

Chapter-5

Synthetic Seeds and its Significance

Nafisa Ekka¹, Sudip Das², Pragyana Paramita Panda³ and
Dr. Samarendra Narayan Mallick^{4*}

¹*Regional Institute of Education, Bhubaneswar, Odisha, India.*

²*Department of Plant Physiology and Biochemistry, Bihar Agricultural
University, Sabour, Bhagalpur, India.*

³*Department of Botany, NIIS Institute of Information Science and
Management, Bhubaneswar, Odisha, India.*

^{4*}*Department of Botany, Ravenshaw University, Cuttack, Odisha.*

ABSTRACT

A ripe ovule that contains an embryo that may regenerate is termed a seed, and it is the link that binds the kingdom of plants together from generation to generation. Artificially encapsulated somatic embryos, shoot buds, cell aggregates, or any other tissue that may be used for seeding and that has the capacity to develop into a plant in vitro or ex vitro, as well as the ability to do so after storage, are referred to as synthetic seeds. Promising plant genotypes can be mass-propagated using the artificial seed production approach, which is also an alternative propagation option for many commercially significant crops. Synthetic seed technology was created for a variety of economically significant plant species, including cereals, spices, fruit crops, ornamental plants, orchids, medicinal plants, wood-bearing forest trees, industrially important commodities, vegetable crops, fodder legumes, and fruit crops. The elite agricultural and endangered medicinal plant species, which are hard to restore using traditional methods and natural seeds, can be multiplied and conserved

with the help of this technology.

KEYWORDS: Synthetic seeds, Crop improvement, Plant breeding, Biotechnology, Hybrid.

INTRODUCTION

In nature, the main means of plant propagation is usually seeds. Certain plants can be propagated vegetatively, but traditional techniques are costly, time-consuming, and unable to generate seedlings on a wider scale. The creation of artificial seeds, or Syn-seeds, may be greatly aided by synthetic seed technology. Plant micropropagules, such as somatic embryos, shoot buds or tips, calli, nodal segments, embryogenic masses, protocorms, and protocorm-like entities, are encapsulated with particular coating materials to create artificial or synthetic seeds. The encapsulated plant tissues are protected and nourished by the outer covering matrix. Because it improves capsule formation and gives alginate beads enough hardness to survive mechanical damage to propagules, calcium alginate gel is the most popular protective coating available. In order to promote the normal development of plant propagules, which results in Synthetic Seed germination and the generation of healthy plants, nutrients, growth regulators, antibiotics, and other adjuvants are added to the coated matrix.

SYNTHETIC SEED

Synthetic seed-based technologies that encapsulate somatic embryos, shoot tissues, or axillary buds in an appropriate matrix have a significant impact on plant propagation by facilitating the exchange of germplasm, enhancing genetic preservation, and facilitating effective genetic modification. This opens up the possibility of planting new seeds and achieving shared objectives. One of the most promising plant biotechnology tools is synthetic seed technology, which can be used in horticultural

and agricultural development studies now and in the future with specific three procedures. A synthetic encapsulation procedure that permits plant components, such as shoot tips, cell aggregates, or somatic embryos, to demonstrate their capacity to mature into a whole plant even after prolonged preservation in *in vitro* or *ex vitro* settings is commonly referred to as synthetic seed. For many commercially significant agricultural and horticultural species, synthetic seed manufacturing technology is regarded as an efficient and successful alternative propagation strategy. One particularly effective method for mass-propagating elite plant species with significant commercial potential is synthetic seed. Essential agricultural crops can now be improved thanks to advancements in biotechnology research over the past few decades. Since the production of synthetic seeds offers numerous commercial advantages for the development of a variety of agricultural crops, it has expanded the potential of the *in vitro* plant propagation approach. Because it offers substantial advantages for the large-scale creation of unique (elite) plant species, it is one of the most crucial instruments for scientists and plant tissue culture breeders.

NATURAL SEED VS SYNTHETIC SEED

Natural seeds, resulting from the fertilization of ovules, are produced through sexual reproduction in plants. They consist of an embryo, stored nutrients, and a protective seed coat, and they germinate when environmental conditions are suitable. On the other hand, synthetic seeds consist of somatic embryos or alternative plant tissues that are encased artificially and have the potential to grow into a complete plant. These are developed in labs through plant tissue culture methods and are mainly used for the mass propagation of plants exhibiting desirable characteristics. Natural seeds, which are found in nature and exhibit genetic variation, differ from synthetic seeds that are typically uniform in genetics and facilitate the swift multiplication of high-quality plants without disease.

TYPES

Various plant propagules are enveloped in coating materials that function as synthetic endosperms, supplying nutrients to embryos while also serving a protective purpose. Depending on the various methods employed to produce them in accordance based on the requirements, synthetic seeds can be broadly categorized into dehydrated and hydrated seeds.

- **Desiccated man-made seedlings:** Somatic embryos get encapsulated in polyoxyethylene and are subsequently dried under controlled conditions. Desiccation can occur at a slow or fast pace, depending on the circumstances. Immediate desiccation involves opening a sealed Petri dish containing syn-seeds and leaving it open overnight for rapid drying, whereas slow desiccation of the encapsulating seeds in a room with decreasing humidity takes one to two weeks. For plant species whose somatic embryos are resistant to desiccation, synthetic desiccated seeds can be produced.

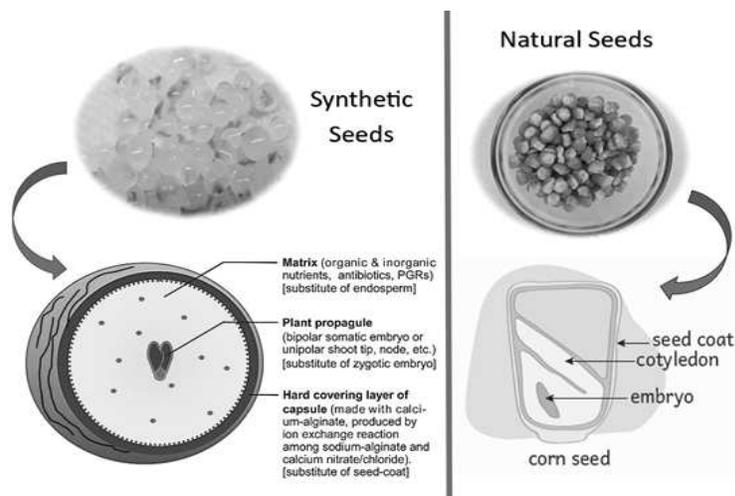


Figure 1. Internal structure of synthetic and natural (corn) seeds.

- **Hydrated synthetic seed:** Hydrated artificial seeds consist of somatic embryos or suitable plant tissues encased in hydrogel. Many materials, such as potassium alginate, agar, gelrite, and sodium pectate, have been examined. Nonetheless, calcium alginate has demonstrated the greatest effectiveness as a coating material for wet synthetic seeds.

KEY MILESTONES

Scientist	Events
Haberlandt (1902)	Tissue culture technique
Karl Ereky (1919)	Term “Biotechnology”
Jost (1941)	Term “Genetic Engineering”
Stewart (1958)	Somatic embryogenesis in carrot
Murashige (1978)	Term “ Synthetic Seed”
Drew (1979)	Somatic embryos as seed delivery system
P.S.Rao (1980)	Synthetic seeds developed at BARC
Lawrence (1981)	Encapsulation technique
Redenbaugh (1986)	Hydrogel Encapsulation technique
Fujii (1989)	Grow plants from synthetic seeds

PROTOCOL FOR SYNTHETIC SEED PRODUCTION

Standard Protocol for Artificial Seed Production

1. Selection of Plant Material

- Choose a plant species suitable for in vitro propagation.
- Collect explants such as leaves, shoot tips, or immature embryos.

2. Induction of Somatic Embryogenesis

- Sterilize explants.
- Culture on a suitable induction medium (e.g., MS medium supplemented with auxins like 2,4-D or NAA).
- Incubate under dark/light conditions depending on species for 1–3 weeks.

3. Development and Maturation of Somatic Embryos

- Transfer induced callus to maturation medium (MS medium with reduced auxin, often with ABA or activated charcoal).
- Incubate for 2-4 weeks until fully formed bipolar somatic embryos develop.

4. Encapsulation

- Prepare **encapsulation matrix** (commonly sodium alginate 2-5% w/v).
- Prepare **complexing solution** (usually calcium chloride 50-100 mM).
- Mix somatic embryos with sodium alginate solution.
- Drop the mixture into CaCl₂ solution to form **beads** via ion exchange gelation.
- Allow beads to harden for 20-30 minutes.
- Rinse beads in sterile water to remove excess CaCl₂.

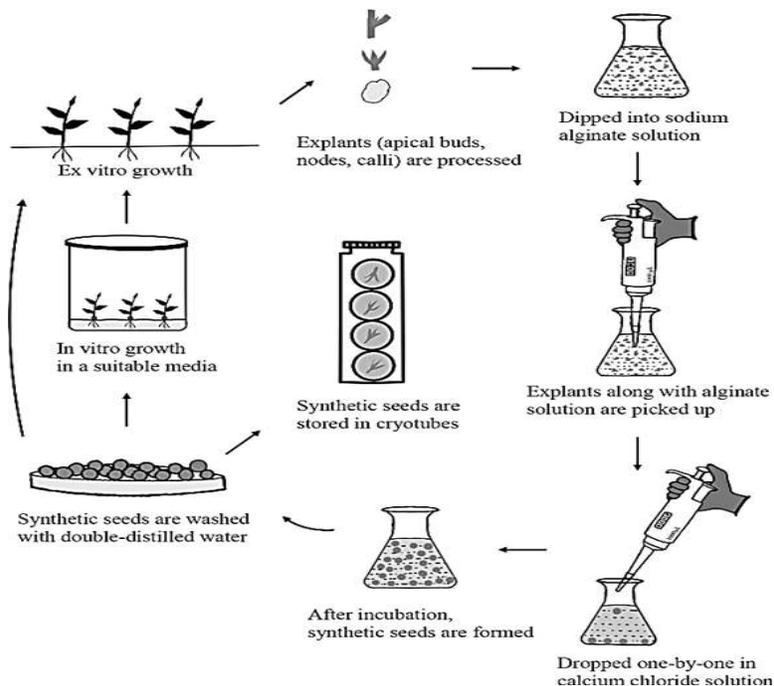


Figure 2. A schematic diagram representing different stages of synthetic seed production under in vitro condition by using plant tissue culture technology (Subrahmanyeswari et al., 2024).

5. Optional Additives in the Beads

- Nutrients (e.g., MS salts, sucrose)
- Growth regulators (e.g., BAP, GA₃)
- Antimicrobials or fungicides
- Activated charcoal

6. Storage (Optional)

- Artificial seeds can be stored at 4°C for short-term storage (1–2 months).
- Desiccation-tolerant formulations can allow longer storage.

7. Germination and Plantlet Regeneration

- Sow encapsulated beads on sterile germination medium (MS or ½ MS medium).
- Maintain in growth chamber at ~25°C with a 16/8 h light/dark cycle.
- Somatic embryos germinate and develop into plantlets in 2–4 weeks.

8. Acclimatization

- Transfer regenerated plantlets to soil or potting mix under high humidity.
- Gradually expose to normal environmental conditions.

ADVANTAGES

With the synthetic seed technology, it will be possible to propagate medicinal plants on a large scale by generating uniform, disease-free specimens in great numbers within a short timeframe and at minimal expense. The synthetic seed technology can tackle various problems, including low seedling

viability, poor seed germination rates, slow seed multiplication, and seasonal dependence on traditional methods of vegetation reproduction. By developing a convenient and efficient method for the storage and transport of plant material, synthesized seed technology can be integrated into the germplasm of medicinal plant storage. Additionally, it is possible to create synthetic seeds that prevent genetic erosion and reduce the metabolic content of medicinal plants by copying or closely mimicking the genotype and phenotype of explants

LIMITATIONS

However, the tech-free seed technology has its shortcomings as well, such as inconsistent conversion and germination rates. These inconsistencies can contribute to a lack of reliability in synthetic seed production. Various factors affect the germination and conversion rates of synthetic seeds, including the type of explants, the encapsulating agent used, the matrix composition, storage conditions, germination conditions, among others. Therefore, it is necessary to optimise the protocols for each plant or species and various types of synthetic seeds to achieve better results.

SYNTHETIC SEED FOR CROP IMPROVEMENT

By facilitating the large-scale reproduction of plants that are disease-free and genetically superior, synthetic seeds contribute greatly to crop enhancement. These seeds are created by encasing somatic embryos or other plant tissues in a gel-like medium, which facilitates easy handling, storage, and transport. Synthetic seeds play a crucial role in crop enhancement initiatives by safeguarding superior genotypes and swiftly propagating plants that exhibit beneficial characteristics like high yield, pest resistance, or drought tolerance. They are particularly useful for crops that are hard to propagate using traditional seeds or have low seed viability. Synthetic seeds promote greater efficiency in breeding, accelerate the spread

of improved varieties, and boost agricultural productivity by guaranteeing quality and uniformity.

ROLE OF SYNTHETIC SEED IN AGRICULTURE

In contemporary agriculture, synthetic seeds are significant because they provide an effective means for propagating and conserving high-quality plant varieties. They are especially beneficial for producing elite or genetically modified plants on a large scale, which are not easy to propagate using traditional seeds. Synthetic seeds guarantee crop uniformity, lower the chances of disease spread, and facilitate cultivation throughout the year, independent of seasonal constraints. Additionally, they make it easier to store and transport valuable plant material while ensuring that its viability is not significantly compromised. Moreover, synthetic seeds aid conservation endeavors by safeguarding rare, at-risk, or slow-growing plant species. Synthetic seeds enhance crop productivity, reduce reliance on traditional seed systems, and support advanced breeding and biotechnology programs, thereby contributing to sustainable agriculture.

REFERENCE

- Chandra, K., Pandey, A., Kumar, P. (2018). *Synthetic seed–Future prospects in crop improvement*. Int J. Agric. Innov. Res., 6(1):120-25.
- Liu, C., He, Z., Zhang, Y., Hu, F., Li, M., Liu, Q., et al. (2022). *Synthetic apomixis enables stable transgenerational transmission of heterotic phenotypes in hybrid rice*. Plant Communications, 4(2):1-9. <https://doi.org/10.1016/j.xplc.2022.100470>
- Mangena, P. (2021). *Synthetic seeds and their role in agriculture: status and progress in sub-Saharan Africa*. Plant Sci. Today, 8(3):482-90. <https://horizonpublishing.com/journals/index.php/PST/article/view/1116>
- Özbay, S., Isak, M. A., & İmrek, Ö. (2024). *Synthetic Seed Pro-*

duction and Cryopreservation for Myrtle (*Myrtus communis* L.) Genotypes. *Çukurova Tarým Ve Gýda Bilimleri Dergisi*, 39(1), 126-136. <https://dergipark.org.tr/en/pub/cutarim/issue/85563/1420329>

- Rihan, H.Z., Kareem, F., ElMahrouk, M.E., Fuller, M.P. (2017). Artificial seeds (principle, aspects and applications). *Agronomy*, 7(4):71. <https://www.mdpi.com/2073-4395/7/4/71>
- Rojas-Vásquez, R., Zuñiga-Umaña, J.M., Abdelnour-Esquivel, A., Hernández-Soto, A., Gatica-Arias, A. (2022). Development of synthetic seeds in Arabica coffee embryos under aseptic and non-aseptic conditions. *Vegetos.*, 35(3):839-49. <https://doi.org/10.1007/s42535-022-00364-9>
- Sahu, S. and Singh, B. A. (2024). The Journey of Artificial Seeds in Modern Agriculture. *Vigyan Varta*, 5(7): 71-75.
- Sahu, S., Monalisa, S.P., Jigile, S., Kar, S., Parida, S.S., Swain, S.K. (2024). Exploring the potential of synthetic seeds: Influence of explant, encapsulating agent and matrix, advantages and challenges. *Plant Science Today*, (Early Access). <https://doi.org/10.14719/pst.3931>
- Subrahmanyeswari, T., Mahanta, M., Bandyopadhyay, S. (2024). Production, Storage, and Regeneration of Synthetic Seeds from Selected Medicinal Plants with Antiallergic Property. In: Gantait, S., Majumder, J., Sharangi, A.B. (eds) *Biotechnology of Medicinal Plants with Antiallergy Properties*. Springer, Singapore. https://doi.org/10.1007/978-981-97-1467-4_19