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Synthetic Seed Technology and Its Applications: A Review

*Madhu Tripathi**
Department of Botany, Banaras Hindu University, Varanasi, Uttar Pradesh, India

ABSTRACT

Synthetic seed technology is a novel approach in plant tissue culture, as it joins the benefits of clonal propagation with those of seed proliferation. Production of synthetic seeds has opened new era in in vitro plant propagation technology, because it offers many useful advantages on a commercial scale for the propagation of a variety of plants. Synthetic seed technology is useful in multiplication and conservation of elite plant species, which are difficult to regenerate through conventional methods and natural seeds. The present paper explains the production methods and various applications of artificial seeds.

Keywords: artificial seed, plant propagation, somatic embryo

***Corresponding Author**
E-mail: mdtripathi22@gmail.com

INTRODUCTION

A synthetic seed or artificial seed is termed as artificially encapsulated somatic embryo, shoot bud or any other meristematic tissue that can be used for sowing as a seed and which possesses the ability to convert into a plant under *in vitro* or *ex vitro* conditions, as well as retain this potential even after storage [1]. Earlier, the concept of synthetic seeds was based only on the encapsulation of somatic embryos, but, in recent years, the encapsulation of non-embryogenic vegetative propagules like apical shoot buds, axillary buds, nodal segments, etc. have also been employed as a suitable alternative to somatic embryos [2, 3].

Previously, synthetic seed formation was only referred to the somatic embryos that were economically useful in crop production and plant delivery to the field or greenhouse. In the recent past, however, other micropropagules like shoot tips shoot buds, nodal segments, organogenic or embryogenic calli, etc. have also been used for the production of synthetic seeds. Therefore, the idea of synthetic seeds has been discharged from its bonds to physical embryogenesis, and links the term not only to its use (storage and sowing) and product (plantlet) but also to other techniques of micropropagation like organogenesis and enhanced axillary bud proliferation.

The main advantage of these non-embryogenic vegetative propagules would be in those crops where either somatic embryogenesis is not well established or do not produce uniform quality embryos [4, 5]. Synthetic seed technology is rapidly growing branch of seed biotechnology. High volume, low production costs and ease of storage and transport are the major advantages of synthetic seed technology [6–8].

This technology offers excellent scope for propagation of rare hybrids, elite genotypes and genetically engineered plants for which the seeds are either very expensive or are not available. This has opened up a new vista for future plant production programs and can be applied for germplasm conservation, storage or means to reduce the need for transplanting and subculturing during off-season periods [9].

The aim and scope for switching toward artificial seed technology was for the fact that the cost-effective mass propagation of elite plant genotypes will be promoted. There would also be a channel for new transgenic plants produced through biotechnological techniques to be transferred directly to the greenhouse or field. Despite the fact that the technology is a rapidly growing and exciting area of research in plant cell and tissue culture, there are many limitations for its practical use. The purpose of this review is to present a report on prospects and applications of synthetic seed technology. The subject has been earlier reviewed in a different context by various researchers.

MATERIAL AND METHODS

The Need of Artificial Seed

A seed is fundamentally a zygotic embryo with enhanced nutritive tissues which is covered by many protective layers. Seeds are durable, desiccation tolerant and quiescent due to protective coat. Such properties of seeds are also utilized for germplasm preservation in seed storehouses. Zygotic embryo seeds are the products of sexual reproduction that means the progeny of two parents. This has led to the establishment of often complex breeding programs from which inbred parental lines are developed. Such inbred lines are used to develop identical hybrid progeny when crossed.

Chief problem related with such seeds is, on one hand for many crops, such as fruits, nuts, and certain ornamental plants; it is not possible to produce a true-breeding seed from two parents due to genetic barriers to selfing. On the other hand many plants, such as forest trees, the generation time is too long to attain rationally an inbred breeding program. This is the major disadvantage of zygotic seeds. Therefore, for such crops, propagation is accomplished either vegetative by cuttings or the use of relatively low quality open pollinated seed is tolerated.

After the detection of somatic embryogenesis in 1950 it was probable to have an alternative of conventional zygotic seeds. Somatic embryo produces from the somatic cells of a single parent. They precisely vary from the zygotic embryos since somatic embryos are developed through *in vitro* culture, without nutritive and protective seed coats and do not typically become quiescent. Somatic embryos are structurally equivalent to zygotic embryos, but are true clones, since they rise from the somatic cells of a single parent. The structural complexity of artificial seeds depends upon the requirements of the specific crop application. Therefore, a functional artificial seed may or may not require a synthetic seed coat, be hydrated or dehydrated, quiescent or non-quiescent, depending on its usage. The field that seeks to use somatic embryos as the functional seed is termed ‘‘artificial or synthetic seed technology’’. Thus, synthetic seeds may be defined from a practical standpoint as somatic embryos engineered to be of use in commercial plant production and germplasm preservation.

The Technology

In general, the method used in preparation of synthetic seeds is as follows: The propagules (somatic embryos/axillary buds/shoot tips) are carefully isolated from aseptic cultures and blot dried on filter paper, and are then mixed in sodium alginate prepared in nutrient medium. The propagules are then picked up manually by forceps and dropped into a solution of calcium chloride for 20–40 minutes. After the incubation period, the beads (synthetic seeds) are recovered by the decanting the calcium chloride solution and washing them in sterile water 3 to 4 times before culturing on nutrient medium or on different substrates such as filter paper, cotton or soil for their growth and conversion to plants. This process is performed under aseptic conditions in a laminar flow chamber, laminar with prior sterilization of the material and culture medium. They are then left in the culture chamber at a temperature of 25ºC in complete darkness.

Types of Artificial Seeds

There are several types of artificial seeds; first two are basically uncoated somatic embryos; (i) uncoated non-quiescent somatic embryos, which could be used to produce those crops that are now laboriously micropropagated by tissue culture; (ii) uncoated, quiescent somatic embryos would be useful for germplasm storage since they can be hand-stored in existing seed storage repositories. The other categories are; (iii) non-quiescent somatic embryos in a hydrated encapsulation establish a type of artificial seed that may be cost effective for certain field crops that pass through a greenhouse transplant stage such as carrot, celery, seedless watermelon, and other vegetables; and (iv) dehydrated, quiescent somatic embryos encapsulated in artificial coatings are the form of artificial seed that most resembles conventional seed in storage and handling qualities. These contain somatic embryos encased in artificial seed coat material, which then is dehydrated. Under these conditions, the somatic embryos become quiescent and the coating hardens. Hypothetically, such artificial seeds are long-lasting under common seed storage and handling conditions. Upon rehydration, the seed coat softens, allowing the somatic embryo to resume growth, enlarging and emerging from the encapsulation (Figure 1).

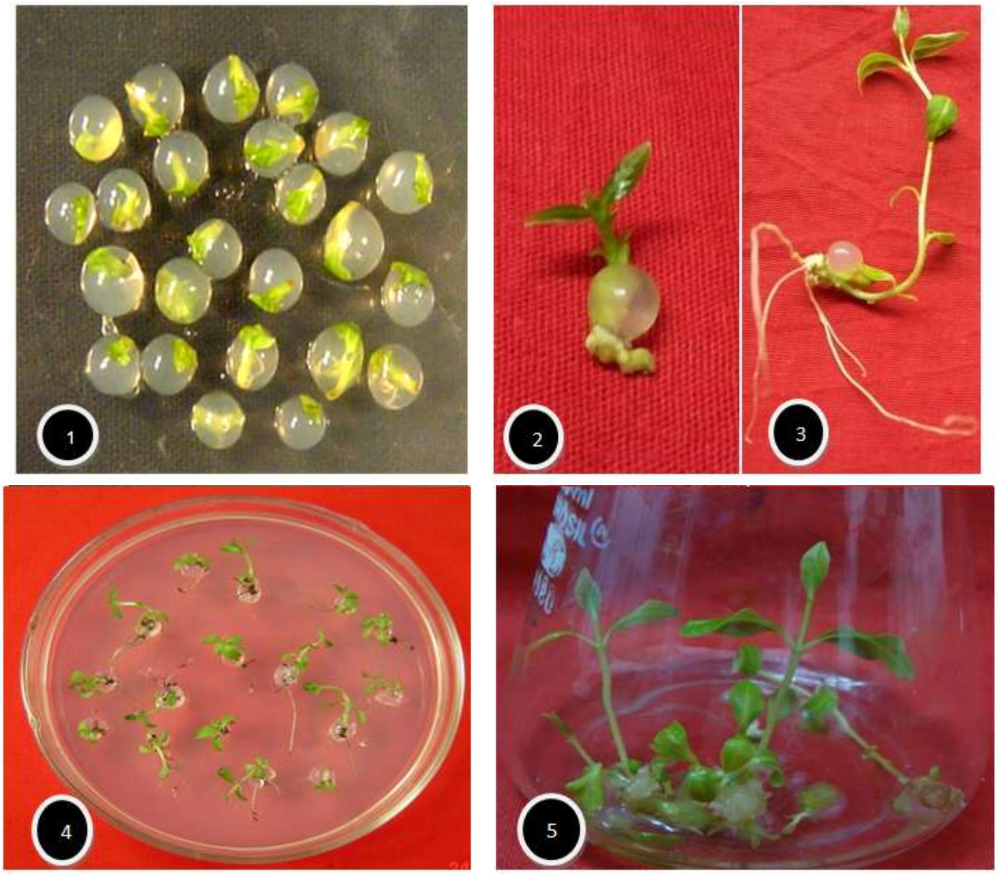

Fig. 1. *Synthetic seed formation and its propagation.*

Results of the research on synthetic seeds in different plants are briefly described here in Table 1.

Table 1. *List of plant species in which encapsulation technology has been applied to produce synthetic seeds.*

Plant species	**Propagules used for encapsulation**
Actinidia deliciosa (Kiwifruit)	Shoot buds
Arachis hypogaea (Groundnut)	Somatic embryos
Brassica campestris (Mustard)	Shoot buds
Camellia japonica L.	Somatic embryos
Oxalis triangularis	Microshoots
Crataegus oxyacantha (Hawthorn)	Shoot buds
Cymbidium giganteum (Orchid)	Protocorn like bodies
Daucus carota (Carrot)	Somatic embryos
Spondias mangifera (Wild mango)	Microshoots
Medicago sativa (Alfalfa)	Somatic embryos
Morus indica (Mulberry)	Shoot buds
Picea abies (Norway spruce)	Somatic embryos
Picea glauca (White spruce)	Somatic embryos
Pistacia vera L. (Pistachio)	Somatic embryos and Embryonic masses
Psidium guajava (Guava)	Somatic embryos
Santalum album (Sandalwood)	Somatic embryos
Rubus idaeus L. (Raspberry)	Shoot buds
Ananas comosus L. Merr.	Micro shoots
Camellia sinensis (L.) O. Kuntze	Nodal explants
Stevia rebaudiana Bertoni	Shoot tips, axillary buds
Vanda coerulea Grifft.	Protocorn like bodies
Tylophora indica (Burm.f.) Merrill	Shoots, somatic embryos

Applications of Artificial Seeds

Artificial seeds have enormous application in various fields of plant biotechnology for cultivation of numerous plant species. They provide the opportunity to store genetically heterozygous plants or plants with a single outstanding combination of genes that could not be propagated by conventional methods of seed production due to genetic recombination exists in every generation for seed multiplication. In this section of the present study, chief applications of artificial seeds technology in various fields have been discussed.

Many species are sterile and produce no seeds. Somatic embryogenesis is an alternative method with respect to propagate these plants conventionally through cutting. Other species, including some tropical produce recalcitrant seeds that cannot be dried. Consequently, long-term storage in gene banks of these species is not possible. The artificial seeds can be a substitute as more is learned about the mechanism by which this type of seed has no tolerance to desiccation. In autogamous species, in which the production of hybrid seed is difficult and expensive, the artificial seed technology offers many advantages and opportunities [10].

One of the restrictions of the method of micro propagation is that they should be in the same physical site of tissue culture laboratories and greenhouses, as production of propagules must be synchronized in periods of peak demand in the market. Artificial seed production in these species would not link the laboratory facilities of the greenhouses [11].

The Genetic Resemblance of Synthetic Seeds

Synthetic seeds have been widely used for micropropagation of many plant species. The molecular studies to identify the genetic stability of synthetic seeds derived plantlets were started from the last decade, but no modifications were revealed at the biochemical and/or molecular levels. There are many reports in literature which cite similar results for the potential advantage of synthetic seeds for genetically identical to natural plants [12, 13]. Currently, synthetic seed technology for the production of artificial seeds in conjunction with micropropagation has become a viable approach for in vitro germplasm conservation [14]. However, the existence of somaclonal variation is a potential drawback when the propagation of an elite germplasm is intended, where clonal stability is required to maintain the advantages of desired elite genotypes. Thus, it is necessary to determine the genetic stability of the conserved propagules.

CONCLUSION

Artificial seeds have wide spread applicability in large scale plant propagation. In many ornamental and extinct plant species, it is the only means of propagation. Apart from this, it is also used in commercial production of autogamous plant species, genetically modified plants, conifers, algae etc. In sum, artificial seed technology has influenced almost every aspect of plant biotechnology and has the potential to become the most promising and viable technology for large scale production of plants.

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