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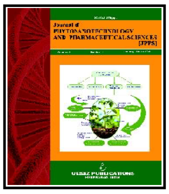

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Potential of bryophytes in nanotechnolohy: An overview

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Abstract

Bryophytes, the amphibian of plant kingdom constitute the second largest group of land plants after angiosperms have remarkable reputation as the ecologically important group of plants. But, the other properties of these plants such as medicinal or therapeutic uses are usually neglected by the researchers and they are remained unexplored in past on these important aspects. However, with increasing knowledge and techniques, these plants are now emerging as a precious pool of important properties. On medicinal aspects of these plants, some articles have been published in recent past but on green synthesis related upholding of these plants, there is insufficient information available till date. This review is an attempt to fill a gap and provide an insight view on the potential of bryophytes as preferred system for nanoparticles synthesis or green synthesis.

1. Introduction

Bryophytes constitute the second largest group of land plants after phenerogams. They are the first land plants and also known as Lilliputians of plant kingdom because of their miniature size. Although, these plants are immensely distributed worldwide under three classes, *viz*., liverworts, hornworts and mosses, yet the information related to their medicinal importance is very limited as their size.

According to few reports, bryophytes are popular remedy among the various tribes of the world and they prefer to use these miniature plants to cure several diseases in their day-to-day lives. Tribal peoples used these plants to cure skin diseases, hepatic disorders, cardiovascular diseases, inflammations, microbial infection, wound, *etc*. Recent attempts on bryophytes showed that these plants have significant antitumor activities counter to diverse sarcomas' cell lines and this possession of bryophytes is getting special attention by many workers nowadays.

Likewise, nanotechnology is now a most encouraged and highly captivated science among the modern researchers. Nanotechnology grips numerous fields including life science arena related to biomedical field to drug delivery (Patra *et al.*, 2018). There are several methods employed to develop the synthesis of nanoparticles including biological method (Pandit and Zeugolis, 2016). Since, biological methods are greener and no risky chemicals are involved compare to other available methods. Therefore, the green synthesis is preferred approach over the physical and chemical methods (Singh *et al.*, 2018).

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The silver metal nanoparticle synthesis is more used method for green synthesis in comparison to other metals, *viz*., platinum, gold, copper and zinc (Dubey *et al.,* 2010). It is happening due to its applicability in biomedical field as an antimicrobial and anticancer agent (Kalpana and Rajeswari, 2018). Earlier, the tracheophytes, *viz*., pteridophytes, gymnosperms and mainly the angiosperms were invariably used in the biosynthesis of silver nanoparticles and atracheophytes (bryophytes) were somewhat untouched or neglected. As a result, sporadic attempts were made using these miniature plants to synthesize the nanoparticles. However, all the three classes of bryophytes were explored for this purpose for instance *Riccia* (a liverwort), *Anthoceros* (a hornwort) and *Fissidens* (a moss) were effectively evaluated to generate the nanoparticles (Kulkarni *et al*., 2012).

The reason behind this is the special plant body which bryophytes have, *i.e*., very primitive and simple, gametophytic in nature, without any well-defined vascular supply for water and nutrient uptake. Further, they are the resurrection plants and absorb water directly from their thallus surfaces.

2. Water relations

The bryophytes do not have cuticle on leaves (ectohydric bryophytes) and stem surface (except seta) that is why absorption and transpiration of water can occur easily. They have high water holding capacity, for example, *Sphagnum*. While endohydric bryophytes have internal conduction system through central strand by symplastic mechanism. Due to these factors, they occur enormously in high humidity and low evaporation rate region.

The regulation of water flow is maintained by faster absorption and low transpiration. They can contribute to relative humidity in environment through evaporation. Bryophytes can quickly absorb moisture from dew, fog and mist. These are the sources of water which are rarely used by other plants (Glime, 2017).

All these characteristics of bryophytes make them suitable plants to develop nanoparticles in the procedure of green synthesis. Consequently, after few attempts, some progress has been evident in this direction. In coming future, bryophytes would become the preferred choice for nanoparticles synthesis or green synthesis.

3. Role of plants in nanotechnology

The incorporation of nanotechnology in remedy has had an incredible influence in the recent past. The finding nanomaterials (NMs) synthesis and their purposes as multipurpose tools encouraged use of plants in nanomedicine and nanobiotechnology. Usage of plant extracts in the biological synthesis system bids unambiguous compensations over peptide, protein, enzyme, and DNA. Usually, various plant extracts have been utilized for medicine, food, NM synthesis, and bioprospecting (Taylor *et al.*, 2014; Pérez-de-Luque, 2017). Numerous feasible methods have been developed for the availability of plant extracts with several contents based on their simple forms, economical nature, and the kind of extract. Hence, many plant species have been used in past for their extracts to be utilized in the synthesis of nanoparticles.

4. Distinctiveness of bryophytes for nanobiotechnology

Bryophytes are the pioneer of ecological succession along with lichens, hence they are well adapted to cope up with severe and naked environment which compelled them to develop several distinct mechanisms unlike other plants. Due to this remarkable adaptive nature, they showed great diversification and it is estimated that this group has about 18,000 and 23,000 extant species (Villareal *et al.*, 2010).

Bryophytes have numerous traits of biological and ecological significance. They do not have lignin which prevents them to grow in to gigantic forms because of the deficiency of mechanical support. Hence, they remained miniature sized, *i.e.*, up to few decimeters in stature. Since well protective cuticles are absent, therefore, they have specific type of water balance according to their ambient environment, *i.e.*, they are poikilohydric in nature. Thus, many of bryophytes have the power of resurrection and able to resume metabolism with almost no injury to the thallus after a period acute growth restriction (Alam *et al.*, 2019). Due to the absence of cuticle and roots, the whole plant body is able to obtain the water from the surroundings, and act as good indicator of alterations going on in their intimate environs. Hence, bryophytes have a colossalimpending to be used in the development of nanoparticles.

5. Impending of bryophytes in nanotechnology

Chemical ingredients of bryophytes fascinate the researchers recently and got attention. These plants have the reputation as a source of antimicrobial compounds. The bioactivities of extracts from many species were found promising to produce biopharmaceutical, biopesticides, or other cures. Due to the environmentally friendly attributes of these products, new technological processes with bryophytes are desirable to be recognized their concrete impending. They have great potential to be used in the treatment of diseases like AIDS, cancers and can also be utilized in the production of new antibiotics. Since they are very well known for skin treatment, therefore, cosmetic industry can also use these plants. The union of nanobiotechnology and bryology can do wonders in coming future.

6. Possible bryophytes in nanotechnology

As mentioned, many bryophytes have been evaluated for their biologically active compounds which have antiviral, antimicrobial and antioxidant properties (Singh *et al.*, 2000).

Many moss taxa have shown great potential in having biologically active compounds and have great future in the formulation of nanoparticles, some of them are: *Atrichum angustatum* (Brid.) B.S.G. (antibacterial), *Atrichum undulatum* (Hedw.) P. Beauv. (antifungal), *Anomodon rostratus* (Hedw.) Schimp. (antimicrobial), *Bryum cuspidatus* Hedw. (wound healing), *Barbula* Hedw. (antibacterial), *Camptothecium* (Hedw.) B.S.G. (effective against polio virus), *Dicranium* Hedw. (antibacterial), *Fissidens* Hedw. (diuretic), *Hyophila involuta* (Hook.) Jaeg. (antibiotic), *Haplocladium microphyllum* (Hedw.) Broth. (antiviral), *Polytrichum commune* Hedw. (diuretic), *Polytrichum juniperinium* Willd. ex Hedw. (anticancer), *Philonotis fontana* (Hedw.) Brid. (antipyretic and anti-inflammatory), *Rhodobryum giganteum* (Schwaegr.) Pars. (cardiac problems), *Sphagnum* L. (antimicrobial, antibiotic) (Singh *et al.*, 2000).

Similarly, many liverworts have also shown bioactivity and in future they can be used in nanotechnology, *viz.*, *Chiloscyphus polyanthus* (L.) Corda (anticancer), *Dumortiera hirsuta* Reinw. BL. et. Nees (antibacterial), *Conocephalum conicum* (L.) Mecker (to cure skin infections), *Diplophyllum taxifolium* (Wahl.) Dumort. (antitumor), *Frullania tamarisci* (L.) Dumort. (antileukemic), *Marchantia polymorpha* (to cure hepatic disorders), *Marchantia palmata* Nees (to cure liver problems), *Pallavicinia* S.F. Gray (antibacterial), *Porella platyphylla* (L.) Dum. (antibacterial), *Radula campanulata* (L.) Dum. (antimicrobial), *Wiesnerella denudata* (Mitt.) Steph. (kidney problems) (Singh *et al.*, 2000).

7. Recent progress with bryophytes in nanotechnology

Keeping the distinctiveness of bryophytes, some attempts have been made in recent past in this direction. Recently a moss, namely; *Campylopus flexuosus* (Hedw.) Bird. mediated synthesis and characterization of silver nanoparticles were done by Vimala *et al.* (2017). This obtained results are encouraging for the future attempts on the huge bryodiversity available worldwide. Beside, this the antioxidant potential of bryophytes is also remarkable along with the antimicrobial and anticancer properties, which makes these plants as a worthy system to work with nanoparticles.

8. The drawbacks

The major problem with the bryophytes to work with is the insignificant availability of biomass, their extreme habitats and they are tough to identify. Therefore, they are somewhat neglected in other aspects except their ecological role.

9. Remedial approach

However, the establishment of axenic and *in vitro* growth chambers for few certain species can overcome these difficulties and a workable biomass can be obtained. However, this set-up will require a coordination amid classical bryologists, biotechnologists and nanobiotechnologist to get desirable success with small plants for synthesis of nanoparticles. Who knows the future of nanobiotechnology shall belongs to these neglected plants of present time?

10. Conclusion

Due to their uniqueness, the huge bryofloristic wealth is available for mankind and there is need to explore these tiny plants in the light of newly developed technologies. Currently, many angiosperms and gymnosperms are being used in the nanotechnology, but these minute plants are usually neglected just because of few basic points, *viz*., hard to collect and identify. However, huge amount of work has been done on the identification and classification of these plants and this aspect is data rich at present. If, the identified taxa can be grown through tissue culture in desire amount, then it is certain that few of the bryophytes will do miracle and can be more efficiently used in the cure of several diseases in future. The evidenced antimicrobial potential will offer a tool to develop a powerful antimicrobial formulation through green synthesis of nanoparticles.

Conflict of interest

The author declares that there are no conflicts of interest relevant to this article.

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