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Techno-economic Efficiency of Micropropagated Industrially Important Crop Plants Heeng, Monk Fruit and Bamboo

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ABSTRACT

Adoption of new crops in any region requires consumer-preferred quality planting material available to distribute in different societies and farmers which are suitable according to their agronomic preferences. Identification of suitable climatic conditions and quality planting material are most important steps towards successful introduction and commercialization of economically important crops. Plant micropropagation has commercialized globally by researchers and industrialists to produce high-quality and virus free planting material in large quantities. Himachal Pradesh has diversified climatic conditions and low labor cost suitable for commercial cultivation of heeng, monk fruit and bamboo species. Mass-scale micropropagation of these species can make this state role model in this area due to its high potential to enhance resources for income generation and employment opportunities. In current article, we have quantified the factors affecting commercial micropropagation and analyzed the economics of *in vitro* production of heeng, monk fruit and bamboo species. Capital budgeting, business analytics tools were applied for thorough calculation of fixed and variable costs on investment. Different formulas were applied to check the commercial *via*bility to indicate that these economically important crops will open unique perspectives for farmers and agripreners promoting livelihood promotion and as a positive approach towards “self-reliant India”. Moreover, cost effectiveness, while maintaining reproducibility and high quality will offer high-throughput functional and structural design to offer technical limits to achieve profitability in these crops.

Key words: Automation, Capital budgeting, Economic analysis, Rural economy, Sustainability, Tissue culture.

Tissue culture foundation was laid down in 1955 by a French botanist George Morel by successfully producing virus-free orchid plants. He standardized the technique for apical meristem culture to produce millions of virus- free orchids (John *et al.,* 1997). During 1970s, tissue culture technology was well established in developed countries and during 1980s these countries generated huge benefits by transferring this technology to the developing countries. Tissue culture-based plant propagation has now emerged as a leading agro-technology globally, because of immense potential to produce millions of identical clones within a short time period (Joshi and Kumar, 2013). This technology has certain advantages over the conventional methods as through micropropagation, disease free, elite and uniform planting material can be produced at a rapid rate. The plants can be multiplied under controlled parameters such as pressure, temperature and light round the year Micropropagation technology is a more capital-intensive enterprise as compared to the conventional methods, major reasons behind this are requirement of skilled manpower, chemicals, consumables and knowledgebase (Bahuguna *et al.,* 2011). Earlier it was difficult to commercialize micropropagation due to higher investments as compared to traditional methods. However, these bottlenecks were resolved through innovations of efficient and reproducible methodologies with improved quality of planting material. Still, cost of inputs like labor and capital, chemical consumables, media preparations, electricity and other inputs must be determined essentially to encourage farmers and entrepreneurs to take up the venture.

Production of disease free, elite and uniform clones of various medicinal and aromatic crops, floriculture and horticulture crops and fruits and vegetables crops has achieved new frontiers in the world trade of planting material to enhance livelihood and employment. Even rural parts of the country are also getting start-ups in tissue culture for rural upliftment and employment. Even, threatened and endangered plant species can also be successfully conserved and mass propagated through micropropagation (Pathak and Abido, 2014). Government of India through Department of Biotechnology (DBT), CSIR, MSME, agriculture department, horticulture department and other RandD Institutes are providing hands on training and skill development to urban and rural populations for setting up

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small tissue culture units for mass scale propagation of different economically important crops.

Due to diverse agro-climatic conditions of Himachal Pradesh and changing economic scenario of Indian agriculture in the present era, our research paper critically reviews the economic importance of heeng, monk fruit and bamboo tissue culture. CSIR-Institute of Himalayan Bioresource Technology (IHBT), Palampur is the only CSIR laboratory in the state dedicated to impart training and skill development of farmers and entrepreneurs to setup tissue culture units to meet the increasing demand of quality planting material for agricultural diversification. CSIR-IHBT, Palampur is also engaged in capacity building of the state government officials for the knowledge dissemination in micropropagation of different plant species to connect between science and public policy reforms to enhance investment for sustainability of rural agriculture and to increase opportunities for economic progress of the state (Withers and Engelmann, 1997; Watt *et al.,* 2000; Vyas and Singh, 2025). For the first time *heeng* and monk fruit cultivation in India has been started by CSIR-IHBT, Palampur under "Self Reliant India" movement.

Current article focuses on economic importance and recent advancements for production of quality planting material of heeng, monk fruit and bamboo crops. In this article we present the first detailed description of the economy of the cost of producing micropropagated plantlets after changing various parameters during different stages of micropropagation. Also presented is a cost/benefit analysis for large scale micropropagation of economically important crops. In addition, few equations were discussed to predict the total cost of tissue culture unit using a standardized protocol. The current study reveals the scope of mass propagation of such crops through determining the overall expenditure and gross returns to motivate farmers for setting up tissue culture units for economic gains and to make micropropagation an economically *via*ble tool for crop improvement and nutritional security.

Asafoetida: A resource for medicine and cuisines

The genus, *Ferula* (Apiaceae) consists of 140 species that are widespread from the Mediterranean region to central Asia. *Ferula assa-foetida* L. is an endangered medicinal, perennial and economically important herbal spice among the thirty species of *Ferula* genus indigenous to Afghanistan and Iran (Yadav *et al.,* 2024). An oleo-gum resin, called asa-foetida (heeng) is obtained by incision from the roots and used as a flavoring spice in cuisines of South Asian region. The plant is monoecious and reaches upto 2 m height and produces either bitter or sweet resin (Iranshahy and Iranshahi, 2011). Rural population residing in Mediterranean region primarily utilize heeng for traditional herbal therapies. It has also been reported in Iranian folk medicine to be antiseptic, aphrodisiac, anthelmintic, analgesic, nervine, sedative, laxative, expectorant, digestive, carminative, aromatic and antispasmodic (Hamayun *et al.,* 2003).

The oleo-gum-resin has a bitter taste and characteristic sulfurous odour and coagulates on exposure to air (Kavoosi and Rowshan, 2013). After drying, it turns into dark brown to black in color and its main constituents are essential oil, which contains monoterpenes, sulfur-containing compounds, sesquiterpene, ferulic acid and other volatile terpenoids (Kavoosi and Rowshan, 2013). Essential oils of different oleo-gum-resins differ in both quantity and quality i.e., chemical composition, reactive nitrogen species (RNS), reactive oxygen species (ROS), H2O2 and TBARS scavenging activities (Punia *et al.,* 2024). For this reason, the essential oil obtained from the young stages of *F. assa-foetida* are used as natural antioxidants in food industry, to improve the oxidative stability of fatty foods during storage, while essential oil from later stages are used in health industry, as antimicrobial agent.

Drastic increase in the global demand of medicinal plants due to resurgence of customer interest in herbal medicines. Most of the demand is being fulfilled from wild populations, but still the extraction methods are invariably crude and unsystematic, causing overexploitation of this species, resulting in depletion of their natural populations and habitat due to poor seed germination (Golmohammadi, 2013; Moghadam *et al.,* 2014). Thus, development and implementation of conservation strategies are urgently required to exploit this important species. In addition, strategic planning is required for appropriate utilization besides monitoring the quantity and quality of products and restoration of the germinating locals and pastures.

Bamboo: A renewable energy resource for circular economy

Bamboo belongs to Poaceae family and 80% global bamboo forests are in tropical, subtropical and mild temperate zones of India, China and Myanmar (~198 lakh ha) (Elejoste *et al.,* 2021). Out of global 90 genera of 1200 species, India is endowed with 125 indigenous and 11 exotic species of bamboo belonging to 23 genera spread in 1,60,037 Km^2 area (Solomon *et al.,* 2020). Out of these, many species are utilized as an industrial material and range of traditional and conventional household, medicines and commercial purposes due to biodegradability, high growth rate, cost effective processing (Benjamin *et al.,* 2021; Borthakur, 2022; Mohan *et al.,* 2022). International trade value of bamboo is 68.8 billion USD affecting 2.5 billion people globally and India contributes 45% to the world bamboo production with 4.5 % global market share (Ting *et al.,* 2008). Singha and Timung (2015) reported that bamboo is back bone of the rural economy and livelihood for tribal population. Bamboo shoots contain proteins, minerals, carbohydrates and vitamins besides other bioactive compounds and antioxidants i.e., vitamins C and E, phenols and trace minerals including iron, zinc, copper and selenium (Kaur, 2018; Nirmala *et al.,* 2018). In addition, due to high tensile strength, bamboo (28,000 PSI) is used for construction of buildings and other household items in comparison to steel (23,000 PSI) (van Dam *et al.,* 2018; Borthakur, 2022). Further, bamboo is an effective carbon sink which can mitigate greenhouse effect (Xu *et al.,* 2022).

Similarly, charcoal obtained from pyrolysis of bamboo biomass possess high surface area, pore distribution, bulk density and better absorption properties than wood charcoal (Chien *et al.,* 2011; Samarawickrama *et al.,* 2020).

At present the energy transition has become an important topic globally, towards developing pathways to reduce deforestation and to achieve carbon neutrality by 2060 (Xu *et al.,* 2022). In the current scenario of global warming and severe climatic vagaries, bamboo provide an environmentally-benign and zero waste model for circular economy by following a closed-loop system to reduce poverty, employment generation and sustainable development (Van Der Lugt and King, 2019; Chauhan *et al.,* 2020; Kumari *et al.,* 2024). The biomass power plant of bamboo has demonstrated economic potential (1kWh of electricity per 1.2 kg) with promising energy for the future and offers environmental benefits for communities (Sharma *et al.,* 2018; Saepullah *et al.,* 2022). Developing nations can produce renewable energy, biofuel, bio-based chemical products and renewable carbon such as cellulose and lignin from bamboo, because it can grow on marginal lands, highly drought tolerant, high growth rate, phytoremediate heavy metals and requires low input (Ekwe *et al.,* 2022). Thus, developing countries can play a key role in the decarbonization process that leap-frogs the industrialized world to maximize the potential benefits and attain net-zero carbon emission (Tripathi *et al.,* 2024).

Monk fruit: An alternative resource for natural sweetener

The sweetener industry is at the crossroads to re-evolve itself for climate resilience, consumer demand for natural sweeteners and urgent need to diversify value added products to encourage for market revenue volatility and sustainable circular economies (Graybill 2020; Aurand *et al.,* 2022). Strategies are required to tolerate climatic vagaries by introducing new genotypes, soil and pest management strategies to improve the sugar industries and livelihood of farmers (McGree *et al.* 2020; Singh, 2020). Monk fruit (*Siraitia grosvenorii*) is a high intensity, zero calorie sweetener and perennial vine endemic to Southeast Asia and Southern China (Gong *et al*. 2019). Fruit extracts are used in traditional Chinese medicine for remediation of obesity, diabetes, lung congestion, cold, cough, sore throat and cancer and also show bioactive potential against diabetes, inflammation, allergy and bacteria (Pandey and Chauhan 2019). Fourty different cucurbitane-type triterpene glycosides, termed as mogrosides, provide 300 times more sweetness than sucrose and given the status of Generally Recognized as Safe (GRAS) (Seki *et al*. 2018). Mogrosides also induce a hypoglycemic reaction by reducing α-glucosidase activity, lipid peroxidation and enhancing insulin secretion (Gong *et al.,* 2020) and improves blood glucose levels (Li *et al.,* 2022). Therefore, monk fruit sweetener has been utilized in several food and beverages (Pandey and Chauhan, 2019).

Despite having substantial applications in food, artificial sweeteners have long-term inflammatory and mutagenesis effects. Thus, natural sweeteners utilization in food and beverage industries is rising at an unprecedented rate globally (USD 85.92 billion in 2020), as a way to avoid health issues and to meet consumer insistence (Eggleston *et al.,* 2021; Anwar *et al.,* 2023). Natural sweeteners positively affect the metabolism, reduces weight and blood sugar levels, have low fructose content and low glycemic index and can adsorb nutritionally beneficial biomolecules, such as minerals, phytoceuticals and vitamins. Monk fruit is not cultivated outside China due to (1) lack of agronomic practices, (2) lack of quality planting materials, (3) low environmental adaptability and (4) less clinical data available (Romo-Romo *et al.,* 2017). However, recently CSIR-IHBT has pioneered in India in developing its micropropagation protocol for mass scale propagation (Patial *et al.,* 2024a; b)

Economic analysis of plant micropropagation

Tissue culture has emerged as one of the leading economic means for multiplication of plants under controlled environment for clonal propagation in short time span and multiplied continuously throughout the year (Tomar *et al.,* 2007). Plant micropropagation has been commercialized past several years with advantage of rapid production of elite and disease free plantlets of ornamentals, fruits and forest trees (Chen, 2016). Current market capacity of tissue cultured products is 500 million to 1 billion plants per annum. Furthermore, to develop transgenic lines and CRISPR-cas mutants for improved traits it is essential to develop and implement reproducible tissue culture protocols, which provides half the gain required for total technology (Nath *et al.,* 2024). Tissue culture for mass propagation relies upon two main factors; one is the ability to produce sufficient quality planting material using controlled environment, while the other depends on the proper management practices. However, being a capital-intensive industry, it is expensive in comparison to conventional propagation and requires specialized manpower. Therefore, practical utility and economic *via*bility of micropropagation technology is a matter of debate. Relatively high cost of tissue culture plantlets is compensated with reducing growth cycles and estimates of increased planting stock and high multiplication rate.

Numerous technological ways to make micropropagation cost effective have been developed, but not extensively quantified such as proliferation rate, growth regulators, time and nutrients required for proliferation and differentiation and scalable framework (Risner *et al.,* 2020). Major problems to be enlisted are shifting to low-cost areas, skilled manpower, elimination of production stages, biological optimization and labor-intensive work (Omar and Aouine, 2007). Thus, few companies have shifted their units to low-cost nations for cost effective production (Chu, 1995; Ilan and Khayat, 1997). Chief components required investment are equipment, electricity (air conditioners), chemicals, glassware, labor (35-60%), office expenses, sales and marketing. The cost of establishing facilities and equipment is too high in developing nations, while labor costs are 60-

70% high in developed countries. Ahloowalia and Savangikar (2004) suggested the application of natural light, temperature regulation and reducing energy consumption of the autoclave, cheaper and disposable containers and cheaper medium for cost effectiveness. Automation makes the management easier, reduce contamination and increase utilization capacity. Alternatively, replacing hardening by extended micropropagation spaces is also beneficial, especially for the root proliferation (Chen 2015; Chen and Huang, 2015).

Economic analyses showed that 5% capital cost of the total cost and 20-25% increase in consumable cost does not affect the cost of plants significantly. Similarly, increase in capacity will increase labor number for subsequent subculturing, which takes 29% of the total cost, while 25% reduction in labor (and increasing remaining efficiency) decreases total cost by USD 100 (Anderson *et al.,* 1977; Donnan, 1986). In addition, axillary budding on the primary shoots increases 4-6 fold multiplication rate, while inducing adventitious shoots increases 10 fold multiplication rate. Further, it was reported earlier that genetic stability in tissue culture is dependent on techniques and/or methods (Dolezel and Novak 1984). Moreover, a drop in rooting efficiency upto 60% increases the base cost by about USD 100. Thus, increasing the efficiency in different stages will improve the overall technology and cost reduction. With the increase in *in vitro* growth of 30% a competitive cost of USD 200 per 1000 plantlets can be achieved (Aitken-Christie 1985; Hakman *et al* 1985). Cost reductions could also be achieved through the automation of labour-intensive steps. In India commercial scale micropropagation is limited to certain crops with high government subsidies. Tissue culture produce are not being able to enter regular plant nurseries in India, because of prohibitive costs and lack of improved genotypes, heavy royalties on imported varieties, low consumption, uncertainty in consignment acceptance, stringent quality parameters and short shelf life.

Automated production technology

Automation helps in achieving more reliable micropropagation products, as it allows standardization of protocols and avoid human error or manual variations besides providing the adaptability required for *in vitro* cultures. The "automated production technology", which has already been well adapted in various industries past several years, offers added advantage in functionality of the system, exact process parameters and extremely high reproducibility in addition to cost effectiveness and high throughput. Thus, apart from investment and maintenance expenditure, the higher quality of products is essential. The global market value for "Automated Production Technology" is predicted to grow at 10% annual rate, with total value between USD 2 to 3.5 billion (Nießing *et al.,* 2021). At present, high throughput and novel technologies are gaining attention, opening up entirely new arena for production of *in vitro* biological, biochemical or pharmacological products (Daniszewski *et al.,* 2018). When handling "Automated Production Technology", primary concern is pluripotency maintenance, due to highly sensitive culture conditions and media compositions for higher multiplication rate (Kinney *et al.,* 2011).

The technical experts need to be familiar with procedures and devices and well planned process chain that can be repeated several times with constant accuracy. Thus, highly qualified and well-trained personnel are essential to handle the cultures correctly to avoid external contamination. The mechanical activity is extremely repetitive for routine media exchange and subculturing. Further, process automation also enables data recording for quality control. The scheduler also enables the platform to plan optimal process and to parallelize processes in order to increase the throughput of the system. In automated production, it is crucial to ensure no negative impact on the quality of cultures. Optimally implemented automation consistently yield reliable produces of higher quality. This increases product value, leading to higher selling price and increasing profitability.

The primary data collection from scientists/technical experts from Agriculture and Biotechnology Divisions. Further data collected through questionnaire designed and pre-tested from state agriculture department and tissue culture laboratories in Himachal Pradesh. Initial information about cost of inputs, apparatus and knowledgebase for the year 2021-22 was gathered and assembled in following three components:

Medium term capital

In this component, large capital investments required to setup latest technology tissue culture lab were illustrated. Capital investments in account of land, architecture, apparatus and equipment's and other mid-terms components required for establishment of hi-tech lab are studied.

Working/ recurring capital

Information related to working capital to meet out the present and short term obligations for operating the hi-tech tissue culture labs were illustrated in this component. Planting material requirement, chemical consumables and manpower expenditure required to meet out the present and future requirements of the labs for regular operations in the tissue culture labs were studied.

Management and production

After depicting the capital investments and working capital, Managerial practices were determined for production related to technical and scientific expertise through practical insight into lab experiments for R and D. Interpretations as well as substantial quantities of material inputs are detailed in study. Further, notations and annotations has been incorporated, wherever required to keep study understandable for readers to enable them to know about techniques to setup tissue culture units with latest technology beneath reference.

Analysis

In line with data collection and study objectives, tabular presentation is deployed to calculated profits and gains, production cost, variable cost on the investment. Further, for commensuration of the project breakeven output, benefit cost ratio (BCR), payback period and recompensing plans were studied as under:

Break even output (Y)

It indicates the level of production at which the producer neither loses money nor makes profit (6).

Table 1: Required mid and short term investment for establishing commercial tissue culture laboratory.

	Particulars	Cost (Rs.)
A	**Medium term investments**	
i.	Cost of land (3000 sq.ft.), construction (800 sq. ft.), polyhouse (1615 sq. ft.), water supply and fencing wire	8,09,300.00
ii.	Cost of machinery, licensing and materials	5,76,625.00
	Total required medium term investment (i+ii) 13,85,925.00	
B	**Short term investments**	
i.	Manpower (1 unskilled @ Rs. 15,300/ month+1 skilled @ Rs. 16,9 00/month)	3,86,400.00
ii.	Cost of chemical consumables, electricity, LPG, lubricants, fertilizer, hicco	2,14,250.00
	trays, stationary and other miscellaneous expenses	6,00,650.00
	Total rquired short term investment (i+ii)	

Table 2: Cost economics of 70,000 *heeng* plants produced through tissue culture.

	Particulars	Cost (Rs.)
A	**70,000 *heeng* plants produced (Numbers)**	
B	**Capital investment (Mid and short term)**	
1.	Long term -	
2.	Medium term	13,85,925.00
3.	Short term	6,00,650.00
	Total capital investment	19,86,575.00
C	**For production of heeng plants in a year**	
	Variable cost (Rs.)	
i.	Cost of polysleeves @ Rs. 2.5/ polysleeve	3,75,000.00
ii.	Recurring cost/ year (i+ii)	6,00,650.00
1	Total recurring cost	9,75,650.00
2	Interest on recurring cost @ 13% per annum	1,26,384.50
a	Total variable cost (TVC) for *heeng* (1+2)	11,02,484.50
b	Fixed cost (Rs.)	
1	Depreciation on equipment's, tools and building excluding land of Table 1 @ 10% per annum	1,22,208.75
2	Interest on fixed cost of Table 1 @ 13.25% per annum	1,79,918.44
3	Rental value of land	1000.00
4	Total fixed cost (TFC) for *heeng*	3,03,127.19
	Total cost (TFC+ TVC) (Rs.)	14,05,611.69
D	**Economic indicators**	
1	Total cost per *heeng* plant (after 10% mortality)	22.311
2	Per unit variable cost of *heeng* plant (Rs.)	17.499
3	Gross returns for *heeng* plants by selling @ Rs. 50/ plant	31,50,000.00
4	Net returns (Rs.)	17,44,388.31
5	Benefit cost ratio (BCR)	1.24
6	Payback period (years)	1.13
7	Break even output (No. of plants)	9326.70
8	Return on investment (ROI)	87.80

$$Y = \frac{F}{P\text{-}V}$$

Where,

Y = Break even output of economically important crops/ plants (No.).

F = Total fixed cost for a tissue culture unit (Rs.).

P = Per unit price of a plant (Rs.).

V = Per unit variable cost of a plant (Rs.).

Benefit cost ratio (BCR)

It is the ratio of present worth of benefits and present worth of costs (5).

$$BCR = \frac{\text{Present worth of benefits}}{\text{Present worth of costs}}$$

Pay back period

It is length of the time required (years) to get back the investment of the project (6).

$$= \frac{\text{Initial investment (Long term + Medium term)}}{\text{Annual net returns}}$$

Return on investment (6):

$$ROI = \frac{\text{Annual net returns}}{\text{Initial investment (Long term + Medium term)}} \times 100$$

Techno-economics feasibility is very important part to start a new venture. Important parameters like initial investments and working capitals *etc*. are very important to evaluate the net profit. At present, plants that are very difficult to propagate through traditional methods can be easily mass propagated through tissue culture techniques. New plant crops which are not traditionally grown in country can be mass propagated through this technique with scientific interventions. A single plants/seeds culture can be able to produce uniform clones for mass multiplication through this method. But, due to high capital investments, this technique cannot be applied to all the crops as it's economically *via*ble. In Himachal Pradesh, this technique is only used to produce plants of some economically *via*ble *i.e.* crops, which are sold at high prices. In this research, we focused on plant tissue culture of newly introduced

Table 3: Cost economics of 1,50,000 monk fruit plant produced through tissue culture.

	Particulars	Cost (Rs.)
A	**1,50,000 monk fruit plants produced**	
B	**Capital investment (Mid and short term)**	
1	Long term	-
2	Medium term	13,85,925.00
3	Short term	6,00,650.00
	Total investment	19,86,575.00
C	**For production of monk fruit plant only in a year**	
	Variable cost (Rs.)	
i	Cost of polysleeves @ Rs. 2.5/polysleeve	3,75,000.00
ii	Recurring cost/year	6,00,650.00
1	Total recurring cost (i+ii)	9,75,650.00
2	Interest on recurring cost @ 13% per annum	1,26,384.50
a	Total variable cost (TVC) monk fruit (1+2)	11,02,484.50
b	Fixed cost (Rs.)	
1	Depreciation on equipment's, tools and building excluding land of Table 1 @ 10%/annum	1,22,208.75
2	Interest on fixed cost of Table 1 @ 13.25% per annum	1,79,918.44
3	Rental value of land	1000
4	Total fixed cost (TFC) for monk fruit	3,03,127.19
	Total cost (TFC+ TVC) (Rs.)	14,05,611.69
D	**Economic indicators**	
1	Total cost per plant (after 10% mortality)	10.41
2	Per unit variable cost of a monk fruit plant (Rs.)	8.17
3	Gross returns for monk fruit by selling @ Rs. 35/ plant	47,25,000.00
4	Net returns (Rs.)	33,19,388.31
5	Benefit cost ratio (BCR)	2.3615
6	Payback period (years)	0.59
7	Break even output (No. of plants)	11298.07
8	Return on investment (ROI)	167.09

economically important crops and bamboo crops. We have studied the economic consequence to start a new venture with this technique.

The short-term capital and mid-term capital requirements were calculated to start new venture i.e. commercially *via*ble plant tissue culture laboratory. It's necessary to workout expenses of land, construction work, machinery and material required (Table 1). It is studied that there is requirement of Rs. 13.86 lakhs initially and Rs. 6.00 lakhs as short-term capital investment (manpower, chemical consumables, raw material cost) by an entrepreneur to setup a plant tissue culture laboratory.

In Table 2, information related to budget execution to produce about 70,000 *heeng* plants per year through plant tissue technique in laboratory is provided. An entrepreneur can have net income of Rs. 17.44 lakhs with BCR 1.24, payback period value of 1.90 years, Break Even analysis at 9326.70 plants and ROI of 87.80 through selling *heeng* plant @ Rs. 50/plant with mortality rate of 10% through plant tissue culture technique.

In Table 3, information related to budget execution to produce about 1,50,000 monk fruit plants per year through plant tissue culture technique is provided. An entrepreneur can have net income of Rs. 33.19 lakhs, Benefit Cost Ratio of 2.3615, payback period of 0.59 years, Break Even Output at 11298.07 plants and ROI of 167.09 by selling monk fruit plants @ Rs. 35/plant with a mortality rate of 10 % through plant tissue culture technique.

Similarly, in Table 4, information related to budget execution to produce about 50,000 bamboo planting material of *Dendrocalamus hamiltonii*, *D. asper and Bambusa balcoa* varieties per year through plant tissue culture technique is provided. An entrepreneur can have net income of Rs. 30.94 lakhs, benefit cost ratio of 2.20, payback period of 0.64 years, break even output at 4014.92 plants and ROI of 155.76 by selling bamboo plants @ 100/ plant with a mortality rate of 10% through plant tissue culture technique.

As *heeng* and monk fruit are being at introduction phase in India and bamboo being the "Green Gold of India", it is encouraging for an entrepreneur to have net return positive, Benefit Cost Ratio being more than one and break even output is less than the actual production of plants. Techno-economics feasibility analysis indicates that the

Table 4: Cost economics of 50,000 bamboo plants produced through tissue culture.

	Particulars	Cost (Rs.)
A	**50,000 Bamboo plants *D. hamiltonii, D. asper* and *Bambusa balcoa***	
B	**Capital investment (Mid and Short term)**	
1	Long term	-
2	Medium term	13,85,925.00
3	Short term	6,00,650.00
	Total investment	19,86,575.00
C	**For production of apple only in a year**	
	Variable cost (Rs.)	
i	Cost of sleeves @ Rs. 1.5/sleeve	3,75,000.00
ii	Recurring cost/year	6,00,650.00
1	Total recurring cost (i+ii)	9,75,650.00
2	Interest on recurring cost @ 13% per annum	1,26,384.50
a	Total variable cost (TVC) for bamboo	11,02,484.50
b	Fixed Cost (Rs.)	
1	Depreciation on equipment's, tools and building excluding land of Table 1 @ 10%/annum	1,22,208.75
2	Interest on fixed cost of Table 1 @ 13.25% per annum	1,79,918.44
3	Rental value of land	1000
4	Total fixed cost (TFC) for bamboo plants	3,03,127.19
	Total cost (TFC+ TVC) (Rs.)	14,05,611.69
D	**Economic indicators**	
1	Total cost per plant (after 10% mortality)	31.23
2	Per unit variable cost of a bamboo plant (V) (Rs.)	24.50
3	Gross returns for bamboo by selling @ Rs. 100/ plant	45,00,000.00
4	Net returns (Rs.)	30,94,388.31
5	Benefit cost ratio (BCR)	2.20
6	Payback period (years)	0.64
7	Break even output (No. of plants)	4014.92
8	Return on Investment (ROI)	155.76

venture for production of these crops is profitable and *via*ble in Himachal Pradesh.

CONCLUSION

Plant tissue culture technique is boon for mass propagation of economically important crops like heeng, monk fruit and bamboo. As we look forward to see the future of these crops in India advance applications like micropropagation, mass production, plant breeding are most promising techniques to increase the area under cultivation of these economically important crops. Tissue culture offers new opportunities for farmers and agri-entrepreneurs to contribute towards "Self-reliant India" mission by cultivating these crops. Advances in tissue culture technology has changed the scenario for cultivation of these crops in non-niche areas and produce in vast geographically diverse areas. Plant tissue culture helps in producing superior quality, disease free and sustained planting material in short time span. Further, tissue culture techniques with proper financial management (provided in table 1, 2, 3 and 4) will enable farmers to take up these crops to their field to improve rural economy in the country. With such economic benefits country will achieve sustainable growth, self-reliance and livelihood promotion of societies/farmers/ agripreneurs in agribusiness. A part from establishing and running cost, the basic cost of tissue culture unit is inversely proportional to the protocol efficiency, multiplication rate, number of steps involved, hardening percentage and better management of manpower. In addition, product automation provides an advantage for reliable reproducibility of the products besides cost reduction and increased throughput. However, better technology development such as cutting-edge protocols, selection strategies for shoot multiplication and regulating photoperiod are promising ways for cost effectiveness.

Author contributions

Manish Kumar collected data and wrote the initial draft of the manuscript; Sukhjinder Singh, conceived idea, designed the study, reviewed and edited the final manuscript; Rohit Joshi wrote and reviewed the manuscript. All authors have read and agreed to the published version of the manuscript. The study was approved by the Institutional Review Board. This manuscript represents CSIR-IHBT communication no 5381.

Data availability statement

Not applicable.

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Compliance with ethical standards

On behalf of all authors, the corresponding author states that there is no conflict of interest. It is confirmed that the current research does not involve any human participants and / or animals. All authors have read and approved the manuscript. The Article is approved by the Institutional Review Committee having CSIR-IHBT Communication No. 5381.

Conflict of interest

The authors declare no conflict of interest.

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