

Biotechnology for Sustainable Agriculture

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Abstract

World population is expected to increase up to 9 billion in the year 2050. Production in agriculture must be sufficient to feed this population. Now it is important to grow more food at affordable prices. Meeting current demands and future demands in agriculture and production, it is essential to adopt new technologies that ensure optimum results. Availability of true to type, pest and disease free, seeds/planting material is an important prerequisite for achieving the higher yield improvement. New tools are available in biotechnology which can provide appropriate solution to specific problems in sustainable agriculture. There is an impact of a new set of agricultural technologies emerging from the fields of biotechnology having potential to advance a sustainable agriculture. Plant tissue-culture technology is an important technology which is useful in basic and applied studies, including crop improvement. Micropropagation is not only a means of vegetative propagation but also it is successful and viable method for the production of disease free and vigorous planting material. Indian Government has identified tissue culture industry as an important/ priority area for further research, commercialization and development

Keywords: Sustainable Agriculture, Biotechnology, Tissue Culture, Micropropagation.

1. INTRODUCTION

The most important challenge in a developing country is food for its growing population. The world population is projected to reach 9 billion by 2050. The arable land area is fixed so some means has to be there to increase the productivity. There is a need to achieve sustainable agriculture that obtain higher yield, increase income without affecting the environment, make better use of water and is less dependent on pesticides and fertilizers and enhance nutritional value of the food.

Sustainable agriculture is a concept which means a capacity of agriculture to contribute to overall welfare by continuously providing sufficient amount of food and other services in ways that are profitable, socially responsible, and economically efficient, as well as helping for improving quality of environment.

Use of new technologies is essential in agriculture because these technologies have the potential to contribute for sustainable farming. New technologies which can help to contribute to farm sector to become economically efficient and which can help to improve the financial viability, while improving performance of environment which is socially acceptable. Various technologies are available such as organic agriculture, biotechnology etc. which can be used to make farming profitable. But the main challenge is to decide appropriate, affordable, suitable, and competitive technology. Biotechnology has the great potential to provide new opportunities which can help to improve productivity of crop and livestock [1].

II. BIOTECHNOLOGY

Biotechnology is the technique which makes use of living organisms viz. fungi, bacteria, yeast, viruses, animal cells, plant cells etc. to make new product or to modify existing product, to improve certain traits in plants or animals or for specific uses micro-organisms can be engineered. Now a day's demand of food is increased so we can make use of biotechnology to meet the growing demand for food. This is possible by making use of various technologies in biotechnology for improving yields, for improving the nutritional quality of crops and for reducing the impact on the environment. Biotechnology can play an important role in the large scale production of newly released improved varieties of crop (through tissue culture in the laboratory followed by clonal propagation), as well as it is used in genetic improvement of various crops [2]. It is also helpful in plant propagation of various species which contain useful and biologically active substances, e.g., pharmaceuticals, bio pesticides, food additive, pigment etc. Tissue and cell culture can be used for extraction of useful substances, which is more efficient than conventional extraction method.

III. BENEFITS OF BIOTECHNOLOGY IN AGRICULTURE

1. **Increased crop productivity-** Biotechnology can be used for the improvement of productivity. Marker-assisted breeding and biotechnology traits are relatively new technologies which can be used for development of high yielding varieties. Breeders can incorporate these technologies into crop improvement programs, which will help them to increase the rates of success of variety development beyond those seen in the past.
2. **Enhanced crop protection-** Genetic engineering can be used to develop new variety with beneficial plant traits like enhanced ability to resist attack by plant pathogens.[3] This technology can be used to develop disease resistant varieties which resist plant pathogens, and ultimately help to prevent crop losses and also help to reduce pesticide usage.
3. **Improved nutritional value-** Advanced technologies in agricultural biotechnology can help for development of new technologies which can be used to correct the deficiency and to improve the nutritional quality of food crops. Bio fortification is a potentially cost-effective and sustainable way to increase a crop's nutritional value
4. **Improvements in food processing-** Today, there is increasing interest in improving the nutritional value, flavor and texture of raw materials which are used for producing food products. We can make use of biotechnology for development of new processes and new food products. We can also use of it for improvement of existing processes, such as fermentation, immobilized biocatalyst technology etc., and for development of new opportunities for food biotechnology.[4] Biotechnology can produce top-quality foods with a reduced need for additives such as flavorings and can also reduce the environmental impact of food processing.
5. **Fresher produce-** Eating fresh fruit and vegetables is promoted as part of a healthy lifestyle. Second generation biotech foods promise to provide consumers with products that stay fresh longer. Scientists have been doing research for delaying fruit ripening. If fruit ripening is delayed then it will help farmers by



giving flexibility in marketing their farm produce and this help to ensure consumers that it is “fresh-from-the-garden” produce.

6. **Better flavor-** Biotechnology can help to produce complex flavors both as fermentation products and single constituents. It can also be used for breeding of food crops for enhanced flavor.
7. **Environmental benefits-**environmental benefits from agricultural biotechnology are-
 - a. Biotechnology helps to increase production yields of the existing crops so there will not be necessity of forcing more land for production. No need to bring marginal and highly erodible land into production.
 - b. We can develop biotech herbicide tolerant crops. If these crops are grown then no-till farming practices can be adopted which leads to reduction in cost of production. It also helps to enhance soil moisture content and to reduce erosion and limiting carbon dioxide emissions.
 - c. Disease and pest resistant varieties can be developed through biotechnology which needs fewer applications of pesticides. This will help to save our environment from pollution.
 - d. Most important benefit of using biotech crops is reduction in energy use on-farm and thereby reduction in greenhouse gas emissions from no-till farming practices
 - e. Biotechnology can help to reduce waste production from livestock feedlots and concentrated animal agriculture operations;

IV. TISSUE CULTURE

Tissue culture is the first major and widely accepted practical application of biotechnology. It is the most crucial development in agriculture and food production. Tissue-culture techniques involve a group of strategies and technologies, which are recombinant DNA studies, molecular genetics, gene-transfer techniques, genome characterization, in vitro growth of cells, tissues, organs and in vitro regeneration of plants which are considered to be plant biotechnologies[5]. Tissue culture (propagation through apical meristem), popularly known for large-scale clonal propagation, is established, not only a popular means of vegetative propagation but also the most successful and viable method for production of disease free planting material.

Tissue culture means use of explant (small pieces of plant tissue), which is inoculated on a nutrient medium under laboratory (sterile) conditions. Appropriate growing conditions are provided to inoculated explants and then explant rapidly produce new shoots. These shoots can also be sub cultured at the shoot stage, to produce large numbers of new shoots. By inoculating these shoots on suitable medium with added hormones, shoots produce new roots. The new rooted plants are then transplanted in the green house on a suitable soil mixture for hardening and grown in the normal manner. After hardening in green house plants are taken out of green house for acclimatization to natural condition outside the green house and finally hardened plants are planted in the field.[6]

Second Green Revolution is possible by making use of tissue culture technology. Biotechnology and gene modification can be used to improve crop yield and quality. Plant tissue-culture technology is having a key role in basic and applied studies, including crop improvement. Commercial applications of plant tissue culture are-

1. When plants are regenerated from callus they show variations. It is found to be an important source of variation, called as somaclonal variation which can be used for the development of new plant varieties which are superior than existing varieties.

2. We can produce secondary metabolite through tissue culture technology. These metabolites have been proved more efficient as compared to metabolites which are extracted by conventional extraction method from field grown plants. Bioreactors can be used for extraction of secondary metabolites by growing plant cells in liquid culture inside bioreactors. It is best source for production of secondary products(recombinant proteins used as biopharmaceuticals).
3. Novel hybrid can be produced by crossing of distantly related species through protoplast fusion and regeneration.
4. *In vitro* conservation of germplasm is possible by making use of plant tissue culture technique.
5. In breeding programshomozygous lines can be producedrapidly through production of doubled monoploid plants from haploid cultures. Colchicine treatment is given for doubling of the chromosome numbers.
6. Tissue culture technique can be used to rescue embryo obtained by cross pollination which would otherwise normally die. Embryo is cultured in a nutrient medium to rescue it).
7. In genetic engineering, culture obtained by tissue culture is used as a tissue for transformation, followed by regeneration of transgenic plants or short term testing of geneticconstructs.
8. Bio-pharmaceuticals, flavors, sweeteners, natural colorants etc. can be produced through plant tissue culture.
9. Forestry and biodiversity conservation can be done by applying plant tissue culture technique. Large scale production of plants for forestation program can be done by tissue culture techniques. Endangered plants can be preserved and conserved through plant tissue culture..

V. COMMERCIAL PRODUCTION OF PLANT MATERIAL

The Government of India,Ministries of Science and Technology, Commerce, Industries and Agriculture has identified Micropropagation industry as a priority area. Government has developed the favorable policies research, development and commercialization. Government is encouraging entrepreneurs and technocrats to set up more than 125 commercial units. Several plant tissue culture laboratories have come up in India and worldwide.

In India massive multiplications of various crophave been conducted by private companies. The recent Indian economic policies have favored the development of agro industries, including biotechnological companies. Since 1992, emerging private companies have successfully multiplied hundreds of thousands of ornamental plants for both the local and international markets. [7]

VI. BENEFITS OF PLANT TISSUE CULTURE

1. Plant material which is developed by tissue culture is having disease-resistant properties because tissue culture improves the "immune system" of plants. [8]
2. Tissue culture can produceplants with good root systems ideal for nutrient absorption.
3. Rapid multiplication of plants is possible by plant tissue culture; it is also possible to grow them in a laboratory under controlled condition. We can maintain these conditions all year-round, without worrying about climate and weather changes. Plants produce by this technique are genetically pure and uniform which possess desirable traits.
4. Genetically homogeneous, disease-free plant material is produced through tissue culture.

5. It's easy to "duplicate" plant materials. If more plants of the same plant are demanded then easily cells can be take out from the mother plant and multiplied through tissue culture to get true to type plants.
6. Production of clones of plants that produce particularly good flowers, fruits, or have other desirable traits .
7. Production of multiples of plants in the absence of seeds or necessary pollinators to produce seeds.
8. We can regenerate whole plants from genetically modified plant cells.
9. Production of plants from seeds that otherwise have very low chances of germinating and growing, e.g. orchids and nepenthes.
10. Plant tissue culture can be used to clean particular plants from viral and other infections and then can quickly multiply these plants as 'cleaned stock' for agriculture and horticulture.

VII. DEMAND OF TISSUE CULTURED PLANTS IN INDIA

There huge demand for micro propagated plants in agriculture, horticulture and in social forestry. Tissue culture plants are mainly demanded by State Agriculture Departments, State Horticulture Departments, Agro Export Zones (AEZs), sugar and paper industries, floriculturists and private farmers.

Now people are aware about the superiority of tissue cultured plants and therefore, there is huge demand for tissue cultured plants of crop like banana, grapes, pineapple, strawberry, sugarcane, potato, turmeric, ginger, cardamom, vanilla. There is also a demand for ornamentals plants like anthuriums, orchids, chrysanthemums, rose, lily, and gerberas are on the rise in different states in the country. There is demand for tissue cultured medicinal plants like Aloe, Patchouli, Melaleuca, Coleus, Chlorophytum, Digitalis, Gloriosa. Forestry crops like Bamboo, Teak, Eucalyptus, Sandal, and Mangium are also produced and consumed in the domestic market.

Tissue culture is now become important plant propagation method, it has revolutionized the horticultural industry. This technique should be considered as important technique for mass propagation and the establishment of disease free plant material. The Indian tissue culture industry is a flourishing industry. Currently there are about 125 tissue culture units in India with a total production capacity of 300 million plants per annum.[9] But demand for tissue cultured plantlets is increased so there is a need for setting up additional units and supply of plants with more competitive prices. This will help for improving the agricultural productivity and for enhancing the social status of the farmers in India.

VIII. GOVERNMENT SUPPORT FOR TISSUE CULTURE INDUSTRY

Government of India is encouraging entrepreneurs to set up tissue culture laboratories in the country for increasing production of tissue cultured plants of various crops .Various central and state government departments have started several schemes and also announced incentives to encourage the tissue culture industry in India.[9] Various schemes and incentives are as below-

- (a) National Horticulture Board (NHB): Support is given by NHB to set up tissue culture laboratory. There is a provision of capital subsidy (not exceeding 20% of the project cost with a maximum of Rs. 25 lakhs per project). These types of subsidies are also given to build up greenhouse for hardening of tissue cultured plantlets and poly house / shade house.
- (b) Department of Biotechnology (DBT): DBT supports research and development projects submitted by various research laboratories in the universities as well as research institutions. This project must be for

development and standardization of tissue culture protocols for any crop. Another scheme called Small Business Innovation Research Initiative (SBIRI) is the scheme of government through which private tissue culture laboratories are entitled for expansion of existing production units as a Phase II activity.

- (c) 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 in public sector for setting up tissue culture units and Rs. 10 Lakhs for private sectors, subject to a maximum of 20% of the project cost. Financial assistance in the form of subsidy up to 50% is provided for purchase of tissue culture banana plants by various state Governments under integrated development of fruits scheme.
- (d) Agriculture and Processed Food Products Export Development Authority (APEDA): State-of-the-art airfreight trans-shipment center has been set up by APEDA for tissue culture plants at New Delhi, Bombay and Bangalore airports under the Ministry of Commerce and Industry. For tissue culture plants airfreight subsidy up to 25% of the freight cost is provided. For development of infrastructure 50% subsidy is given. Infrastructure like consultancy services, feasibility studies, packing, refrigerated van, export promotion, market development, human resource development and organization building. Financial assistance is also given for implementation of ISO 9000 and for strengthening quality control facilities.
- (e) The Government of India has set up a national facility at New Delhi for virus diagnosis and quality control of tissue culture plants. Government also started 5 satellite centers for helping tissue culture industries in various parts of the country.
- (f) Small Farmers Agri-business Consortium (SFAC): Co-operative societies formed by small scale farmers can start tissue culture laboratory. Under the Ministry of Agriculture SFAC gives soft loans up to 50 lakhs for setting up small tissue culture labs.
- (g) DBT has established two Micropropagation technology parks (MTPs) to promote the adoption of tissue culture technology by the industry and the end user. These MTPs provide a various service packages and important mandate of MTPs is giving training and generating skilled manpower.
- (h) The states of Karnataka, Gujarat, Maharashtra, and Andhra Pradesh have developed new agro-industrial policy. They are giving financial assistance for setting up tissue culture units under this new policy. Capital subsidy of 20% on investments is given by Karnataka.

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.

XI. CONCLUSION

There will be increase in demand for food in future. To meet this future demand, it is essential to adopt new technologies for increasing production in agriculture and these technologies must have the potential to contribute to sustainable farming systems. We can make use of biotechnology to meet the future growing demand for food by improving crops, for developing new varieties (higher yield, disease resistance etc.), for improving the nutritional quality of crops and for reducing the adverse effect on the environment. Tissue culture is the first major and widely accepted practical application of biotechnology. Plant tissue-culture technology is playing an increasingly important role in basic and applied studies, including crop improvement. The technique of plant tissue culture may play a key role in the "Second Green Revolution". Government of India is

encouraging entrepreneurs to set up tissue culture laboratories in the country for increasing production of tissue cultured plants of various crops. Government has started several schemes for helping entrepreneurs to set up tissue culture laboratories. Various research institutes are working on development of tissue culture technology for various crops.

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