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Popular Article

## Plant Tissue Culture for climate resilient agriculture

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### Introduction

Global climate change is posing a great threat for agriculture. The agriculture has to face multi-layered scenario owing to the high frequency of multi-stressed environments in this climate change era. Some of the notable effects include:

1. Rising temperatures which are reducing crop yields.
2. Changing weather patterns which are leading to an increase in problems such as droughts, heatwaves, and floods. Most importantly, the weather is becoming increasingly unpredictable, leading to the failure of stress management practices.
3. Changes in rainfall patterns are leading to both heavy rainfall and prolonged droughts in the same region.
4. The number of pests and diseases is increasing.
5. Due to the growth of weeds, competition between crops and weeds is increasing.
6. Climate change is reducing the amount of arable land.

These changes increase the likelihood of short-run crop failures and long-run production declines. This creates a demand for the climate resilient crops. The conventional methods of plant breeding can no longer meet the challenges of the acceleration in climate change-driven impacts and vitality of food security. Therefore, it is necessary to devote focus and financial resources to techniques of agricultural biotechnology, which can help to reduce time for the development of climate resilient crops. Of the numerous methods of accelerated breeding, plant tissue culture is an important method which acts as an indispensable part of all the advanced breeding programs.



## **Introduction to plant tissue culture**

Plant tissue culture is an important propagation method which is used to develop plants from very small parts of plants in a laboratory. It is an important tool for both basic and applied aspects of plant biotechnology. It has commercial applications particularly for the propagation of vegetatively propagated plants and production of genetically identical plants. This technique utilizes a small part of plant, known as explant, as a starting material to produce complete plant, thus the technique is known as micropropagation. The explants can be leaves, seeds, anther, nodal stem, shoot apex, flowers, embryo etc. Since the plants are produced from vegetative parts of the plant, they are genetically identical to the mother plant (Anjani and Kumar, 2018a). Thus, this method has become a technique of choice for the production of planting material of economically important plants like banana, sugarcane, grapes, orchids, potato and others. Through this technique, large number of propagative materials can be produced in a very short duration in a limited space.

Plant tissue culture is a crucial technique in modern agriculture. It satisfies large-scale plant propagation needs and is an essential tool facilitating other biotechnology applications in plant improvement space (Anjani and Kumar, 2018b). In addition, its importance as a tool and direct application in fundamental studies relating to plant biology, biochemistry, and molecular biology is well recognized. Plant tissue culture provides an effective, efficient, and comparatively economical platform to screen plants for biotic and abiotic stresses. The plants are cultured in controlled environments on defined media during *in vitro* culture. Such a condition where there is no external environmental influence, provides an opportunity for efficient screening for desirable characteristics. Thus, tissue culture techniques are also utilized for screening of plants for their tolerance to selective agents such as toxins and antibiotics. This *in vitro* selection helps to shorten the time and cost of the selection process under selection pressure with minimal environmental interaction. The plant tissue culture thus, enables the production of disease-free and high-quality plants, which are better suited to changing climatic conditions. This increases crop productivity and contributes to global food security.

## **Applications of plant tissue culture in context to climate resilient agriculture**

Plant tissue culturing techniques have become especially important in the agricultural community over the past 15 years. During this time period plant tissue culture has effectively moved from the confines of small laboratories and has taken its place among some of the more mainstream, broad scale technique employed by the agriculture industry. It has particularly gained important and crucial role in climate resilient agricultural practices. The



micropropagation, used for production of large number of plants in short amount of time; meristem culture for production of virus free plants; microspore culture and embryo rescue to shorten the breeding cycle; *in vitro* screening for desirable traits; *in vitro* screening for biotic and abiotic stresses; germplasm conservation; transgenics production; hi-tech methods of potato seed production; rapid production of new varieties of plants etc. are some of the notable applications of plant tissue culture which help to mitigate adverse effects of climate change (Wijerathna-Yapa and Hiti-Bandaralage, 2023).

1. *Micropropagation for rapid, disease free production of plants:* Micropropagation is favourable to traditional crop breeding methods in many respects. It allows for the production of huge numbers of plants in a very short period of time. In India over 100,000,000 plants are produced using micropropagation each year. Plant tissue culture is also advantageous because tissue is collected from a single parent plant and the plant itself remains unharmed in the tissue harvesting process. Crop production through micropropagation also eliminates the possibility of any interruption due to the growing season because it can be carried out inside the carefully regulated environment of a green house. This method also helps to minimise the use of chemical pesticides and insecticides, since the plants are grown in controlled environment, which has minimal interference of the outside agents.
2. *Role in distant hybridization and Speeding Up Breeding Programs:* The tissue culture techniques aid in production of distant hybrids by overcoming the barriers of wide hybridization. In recent years, isolated microspore culture has developed as a breeding tool and an experimental system for various genetic manipulations. The technique helps for the production of haploid plants, which can be used to develop homozygous plants through doubled haploid production, thus shortening the breeding cycle and speeding up the breeding programme.

*In vitro* pollination has been employed to overcome morphological and physiological sterility and incompatibility.

Embryo rescue technique has helped to overcome post-fertilization barriers. Embryo rescue means to cross-pollinate distantly related species and then tissue culture the resulting embryo which would otherwise normally die. Embryo culture has many potential uses ranging from overcoming seed dormancy to facilitation of inter-specific hybridization.

Protoplast fusion technique can be used for the transfer of cytoplasmic male sterility from one species to another in a short period of time. In cabbage, male sterile cybrids are



being utilized by seed companies to produce hybrid seeds on commercial scale and at competitive rates.

3. *Meristem culture for production of virus free plants:* The meristem can be cultured *in vitro* to produce plants which are virus free. The production of virus-free plants can reduce losses caused by phyto-pathogens. It has helped to produce virus free plants and artificial seeds. It has also helped to clean particular plant of viral and other infection and to quickly multiply these plants as cleaned stock for horticulture and agriculture (Anjani, 2025).
4. *Opportunity for screening for desirable traits and development of Climate-Resilient Crops:* Utilization of *in vitro* selection can considerably shorten the time and cost of the selection process under selection pressure with minimal environmental interaction. Conducting *in vitro* screening for stress can replace and complement field selection, resulting in better insight and outcome. Moreover, it can be used as an early evaluation platform to understand and provide direction with justification for the further need for field evaluation. Tissue culture allows for the selection and cloning of plants with high tolerance to environmental stresses like heat, salinity, and waterlogging. This includes, for example, developing heat-tolerant wheat or drought-tolerant tubers.
5. *In Vitro Screening of Drought Tolerance:* *In vitro* applications for drought screening can be a smart and easy method compared to field studies. The strategy to apply drought conditions *in vitro* is to impose similar conditions created at cellular levels when plants are subjected to drought in the field environment. To induce physiological stress *in vitro*, high molecular weight solutes such as sucrose, sorbitol, mannitol, and poly-ethylene glycol (PEG) are used (Mishra et al., 2021). Durumwheat, Sorghum, wheat, rice, potato, groundnut, coconut etc. are some of the plants for which drought screening has been performed using *in vitro* methods (Deepti et al., 2020).
6. *In Vitro Screening of Salinity Tolerance:* Using two *in vitro* culture methods, salt-tolerant plants have been obtained through cell and tissue culture procedures. The first method involves selecting mutant cell lines from cultivated cells, followed by plant regeneration using these cells (somaclones). The second method is the *in vitro* screening of plant germplasm for salt tolerance, which has been successfully used in durum wheat. Doubled haploid lines generated from pollen culture of salt-tolerant F1 hybrid parents have the potential to enhance salt tolerance. Somaclonal variation and *in vitro*-induced mutagenesis can create variability from which crop plants can be improved.
7. *In Vitro Screening of Disease Resistance:* *In vitro* selection using pathogenesis-related proteins, antifungal peptides, or phytoalexin production can help select elite-resistant



varieties. This method is simpler and cheaper than generating plants through transgenic technology, which is costly, time-consuming, and more challenging to commercialize due to policy and social acceptance barriers. Exposing organogenic or embryogenic calli, shoots, somatic embryos, or cell suspensions to pathogen toxins, culture filtrate, or the direct pathogen can effectively screen plant samples for pathogen resistance *in vitro*.

8. **Reducing Environmental Impact:** By producing disease-free plantlets, plant tissue culture reduces the reliance on pesticides and chemical agents, which contributes to more sustainable agricultural practices. Moreover, the sterile conditions in tissue culture prevent many common pests and diseases, reducing or eliminating the need for pesticides, herbicides, and fertilizers. This leads to lower chemical runoff, minimizing environmental contamination and promoting healthier ecosystems. Additionally, tissue culture techniques use minimal water thereby reducing water use. This makes tissue culture an attractive method for propagation in areas facing water scarcity, meeting agricultural needs while conserving valuable resources. Tissue culture also allows for dense, high-yield plant production on smaller plots of land, which is particularly beneficial in urban or resource-limited areas. By maximizing output on minimal land, this method reduces pressure on natural habitats and helps preserve biodiversity (Anjani and Chandra, 2024).
9. **Bio-energy Production** Tissue culture helps produce high-yield energy crops (like Miscanthus) that can be used to capture and store carbon, contributing to negative emission technologies.
10. **Transgenics production:** Plant tissue culture is an indispensable part of the transgenics production protocol. It thus helps in the development of novel, climate resilient and tailor-made crops (Sharma et al, 2025).
11. **Production of disease-free planting material:** The *in vitro* methods enable production of plants which are free from virus, fungal and bacterial pathogens or any type of diseases (Anjani, 2024). These plants can be used as planting materials. Today, maximum planting material used in banana, orchids, grapes and sugarcane are produced by plant tissue culture. The method has also taken over the potato seed production market through Aeroponics and other hi-tech method of potato seed production (Jha et al., 2025).
12. **Germplasm conservation:** Plant tissue is also an important aid in germplasm conservation. Plant tissue culture and cell culture are providing useful methods for germplasm storage either by low temperature storage of organized tissue, or cryopreservation of cell or embryo culture (Rani et al., 2021). It offers a method to preserve rare, endangered, or threatened plant species, protecting biodiversity against habitat loss caused by climate change. Tissue



culture is invaluable for preserving and restoring rare, endangered, or threatened plant species. Through techniques like cryopreservation and *in vitro* propagation, tissue culture allows plants to be grown and conserved outside their natural habitats, protecting biodiversity and supporting ecological balance.

## Conclusion

Plant tissue culture is a vital technique in modern climate resilient agriculture. The production of exact copies of plants that produce particularly good flowers, fruits, or have other desirable traits and to quickly produce mature plants, are some of the advantages, which gives this technique an edge from other methods. It has helped in the production of multiples of plants in the absence of seeds or necessary pollinators to produce seeds. It is also used for the regeneration of whole plants from plant cells that have been genetically modified. Due to the production of plants in sterile containers that allows them to be moved; chances of transmitting diseases, pests, and pathogen are greatly reduced. The production of plants from seeds that otherwise have very low chances of germinating and growing *i.e.* orchid and nepenthes is also one of its advantages. A Plant breeder may use tissue culture to screen cells rather than plants for advantageous characters, e.g. herbicide resistance /tolerance. Micropropagation has become crucial to the agriculture industry in the future because it is used to produce plants which have been genetically modified and selected for their ability to resist certain indigenous environment stresses. Currently scientists and members of the agricultural community have joined forces to investigate the possibility of creating lines of tomatoes that possess increased salt tolerance, plants that are completely resistant to various viral, bacterial, algal and fungal infection, tobacco plants whose leaves can withstand freezing temperatures and crop that are entirely resistant to harmful destructive insects With the capacity to propagate a large number of crops in shorter periods, tissue culture supports food security by providing a steady supply of important food crops, regardless of environmental conditions. This adaptability makes it an effective method for addressing food shortages and meeting the demands of growing populations.

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