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Seed quality enhancement techniques in medicinal and aromatic crops: a review

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Abstract
Medicinal plants were considered as rich sources of chemical components which can be used in pharmaceutical industry. Most of the medicinal and aromatic plants have some problems in seed germination and stand establishment in the field. Since germination and seedling establishment are critical stages in the plant life cycle, offering the solutions for improvement of seed germination and seedling establishment will help in better performance of medicinal and aromatic crops. A simple way to improve seed germination and seedling establishment and consequently field performance of medicinal and aromatic plants by using various seed quality enhancement techniques. Since the ancient past the importance of seed quality enhancement to boost productivity is well evident as mentioned in old literatures and many other ancient documents. In course of time through critical observation and elaborate experimentations conducted over years across continents, it was observed that there are several ways and means to enhance vigour of germinating seedlings while emerging from the seed, which produce a uniform crop stand and finally substantially more yield is achieved by adopting simple seed quality enhancement techniques. Amongst a couple of such techniques, seed priming, seed coating and seed pelleting are unique. This review has mainly been focused on contemplating and prospecting the major seed enhancement techniques on various seed quality parameters *viz*., seed germination, filed performance and essential seed oil of medicinal and aromatic plants under favorable and unfavorable conditions.

Keywords: Seed Coating, Medicinal & Aromatic Crops, Seed Pelleting, and Seed Quality

Introduction
Medicinal plants were considered as rich sources of components which can be used in pharmaceutical industry. In medicinal and aromatic crops often germination of seed and establishment of seedlings in the field are difficult. The easy way to enhance seed germination and seedling establishment and consequently field performance of medicinal plants by using various seed quality enhancement techniques (Patel and Gupta, 2000) [1]. Quality seed plays seminal role in augmenting crop productivity as well as production. Only by using quality seeds, productivity can be enhanced to the tune of 15-20 per cent and under optimum management the increment may reach up to 45% depending upon the crops. Hence, the efficiency and efficacy of all other inputs in the production technology depends upon the quality of seeds being used. Since antiquity the importance of quality seed to increase crop productivity is well evident as mentioned in old testimonials, literatures, scriptures, treatises, epics and many other ancient documents. In course of time through critical observation and elaborate experimentations conducted over years across continents, it was observed that there are several ways and means to enhance vigour of germinating seedlings while emerging from the seed, which produce a uniform crop stand and finally substantially more yield is achieved by adopting simple techniques *viz*., seed priming, seed Pelleting and seed coating. Nowadays, nanoparticles are being used to obtain invigoration in respect of diverse characters especially in dispensing nutrients directly to germinating embryos or in halting seed borne pathogen incidence by clogging the pores in the cell membrane for achieving higher productivity owing to healthy crops. The present review has mainly been focused on contemplating and prospecting the major seed enhancement techniques and the success stories in medicinal and aromatic crops.

Which is considered, to be useful to the readers to explore the possibility of using such prospective emerging technologies on large–scale to enhance productivity of medicinal and aromatic crops through value addition in nutshell (Halmer, 1987) [2].

Seed priming

Seed priming is the process of controlled hydration of seeds to a level that permits pre-germinative metabolic activity to proceed, but prevents actual emergence of the radical (TeKrony, 2016) [3]. During priming seeds are partially hydrated and then they are dried in the next step (Sivasubramaniam *et al*., 2017) [4]. In general, water uptake by dry seed under optimal conditions during germination can be divided into three phases. Phase I, where imbibition is rapid that is largely as a consequence of the matric forces exerted by the seed. This phase occurs in dormant or non-dormant, viable or non-viable seeds. During first phase, DNA and mitochondria are repaired and proteins are synthesized using existing messenger ribonucleic acid (mRNA) (McDonald, 2000) [5]. Phase II is the lag phase, where there is very little net gain of water but considerable metabolic activities that prepare viable non-dormant seeds for radicle emergence. In this phase, the syntheses of mitochondria and proteins by new mRNA occur. Phase II is also called activation phase (Bradford, 1994) [6]. In phase III (final phase) water uptake increases and coupled with radicle elongation (Bewley and Black, 1994) [7]. In primed seeds phases I and II of water uptake are passed, but seeds do not enter the third phase of water uptake. This hydration is sufficient to permit pre-germinative metabolic events but insufficient to allow radicle protrusion (Bewley and Black, 1994) [7]. Amongst a couple of such techniques, seed priming is a unique one, through which invigouration of germinating seedlings. Depends upon the ingratiates used for hydration of seed the seed priming are hydro priming (use of water double the volume of seed), halo priming (use of salt solution-NaCl), osmo priming (use of osmotic solution – PEG), sand matric priming – (use of moist sand). There are various advantages of seed priming *viz*., enhances the germination percentage, enhances the speed and uniformity of germination, improves the resistance towards water and temperature stress, increases the shelf life of seed, highly suitable for small seeds and enhances the yield (Bahareh Dalil, 2014) [8].

Seed pelleting

Seed pelleting is the process of adding inert materials to seeds to change their size and shape for improved plantability (Fig. 1). Small, round or irregularly shaped seeds can be covered with a coating of inert material and built up into pellets almost spherical in shape and containing a single seed each. Pelleting permits the use of precision planting equipment which results in more even distribution of small seeds and in a reduction of the number of seeds required to plant a given area than is the case with usual planting methods (Farooq *et al*., 2017) [9]. This better distribution should facilitate thinning operations markedly, and reduce the check in growth to the remaining plants resulting from the thinning of a closely planted row of seedlings (Asit *et al*., 2015) [10].

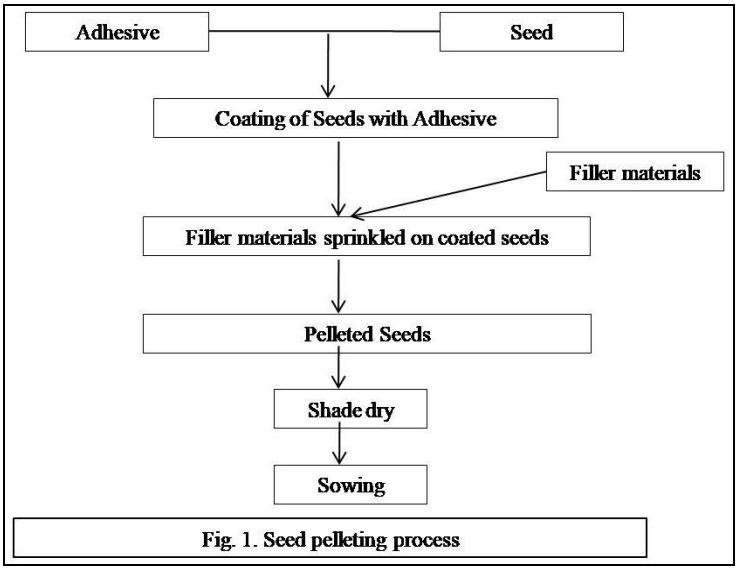

Fig. 1. Seed pelleting process

Seed coating

Seed coating is a technology to improve germination and homogenize stand establishment. It refers to the hard or semi-hard covering that sheathes a seed, protecting it from various types of insects and diseases. Seed coats additionally prevent premature germination by obstructing any excess water from penetrating the seed (Halmer, 2016) [11]. It also protects the seed from fluctuations in humidity as well as mechanical stress. The function of the seed coat is also to create a barrier between environmental factors and the budding seed. Coating plant seeds prior to planting is a common practice in modern agriculture. Seed is coated when growers need a precision-sown crop and the non-coated ("raw") seed is too small, too light, or too variable in size or shape to be sown accurately with existing equipment (Asit *et al*., 2015) [10]. The objective of coating is to deliver the seed in a form that is larger, rounder, smoother, heavier and more uniform than the original seed. Precision sowing is desirable when growers need singulation, e.g., for cell-tray plant production in a greenhouse or strict control of spacing or depth of placement. For example, onion spacing is critical to achieve desired bulb size at harvest (Bahareh Dalil, 2014) [8]. Singulation and controlled spacing are also vital for crops that are direct sown and then thinned back to the desired population. The field thinning operation is faster, cheaper and more accurate when coated seeds are used. A further advantage to coating seeds is the additional weight the coating adds to each seed. The additional weight renders the seeds more resistant to water and wind erosion (Jiang *et al*., 2008) [12].

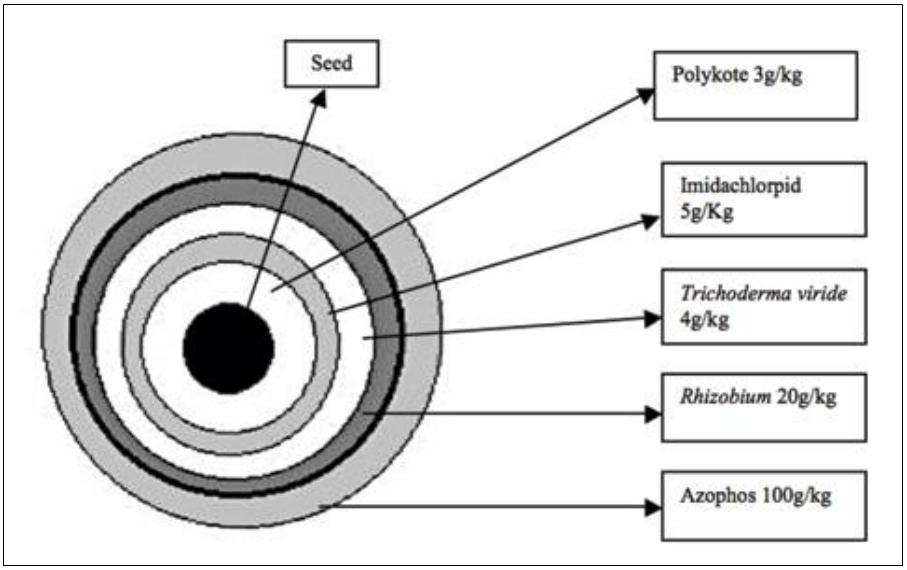

Fig 2: Diagrammatic representation of sequential coating involving diverse ingredients for seed enhancement

Effect of seed quality enhancement techniques on seed germination, growth and yield of medicinal and aromatic crops

Seed quality enhancement methods are applied to enhance the seed quality parameters (increase seed germination rate and vigor of seedlings) and also eliminate or decrease adverse environmental stresses effects. There are ample evidences that seed priming by using specific chemicals/organics and soaking the seeds in diverse treatments have achieved invigoration in many crops (Muhyaddin and Weibe, 1989) [13]. Pelleting, an another magnificent technique, is normally used in case of irregular shaped seed or for extremely small seeds so as to achieve uniform shape, which makes sowing efficient and uniform. Similarly by coating seeds with diverse materials like insecticides, nutrient coating *etc*., uniform seed germination and development of uniform crop stand have been demonstrated in many crops, which finally display enhanced productivity coupled with good seed quality attributes (Asit *et al*., 2015) [10].

Seed germination

Seed quality enhancement techniques improve seed germination of medicinal and aromatic crops. (Hoseini *et al.*, 2013) [14] reported that seed priming treatments in 2 varieties of lemon balm increase antioxidant enzymes *viz*., cation eskorbate. This enzyme helps to reduce lipid peroxidation at the time of seed germination. Hence, the increases in germination percentage was recorded. It was also observed that chemical seed treatments (seed coating) before sowing can enhance and improve seed germination in *Heracleum candicans* (Joshi and Dhar, 2003) [15]. Similarly, in marigold (*Calendula officinalis*) (Ganji Arjenaki *et al*., 2011) [16] observed that osmo-priming with PEG-6000 enhanced germination percentage, germination rate and radicle & shoot lengths. (Fariman *et al*., 2011) [17] also reported that seed priming improves germination percentage and speed of germination in *Echinacea purpurea*. The increases in germination percentage and rate of germination of primed seeds might be due to increase in enzymes activity *viz*., amylase, protease and lipase. These enzymes plays great role in convertion of complex sugar molecules to simpler sugar molecules for the growth and development of embryo and establishment of seedlings (Dell-Aquila and Tritto, 1990) [18]. The soaking duration greatly influences on the seed quality *viz*., gerimation seed and vigour of seedling and methods of seed treatment (Ghassemi-Golezani *et al*., 2012) [19]. (Aliabadi *et al*., 2011) [20] Presented that the highest seedling vigor, germination percentage and seedling dry weight were achieved by soaking of seeds in water for 12 hours in Basil (*Ocimum basilicum* L). Hajebi and Soltanipoor, 2016 [21] reported that seed treatment with sulfuric acid for 15 minutes as pre-treatment on *Salvia mirzayanii* seeds show the highest positive effect on seed germination percentage and germination rate. The higest germination percentage of coriander (*Coriandrum sativum*) was obtained by seed pelleted with micronutients *viz*.,zn, mg and mn 4 g per kg of seeds (Fredj *et al*., 2013) [22]. Response of fennel (*Foeniculum vulgare*) to different seed coating and priming treatments (gibberellic acid with a dosage of 500ppm, hydro-priming with 24 hours duration and nitrate potassium 3%) as reported by Hoseini *et al*., 2013 [14]. The more germination percentage was observed by hydrated seeds with KNO_3. The highest length of seedling and seedling dry weight was seen in KNO_3 and GA_3 treatments as compared with the other treatments. Dhoran and Gudadhe, 2013 [23] reported that seed priming with GA_3 at 50 ppm in *Asparagus sprengeri* was better as compared to IAA, IBA and NAA in enhancing seed germination and root growth. According to Takhti and Shekafandeh, 2012 [24] germination rate of seeds soaked in water and osmotic agents (different concentrations of NaCl and ZnS) were higher as compared to that of control (seeds without treatment) in thorn jujub (*Ziziphus spinachristi).* Ramesh and Siddique, 2015 [25] observed that highest germination rate occurred in seeds pelleted with Zn and GA_3 and along with lowest leakage of solutes with an electrical conductivity (EC) of $8dS/m^2$ which was lower than that of control ($16dS/m^2$). It means that high concentration of solutes leakage had adverse effect on the germination rate and vigour. The seed quality enhancement techniques improves the germination speed and vigour, the effectiveness of different techniques varies with use chemicals, method of application, its concentration and duration of treatment and crop species (Hajebi and Soltanipoor, 2016) [21].

Seed priming and field performance

Seeds are central to crop production, human nutrition, and food security. A key component of the performance of crop seeds is the complex trait of seed vigour. Crop yield and resource use efficiency depend on successful plant establishment in the field, and it is the vigour of seeds that

defines their ability to germinate and establish seedlings rapidly, uniformly, and robustly across diverse environmental conditions (Finch-Savage and Bassel, 2016) [26]. Seed quality enhancement techniques are used to reduce emergence time, accomplish uniform emergence and better allometric (changes in growth of plant parts over time) in many horticultural and field crops (Ashraf Foolad, 2015) [27]. It has been reported that hydropriming increased percentage and rate of seedling emergence and seedling dry weight in *Echium amoenum* (Ebrahim *et al.*, 2012) [28]. According to Tzortzakis, 2009 [29] pre-sowing treatments increase fresh weight of seedlings in endive (*Cichorium endivia*) and chicory (*Cichorium intybus*) and found that the use of water and potassium nitrate (1%) as seed primers improves the emergence percentage and initial seedling establishment in field. This is in agreement with the results of another research about two landraces of the 'Balady' cumin (Tawfik and Allam, 2014) [30]. Rapid emergence of seedlings could lead to the production of vigorous plants. The pre-sowing seed management techniques with the benefit of invigoration, protection and production (Gopal Singh and Ramarao, 1993) [31]. Among the various seed treatments, *viz*. the seed priming, seed pelleting and seed coating are widely under the usage by the seed producers and are normally included as a continuous treatment in sequencing the various post-harvest seed handling techniques. Basu (1990) [32] revealed that the seed treatment implies an improvement in seed performance resulting in better field performance than the corresponding untreated seed and the establishment of a seedling in the soil is an important and foremost need for the better crop production (Sathiya *et al*., 2011 [33]). In addition, improvement of seedling emergence percentage could help to establish optimum plant population density under a wide range of environmental conditions. Ghassemi- Golezani *et al*., 2013 [34] reported that percentage ground cover (PGC) of borage was improved as a result of seed invigoration, particularly hydro-priming. It has been observed that high ground cover of plants from invigorated seeds also showed early emergence and well establishment of the seedlings (Ghassemi-Golezani *et al*., 2013) [34]. There is a linear relationship between percentage ground green cover and light interception, it can be used as a reliable index to estimate yield potential of the plants under favorable and adverse environmental conditions (Golezani *et al*., 2012) [19]. Sajjadi *et al*., 2013 [35] reveled that seed invigorated with gibberellic acid helps to enhance seedling growth and leaf area in chamomile. Karthikeyan *et al.*, 2009 [36] observed that seeds invigorated with *Pseudomonas fluorescens* and *Azospirillum brasilense* recorded highest plant height, root length, number of leaves and alkaloid contents of periwinkle varieties *viz*., rose and alba. It has been observed that seed soaked in SA can be used as an appropriate strategy to improve photosynthetic parameters of safflower (Jamshidi *et al*., 2013) [37]. Shabbir *et al*., 2013 [38], found that different seed quality enhancement techniques improve growth and yield of Fennel *viz*., plant height, number of leaves per plant, fresh and dry weight per plant, number of umbels per plant, seeds per umbel, 1000-seed weight, seed yield, biological yield and harvest index. They observed that the plants from primed seeds with $CaCl_2$ @ 2.2 per cent produced the highest seed yield compared with KCl @ 2.2 per cent treatment. Ghassemi-Golezani *et al*., 2012 [19] presented that seed treated with NaCl can be used to promote grain yield of isabgol (*Plantago ovata* Forsk) which ultimately can enhance mucilage production. It has been indicated that seed invigourated with KNO_3 and GA_3 improve essential oil percentage of fennel (Hoseini *et al*., 2013) [14].

Advantages of seed quality enhancement techniques under stress

Effects of seed invigoration persist under sub-optimal conditions. Chen *et al*., 2010 [39] found that seed quality enhancement in spinach by PEG at -0.6 MPa at 15 °C for 8 days enhanced stress tolerance by improving germination performance at sub-optimal and supra-optimal temperatures and under water stress of -0.8 and -1.2 MPa. Ahmadian *et al*., 2010 [40] concluded that invigoration increases germination and seedling growth under salt stress in cumin. Movaghatian and Khorsandi 2014 [41] observed that seed invigorated by using salicylic acid (0.00001 mM) improved all germination characteristics (percentage and rate of germination, radical and plumule lengths and seed vigor) in ajowan (*Carum copticum*) under salt stress. Ghassemi-Golezani *et al*., 2012 [19] found that reductions in ears and grains per plant due to salinity in isabgol were largely compensated by seed coated with KNO_3. Hajebi and Soltanipoor, 2016 [21] indicated that with increasing salinity, emergence traits such as total emergence and mean emergence time, growth parameters such as plant height and shoot fresh and dry weights and mineral contents such as K+ and Ca2+ decreased, but to a less degree in invigorated seeds. They observed that seedlings from primed seeds had higher emergence and growth rate than control under different salinity levels. Gholami *et al*., 2013 [42] observed that seed invigorated with hormones alleviated negative effects of drought stress on emergence percentage, morphological characteristics, 1000-seed weight and yield of essential oil, chlorophyll contents and antioxidant enzymes in basil (*Ocimum basilicum*).

Conclusion

Based on available previous reviewed literature it is concluded that seed quality enhancement techniques plays very important role in the medicinal and aromatic crops for enhancing quality before sowing. But the information on seed invigoration techniques in medicinal and aromatic crops is scanty. Therefore, it is the need of time to study the potential of such techniques that can ensure the successful emergence and early development of seedlings in medicinal and aromatic crops. Among the various seed quality enhancement techniques seed priming is a popular and commercially used technique developed mainly to accelerate the process of germination both under favorable and unfavorable conditions. Hence, it is the best solution for the crop having germination related problems. Similarly, seed pelleting and seed coating are also common and popular techniques used for seed quality enhancement.

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