VII - | To improve the efficiency of in vitro selection | 1. Involves regeneration from callus, cell suspension and pollen. Constraints and limitation as mentioned in embryo culture.  
2. Important to have the frequency of regeneration and to be able to distinguish between plants regenerated from haploid somatic tissue found in the anther.  
3. The use of colchicines may be needed to double the chromosome number of haploid plants [17,18]. |
| VIII - | To incorporate potentially useful genes from one plant species to another by fusion of protoplast and regeneration from the hybrid cell line | 1. Protoplast are cells from which the cell wall has been removed either by mechanical and/or enzymatic methods.  
2. Orbital shakers, centrifuge and microscopes are needed.  
3. Regeneration of plants from protoplast is generally very difficult to accomplish and a long lead time is often needed to develop the techniques with a particular species [19,20]. |
| VIII - | Somatic hybridization | 1. Protoplast are cells from which the cell wall has been removed either by mechanical and/or enzymatic methods.  
2. Orbital shakers, centrifuge and microscopes are needed.  
3. Regeneration of plants from protoplast is generally very difficult to accomplish and a long lead time is often needed to develop the techniques with a particular species [19,20]. |
| VIII - | To transfer specific genes into protoplasts and regenerate transgenic plants | 1. Protoplast are cells from which the cell wall has been removed either by mechanical and/or enzymatic methods.  
2. Orbital shakers, centrifuge and microscopes are needed.  
3. Regeneration of plants from protoplast is generally very difficult to accomplish and a long lead time is often needed to develop the techniques with a particular species [19,20]. |

*I - Micropropagation, II - Meristem culture, III - Somatic embryogenesis, IV - Somaclonal variation, V - Embryo culture, VI - In vitro selection, VII - Anther culture, VIII - Protoplast culture

and agro-forestry sectors, which form the core sectors of agriculture. This need has been successfully tapped through micropropagation by the application of techniques of plant tissue culture thereby effectively translating the concept of technology for the commercial needs. As a result, several hundred plant tissue culture laboratories have come up world wide, and more so in India. In India, there are about 100 commercial plant tissue culture units with a minimum production capacity of about 1 million plants per year from each of the units. Among these, at least 20 of the units have larger production capacities, with 5 to 10 million plants/year. In addition, there are more than a dozen smaller units with 0.2 to 0.5 million plant production capacities where single crops are being produced. The Government of India has identified micropropagation industry as a priority area for further research, development and commercialization. The statistical survey reported by Prakash [22] reveals very interesting data on this aspect. Over the last 20 years, the Ministry of Science and Technology has supported 150 projects for research and development in this field. The favorable policies from the Ministries of Science and Technology, Commerce, Industries and Agriculture, Government of India have encouraged entrepreneurs and technocrats to set up more than 50 commercial units between 1987 and 1995 with a total installed capacity of
about 210 million plants per annum. From 1986 to 1989 the targets achieved were 50% of the installed capacity. In 1991, there was a decline and only 20% of the target was achieved. In 1996, there was an increase in the number of plant tissue culture units and as a result most of the units had to suffer under-utilization of their facilities. The history of commercialization of plant tissue culture in India is a story of ‘Rise and Fall and Rise Again’. The percentage increase in production decreased by 50% from 1991 to 1994 and in 1998 there was a negative growth showing rapid decline. However, between 1999 till date there has been an average of 35% rise in tissue culture production per year. This trend resulted in better capacity utilization of the existing facilities by 2002 and additional facilities are now being set up to increase the total installed capacity in the country to 300 million plants per annum. The statistics of the year-wise growth trend in micropropagation industry in India are detailed in table 2 [22].

Table 2. Year-wise growth trend in micropropagation industry in India.

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of commercial Tissue culture units</th>
<th>Installed capacity (Million plants/year)</th>
<th>Millions of plants produced</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986</td>
<td>1</td>
<td>1.00</td>
<td>0.5</td>
</tr>
<tr>
<td>1987</td>
<td>1</td>
<td>4.00</td>
<td>2.5</td>
</tr>
<tr>
<td>1989</td>
<td>3</td>
<td>10.00</td>
<td>5</td>
</tr>
<tr>
<td>1991</td>
<td>17</td>
<td>50.00</td>
<td>10</td>
</tr>
<tr>
<td>1994</td>
<td>21</td>
<td>80.00</td>
<td>15</td>
</tr>
<tr>
<td>1996</td>
<td>51</td>
<td>210.00</td>
<td>22</td>
</tr>
<tr>
<td>1998</td>
<td>51</td>
<td>210.00</td>
<td>15</td>
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<tr>
<td>1999</td>
<td>57</td>
<td>225.00</td>
<td>20</td>
</tr>
<tr>
<td>2000</td>
<td>61</td>
<td>255.00</td>
<td>25</td>
</tr>
<tr>
<td>2001</td>
<td>69</td>
<td>280.00</td>
<td>22</td>
</tr>
<tr>
<td>2002</td>
<td>76</td>
<td>300.00</td>
<td>30</td>
</tr>
<tr>
<td>2003</td>
<td>76</td>
<td>300.00</td>
<td>50</td>
</tr>
<tr>
<td>2005*</td>
<td>85</td>
<td>NA</td>
<td>60</td>
</tr>
<tr>
<td>2006*</td>
<td>85</td>
<td>NA</td>
<td>65</td>
</tr>
<tr>
<td>2007*</td>
<td>100</td>
<td>NA</td>
<td>75</td>
</tr>
<tr>
<td>2008*</td>
<td>125</td>
<td>NA</td>
<td>85</td>
</tr>
</tbody>
</table>

*Labland’s database; NA, not available

DEMAND VS SUPPLY

The demand for micropropagated plants in agriculture, horticulture and in social forestry is growing by the day, since the traditional methods of propagation do not yield sufficient quantity and in some crops they are cumbersome. The emerging scenario on the growing use of tissue culture plantlets predicts that each state in our country should, at least, have ten tissue culture laboratories. The major consumers of tissue culture plants are the State Agriculture and Horticulture Departments, Agri Export Zones (AEZs), sugar and paper industries, private farmers and floriculturists. State-wise, the requirement of the crop type is different for the domestic consumption. It is important to note that the demand for some crops like banana, grapes, pineapple, strawberry, sugarcane, potato, turmeric, ginger, cardamom, vanilla and ornamentals like anthuriums, orchids, chrysanthemums, rose, lily, and gerberas are on the rise in different states in the country. Small quantities of medicinal plants like Aloe, Coleus, Chlorophyllum, Digitalis, Melaleuca, Patchouli, Gloriosa and forestry crops like Bamboo, Teak, Eucalyptus, Sandal, Mangium are also produced and consumed in the domestic market [23]. A market survey made on tissue cultured plants by the Biotech Consortium India Limited [23] for the Department of Biotechnology and Small Farmers Agri-business Consortium reveals that a total of about 45 million plant species mentioned above was for the domestic
consumption valuing Rs. 38.5 crores. The survey had also projected that for the year 2007-08 the overall market demand for tissue culture plants would be 145 million plants of the above species valuing Rs. 136 crores, with a growth rate of 20-25%. The consumption of plants for 2002-03 has been approximately 45 million plants with banana constituting 41% share followed by sugarcane at 31% and ornamentals at 14%, spices at 6% and medicinal plants at 4%.

The growth in demand for tissue culture banana has increased at a high rate of 25-30% and a similar trend for other crops is observed particularly for that of sugarcane due to the introduction of ethanol blended petrol. It can be noted that there is growing awareness of superiority of tissue cultured plants, and demand for crops like banana, grapes, papaya, ginger, turmeric, cardamom, vanilla, potato, Jatropha is increasing. When it comes to the international demand, the foliages and ornamentals have a great potential and the products have an unending elongated list. Major pot plants and landscaping ornamentals like Ficus, Spathiphyllums, Syngoniums, Philodendrons, Nerium, Alpenia, Yucca, Cordyline, Pulcherrima, Sansevieria, Gerbera, Anthuriums, Rose, Statis, Lilies, Alstromeria etc. are routinely produced by various plant tissue culture laboratories in India. About 212.5 million plants including 157 million ornamental plants amounting to 78% of the total production are reported [24,25]. It may be pointed out that tissue culture laboratory can also be used to produce biofertilisers like rhizobium, azotobacter, azospirillum, phosphate solubilising bacteria culture as well as mushroom spawn culture that indirectly contribute to the agricultural sector.

DEMAND SUPPLY GAP

The aggregate production capacity of the established commercial tissue culture units is estimated at 300 million plants per annum [22]. It is important to note that the installed production capacity is not always utilized completely and only 80-85% utilization is generally best utilized. The demand projections of about 145 million plants requirement in the domestic market are highly conservative. Assuming that only 50% of the installed capacity is being used for addressing the domestic demand, the remaining capacity is used to cater to the export demand; still there is a large gap between the demand and supply. This clearly indicates a need for setting up additional units and supply plants with more competitive prices for improving the agricultural productivity, and enhancing the social status of the farmers.

ROLE OF GOVERNMENT IN PLANT TISSUE CULTURE INDUSTRY

To encourage the tissue culture industry, various central and state government departments have framed several schemes and have announced incentives.

(a) Ministry of Agriculture: The Department of Agriculture and Cooperation under the Ministry of Agriculture, Government of India provides financial assistance up to Rs. 21 lakhs and Rs. 10 Lakhs for setting up tissue culture units in public and private sectors respectively, subject to a maximum of 20% of the project cost. Under integrated development of fruits scheme, financial assistance in the form of subsidy, up to 50% is provided for purchase of tissue culture banana plants by various state Governments. The Government of India has set up a national facility for virus diagnosis and quality control of tissue culture plants at New Delhi with 5 satellite centers catering to the needs of the tissue culture industries in various parts of the country.

(b) Agriculture and Processed Food Products Export Development Authority (APEDA): Under the Ministry of Commerce and Industry, state-of-the-art airfreight trans-shipment centre has been set up for tissue culture plants (perishables) at New Delhi, Bombay and Bangalore airports. Airfreight subsidy up to 25% of the freight cost is provided to tissue culture plants. 50% subsidy is given for the development of infrastructure like refrigerated van, packing, export promotion, market development, consultancy services, feasibility studies, organization building and human resource
development. Financial assistance is also given for strengthening quality control facilities and implementation of ISO 9000.

(c) National Horticulture Board (NHB): For setting up tissue culture lab there is a provision for back-ended capital subsidy not exceeding 20% of the project cost with a maximum of Rs. 25 lakh per project. Such subsidies are also extended to build up greenhouse and climate controlled poly house/shade house.

(d) Small Farmers Agri-business Consortium (SFAC): SFAC under the Ministry of Agriculture gives soft loans up to 50 lakhs for setting up small tissue culture labs by co-operative societies formed by small scale farmers.

(e) Department of Biotechnology (DBT): DBT supports research and development projects across the country at various laboratories in the universities and research institutions for development and standardization of tissue culture protocols. The private tissue culture units are entitled for expansion of existing units as a Phase II activity under a scheme called Small Business Innovation Research Initiative (SBIRI). To promote the adoption of tissue culture technology by the industry and the end user, the department has established two micropropagation technology parks (MTPs) which provide a large number of service packages and have an important mandate of training and generating skilled manpower. The MTPs have transferred about 10 technologies to the industry and have also provided consultancy and taken up turn-key projects for various end users and state departments. The department has also set up a national facility for virus diagnosis and quality control of tissue culture raised plants, which are located at 6 different centers in India to ensure supply of disease free plants to the end users.

(f) State level incentives: The states of Karnataka, Gujarat, Maharashtra, and Andhra Pradesh are giving financial assistance for setting up tissue culture units under the new agro-industrial policy. Karnataka gives capital subsidy of 20% on investments.

All the above schemes have encouraged the establishment of tissue culture industry, which in turn have tremendously improved the demand for tissue culture generated quality planting material. A concerted effort is being made by the Government and the Industries to ensure that plant tissue culture, a technology with enormous commercial potential, would be an important industrial activity during the 21st century.

INDIAN SCENARIO VS REST OF THE WORLD

The Indian scenario of tissue culture industry clearly indicates that it is a flourishing industry with about 125 tissue culture units with a total production capacity of 300 million plants per annum currently. The analysis of the product range indicates that it is mainly concentrating on ornamentals, and horticultural crops. Fruit plants like banana, strawberry, pineapple, papaya; vegetables like tomato and potato, spices like cardamom, turmeric, ginger, pepper; plantation crops like sugarcane, vanilla, tea, coffee, Jatropha, and a very few forest crops like Eucalyptus, Paulownia, Sandal and Teak are being produced. The global scenario of tissue culture industry has been well reviewed by Prakash [22]. Among the Asian countries that are active in commercial tissue culture plants production, it is in India that about 125 commercial units are functioning, while Indonesia and Japan have 33 units each, Korea has 20 and Thailand has 18 units. Other global countries involved in tissue culture plants production include European countries, USA, Canada, Australia, New Zealand, Israel, Middle East, South and Central America and Africa. All these countries together produced about 900 million plants in the year 2003.

PLANT TISSUE CULTURE AND THE EVOLUTION OF NEW VARIETIES
The use of plant tissue culture to produce somaclonal variation is one means of generating variation that may be needed in breeding programs. This is particularly true in species that are traditionally propagated asexually or for which only few cultivars are available. Deliberate attempts to induce variations in tissue culture have been in progress for the last 60 years and a large number of variants in ornamentals and horticultural crops have been reported [26]. However, there are only a few instances where somaclonal variations have produced agriculturally desirable changes in the progeny. These include sugarcane - increase in cane and sugar yield, and resistance to eye-spot disease [27]; potato - improvement of tuber shape, colour and uniformity, and late blight resistance [28]; tomato - increased solids, resistance to Fusarium race 2 [11]. In the ornamental sector, Syngonium provides an excellent example of somaclonal variant where 22 new cultivars, all somaclonal variants, were selected from large populations of tissue-cultured material grown in commercial greenhouses. All 22 cultivars can be traced back to the original 'White Butterfly' clones. Each variant remained stable enough to become a named cultivar. Several of the cultivars have pink or reddish coloration in the foliage (Infra Red, Bronze, Roxane are a few new varieties) that was not evident in 'White Butterfly'. Similarly, Labland Biotech, Mysore has obtained one unique, stable variant of Spathiphyllum with golden yellow leaves that has not been found in any Spathiphyllum varieties so far. It is being registered as the new variety of Spathiphyllum named 'Sona' and is being multiplied commercially for both domestic and overseas market in large numbers.

Among the other agricultural crops, CIEN BTA-03, a variant of Williams variety of Banana resistant to yellow Sigatoka disease; AT626 & BT 627 of sugarcane variant resistant to sugarcane mosaic virus A and B are released for commercial usage. In addition, ‘Ono’, a sugarcane variant from variety, Pindar resistant to Fiji disease; ATCC 40463, a tobacco variety with enhanced flavour; DK 671, corn variety with higher yield, with lasting green colour and higher seedling vigour are the varieties from overseas inventions. Bio-13 a variety of Citronella released by CIMAP, India; Bio-902, Bio-YSR variants of Brassica parent ‘Varuna’ with enhanced seed yields are from India that are being multiplied and are cultivated successfully on commercial scale.

PLANT TISSUE CULTURE AND SUPPLY OF SPECIFIC CROPS IN DEMAND

The impact of tissue culture technology in bridging the gap between the demand and supply could be exemplified by banana and Jatropha. It is now almost certain that only this technology can help in catering to the needs of quality planting material of banana and Jatropha. Banana is being cultivated in India in an area of about 500,000 hectares with an average productivity of about 15 kg of yield per plant. However, by replacing the conventional methods of use of suckers with tissue cultured plantlets, the productivity can be enhanced to about 50 kg/plant from the same area. In countries like Australia and Central America, bananas are always cultivated with tissue cultured plants after indexing for virus. At present, India is the largest producer of banana in the world with about 30% of total global production. But, the export market share is a meager 1%. With increased productivity/unit area, the export capabilities can certainly be improved. This is possible by adopting the cultivation with virus indexed, tissue cultured plants instead of using the conventional suckers. Similar is the case with Jatropha curcas. The demand within the country for quality Jatropha plants is about 5 billion (50,000 lakhs). This huge quantum of quality planting material supply is possible either through the adoption of tissue culture technique or by providing hybrid seeds.

CONSTRAINTS

The main advantage of tissue culture technology lies in the production of high quality and uniform planting material that can be multiplied on a year-round basis under disease-free conditions, and
supplied anywhere irrespective of the season and weather. However, the industry is technology-driven. This technology is the amalgamation of triple alliance: capital, labor and energy. Although, labor is cheap in many developing countries, the resources of trained personnel and equipment are often not readily available. In addition, energy, particularly electricity, and clean water are expensive. Acclimatization *en mass* is also another expensive part of the industry wherein sophisticated greenhouses are essential to generate suitable end products. It is necessary to have low cost options for weaning/hardening of micropropagated plants and finally growing them in the field. The most important aspect of plant tissue culture industry is to handle the technology very carefully. The technology in the wrong hands or the wrong use of the technology leads to unproductive results.

**FUTURE GROWTH OF PLANT TISSUE CULTURE INDUSTRY**

Long-term agriculture and forestry could be sustainable, with the use of little or no crop-protection chemicals, low energy inputs and yet maintaining high yields, while producing quality material. Biotechnology-assisted plant breeding is an essential step to achieve these goals. Plant tissue culture techniques have a vast potential to produce plants of superior quality, but this potential has not been fully exploited in the developing countries. During their growth under *in vitro* conditions, plants can also be primed for optimal performance after transfer to soil. In most cases, tissue-cultured plants out-perform those propagated conventionally. Thus, *in vitro* culture has a unique role in sustainable and competitive agriculture and forestry. It has been successfully applied in plant breeding, and for the rapid introduction of improved plants. Bringing new improved varieties to market can take several years if the multiplication rate is slow. For example, it may take a lily breeder 15 to 20 years to produce sufficient numbers of bulbs of a newly bred cultivar before it can be marketed. *In vitro* propagation can considerably speed up this process. Plant tissue culture has also become an integral part of plant breeding. For example, the development of pest- and disease-resistant plants through biotechnology depends on a tissue culture based genetic transformation. The improved resistance to diseases and pests enables growers to reduce or eliminate the application of chemicals. The potential of plant tissue culture in increasing agricultural production and generating rural employment is well recognized by both investors and policy makers in developing countries. These trends have augmented the firm footage of tissue culture industry as an established input into agriculture and have further opened up avenues for future growth.

**WOMEN IN PLANT TISSUE CULTURE RESEARCH AND INDUSTRY**

The Government of India declared 2001 as the year for Women’s empowerment. Recent trends have demonstrated the impressive contributions of womenfolk in various fields. Remarkable contributions have been made by women scientists in plant tissue culture arena. Important breakthrough results in the field of plant tissue culture such as perfection of ovule culture [29], production of somatic embryos in Sandal [30], *in vitro* flowering in Bamboo [31], are a few to be named. Eminent women scientists working in the research filed of plant tissue culture would consist of a long list. Not to beat, there are at least a dozen proficient women entrepreneurs running this industry producing different plant species for domestic and export market. Most significant fact is that, this industry employs women staff to the extent of about 85% of the total staff required for this industry. The kind of working environment available to the staff is more suitable to the womenfolk. Besides, the work demands lot of involvement, patience, dedication, and commitment, which compliment each other. The industry is poised to synchronize with the interest of women empowerment that has been greatly contributing to the success of this industry in India.
CONCLUSION

The plant tissue culture technology has been very successful as an industry and has greatly contributed to successful agriculture. The technology has created several employment opportunities and opened up many entrepreneurial fields. Usage of tissue culture-generated plants has increased productivity per unit area, particularly in horticultural crops. This industry has made available different unique commercial plant species such as ornamentals and foliages in large scale, which were not produced earlier by the conventional methods. Tissue culture has been one of the main technological tools and reasons that have contributed to the ‘Second Green Revolution and Gene Revolution’. India is being looked upon by the world as the main technology base for production and supply of economically important plant varieties. With more innovative work, and intensive exploitation of our flora, the tissue culture technique will help us in consolidating our leadership at the global level.

REFERENCES