Review Article

ISAH Indian Journal of Arid Horticulture
Year 2024, Volume-6, Issue-2 (July-December)

Propagation strategies for conservation and commercial development of root medicinal crops: A review

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ARTICLE INFO

Received: 09 December 2024
Accepted: 07 March 2025

Keywords: Ayurvedic formulations, germplasm conservation, herbal medicine, *in vitro* propagation, tuber

doi:10.48165/ijah.2024.6.2.2

ABSTRACT

India is one of the mega diversity regions endowed with a rich array of medicinal plants. However, the surging demand for herbal medicines has triggered destructive harvesting methods, jeopardizing the natural populations of these plants. Medicinal crops such as *ashwagandha*, *mulethi*, and *shatavari* are globally sought-after due to their therapeutic potential, addressing stress relief, immune function, and hormonal balance. Despite their historical use as natural remedies, the escalating demand is primarily met by wild populations, endangering the survival of these crop species. The alarming rate of over-exploitation necessitates the development of efficient propagation protocols. This ensures planting material for commercial cultivation and contributes to conservation efforts. Moreover, the cultivation of high-value medicinal plants is creating a new dimension in the field of agriculture, propelling the Indian herbal industry into a flourishing stage. However, the intricate nature of medicinal plant cultivation poses challenges, particularly due to limited knowledge of seed biology. This review concentrates on *ashwagandha*, *mulethi*, and *shatavari* cultivation practices, compiling existing literature to serve as a guide for future research in this crucial field.

Introduction

Medicinal plants have been providing a tremendous source of natural medicines since time immemorial. *Ashwagandha* (*Withania somnifera* (L.) Dunal), *mulethi* (*Glycyrrhiza glabra* L.) and *shatavari* (*Asparagus racemosus* Willd.) are popular medicinal root crops used in traditional Ayurvedic medicine (Niraj and Varsha, 2020). These have been used for centuries for their various health benefits and therapeutic properties (Das and Pandey, 2023). They can be used individually or in combination with other herbs in Ayurvedic formulations to address specific health concerns and promote overall well-being. *Ashwagandha* also known as Indian Ginseng/winter cherry provides benefits to the nervous system, rejuvenates the body, prevents aging, improves muscle and joint function, and aids in sleep (Saran *et al*., 2025; Singh *et al*., 2021). While *mulethi* or licorice has sweet-tasting roots, is commonly used for respiratory health, digestive support, anti-inflammatory, antioxidant properties, immune-modulatory effects, and more (Ahemed *et al*., 2021). Similarly, *Shatavari* is believed to enhance fertility and is associated with various health benefits, particularly for the female reproductive system (Alok *et al*., 2013).

However, the conservation of these plants is among the most pressing issues. To satisfy the need for medicinal plants, natural resources are being depleted at an exponential

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pace (Sen *et al.*, 2011). The medicinal crops are not grown systematically; people generally collect them from the forest. In this context, it is important to promote their cultivation scientifically to prevent genetic erosion and maximize profits. To achieve the full health benefits of these medicinal crops, proper GAP (Good Agricultural Practices) protocols are needed during planting (Saha *et al.*, 2018). Planting root crops such as *ashwagandha*, *mulethi* and *shatavari* can be done through a few different methods, depending on the specific requirements of each plant as outlined in Fig. 1. These plants are commonly propagated through their seeds or root divisions/cuttings. However, the rapidly changing climate has resulted in changes in the key components of certain Medicinal and Aromatic Plants (MAPs) (Manish *et al.*, 2016). Hence, it is essential to explore alternative ways of growing Medicinal and Aromatic Plants (MAPs). Currently, micropropagation, hydroponics, and aeroponics are gaining popularity in this regard. However, micropropagation has started for certain medicinal plants, the adoption of hydroponics and aeroponics in the production of Medicinal and Aromatic Plants (MAPs) is still at an early stage. These techniques offer a sustainable alternative, providing high-quality roots that are devoid of pesticides and soil-borne diseases (Mehdizadeh and Moghaddam, 2023). The conservation and sustainable use of medicinal plants require a long-term approach, so this review focuses primarily on their propagation methods. Here is a general guide to planting these root crops:

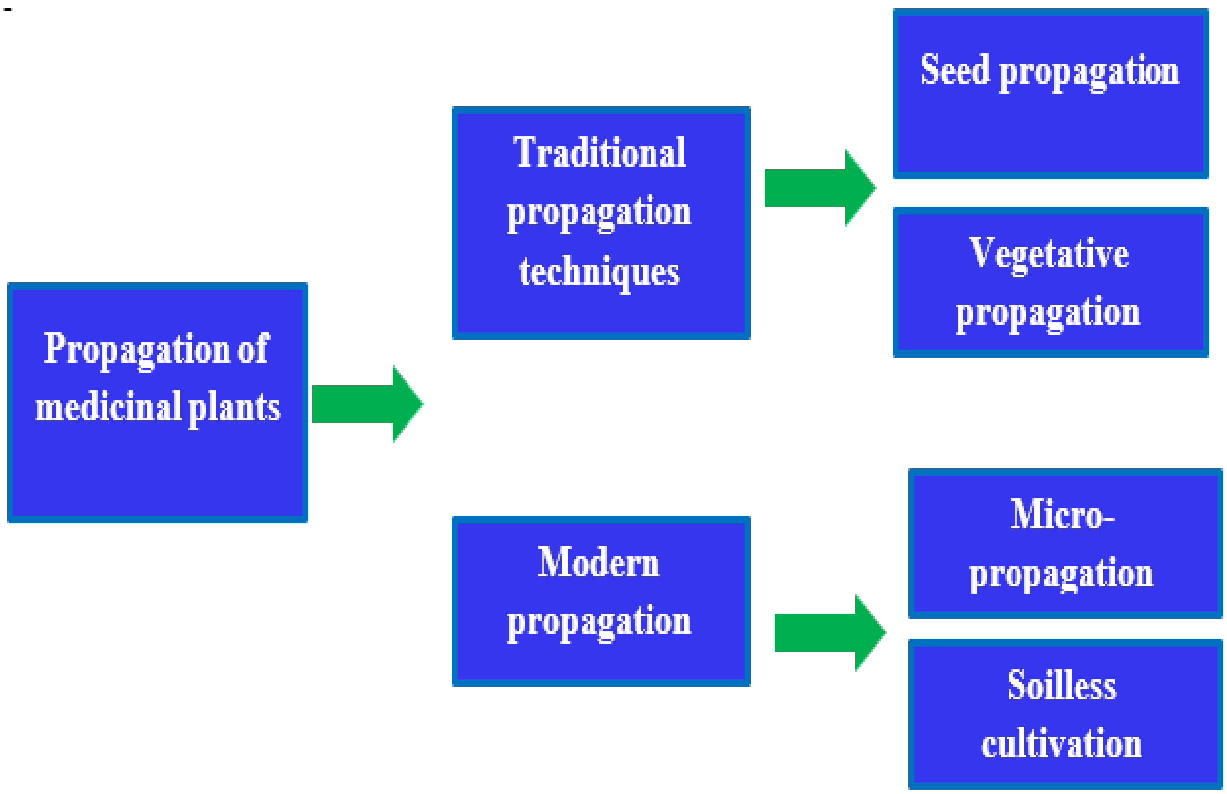

Fig. 1. Different propagation methods of medicinal plants

Planting methods of different medicinal root crops

The planting method is almost similar for *ashwagandha*, *mulethi* and *shatavari*. However, specific climatic and soil conditions may affect their growth.

Site selection

Selecting an ideal location for cultivating medicinal root crops is essential for a successful harvest. Medicinal root crops such as *ashwagandha*, *mulethi* and *shatavari* thrive well when they receive a minimum of 6-8 hours of direct sunlight daily. Sunlight is vital for photosynthesis, enabling plants to produce energy for robust root growth. Root crops prefer loose, fertile, and well-drained soil that allows their roots to penetrate easily. Well-drained soil prevents water logging and the risk of root diseases. Ensuring there are no hard layers beneath the soil further aids good root penetration (Gupta, 2017).

Soil and climate

Ashwagandha, *mulethi* and *shatavari* are medicinal herbs that thrive in warm climates and have specific soil and environmental preferences conducive to their growth. These herbs can adapt to various soil types but perform exceptionally well in specific conditions. For instance, *ashwagandha* does best in sandy or loamy soil within a pH range of 7.5 to 8.0 (Kumar *et al*., 2023, while *mulethi* prefers a pH range of 5.5 to 8.2 (Cui *et al*., 2023), and *shatavari* thrives in soil with a pH range of 6.0 to 8.0 (Chaudhary *et al*., 2023). These pH ranges reflect their soil acidity or alkalinity requirements for optimal nutrient absorption. However, it is equally important to provide good air circulation in the planting area. Adequate air circulation prevents the development of fungal diseases and promotes overall plant health by reducing humidity levels.

Land preparation

Preparing the soil for the cultivation of *ashwagandha*, *mulethi*, and *shatavari* is a crucial step in ensuring their successful growth. To create optimal growing conditions, it is essential to thoroughly pulverize the field. This process typically involves ploughing and harrowing, which break up compact soil and enhance its structure. For root crops, loose soil with good aeration is essential as it allows their roots to penetrate easily and promotes healthy growth. Therefore, it is advisable to loosen the soil to a depth of about 12 inches (30 cm) to provide ample space for root development (Gupta, 2017). In regions with heavy or clayey soil, additional measures are necessary. Two to three rounds of ploughing before the rainy season can help break down the soil structure further. Moreover, incorporating well-decomposed farmyard manure (FMY) or organic matter into the soil can significantly improve its texture and fertility.

Propagation of Ashwagandha (*Withania somnifera* (L.) Dunal)

Propagating *ashwagandha*, an important medicinal plant, can be achieved through two primary methods: direct sowing and propagule raising in a nursery. The choice of method depends on factors such as the availability of seeds or seedlings, the local climate, and the specific needs of the cultivation process. However, the best way to propagate *ashwagandha* is through seed. Choose disease-free and high-quality seeds from well-recognized fibrous varieties, like Jawahar Asgand-134, Jawahar Asgand-20, Raj Vijay Ashwagandha-100, Gujarat Anand Ashwagandha-1, Vallabh Ashwagandha-1 (Khabiya *et al.,* 2023). The second group of *ashwagandha* varieties is rich in starch (low crude fiber) having long, stout, and thick root quality of produce obtained (Saran, 2023, Saran and Das, 2023). The starchy type high-yielding varieties/landrace/germplasm are Vallabh Shahi Ashwagandha-1 (DTWr-1), DNA-4, Nagori, CIM Pratap and CIM Chetak are rich in starch and low crude fiber content (Saran *et al*., 2025).

Ashwagandha cultivation can involve either using seeds directly or purchasing seedlings from a nursery. When directly planting seedlings in the field, dig a hole slightly larger than the root ball of the plant, carefully place the seedling in the hole, fill it with soil, and gently firm the soil around the plant. As a precautionary measure, treat the seeds with Captan at a rate of 5 g/kg seed before sowing to protect emerging seedlings from potential seed-borne diseases (Kumar *et al.,* 2023).

Direct sowing

The process of sowing seeds for *ashwagandha* typically involves the broadcasting method, where the seeds are evenly scattered across the main field. Sowing of the seeds generally occurs in the second week of July to August. During this period, the soil is adequately moistened by the rains, creating ideal conditions for germination. However, it is worth noting that the timing of sowing can be somewhat flexible depending on local weather conditions. In cases where there is ample rainfall and soil moisture, the sowing can be extended up to September. The field is divided into convenient-sized plots or rows to facilitate organized and efficient planting. The recommended seed rate is typically 10-12 kg of seeds per hectare, ensuring sufficient plant density for a successful crop (Mathew *et al*., 2005). Matured seedlings, whether raised through sowing or broadcasting, should be manually thinned approximately 25 to 30 days after seed sowing. This thinning process aims to achieve a plant population ranging from about 30 to 60 plants per square meter (Moharana *et al.,* 2020).

Nursery raising

In a nursery bed, compost and sand are thoroughly mixed and then raised from ground level. Fresh seeds are sown in well-prepared nursery beds in rows, spaced at 5 cm and sown at a depth of 1-3 cm (Chaurasiya *et al*., 2019). The spacing between plants and rows can be adjusted based on soil fertility and the variety being cultivated. In less fertile soil, closer spacing is recommended, while in more fertile soil, greater distances are advisable, taking into account factors such as resource competition, root development, water management, and pest control to facilitate robust growth and maximize yield. Maintaining a gap of 20 to 25 cm between rows and 8 to 10 cm between individual plants is generally recommended (Moharana *et al.,* 2020). Approximately 5-10 kg of seeds are required for planting in one hectare of the primary field (Namdeo and Ingawale, 2021). Sowing takes place right before the beginning of the monsoon and is lightly covered with sand. Germination typically occurs within 5 to 7 days. Once the seedlings reach approximately 35 days of age, they are transplanted into the well-prepared main field during July-August (Farooqi and Sreeramu, 2004). Adequate moisture, facilitated by a light shower after sowing, is essential for good germination. It is crucial to maintain consistently moist soil until the seedlings emerge. Although transplanting *ashwagandha* seedlings is a common practice, it has been observed that transplanted seedlings exhibit bifurcated roots, hence, direct sowing is recommended (Fig. 2).

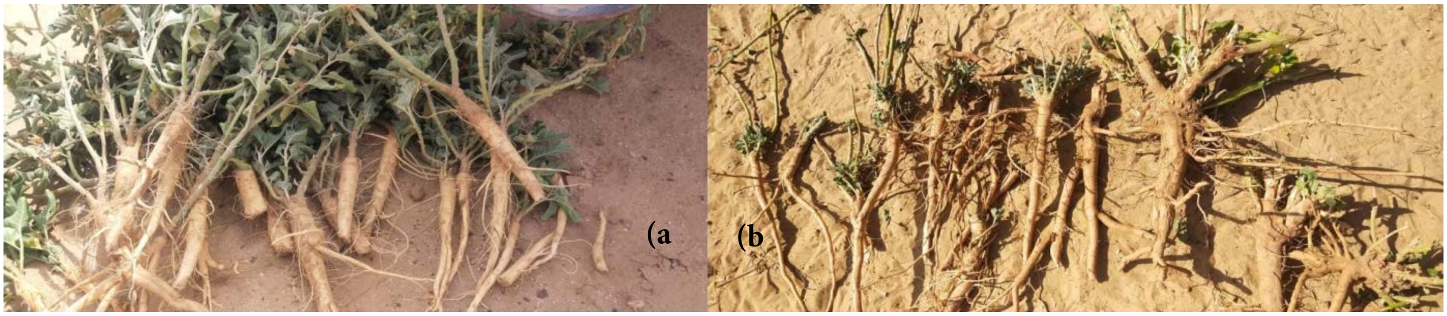

Fig. 2. Nagori ashwagandha root (a) direct sowing (b) transplanting

Transplanting

For the cultivation of *ashwagandha*, the selected field should be thoroughly pulverized through ploughing or harrowing, followed by leveling. While the *ashwagandha* crop does not demand heavy doses of manure, it is advisable to apply 10 to 20 tons of Farm Yard Manure (FYM). Ridges are prepared at a spacing of 60 cm, and healthy seedlings are planted at intervals of 30 cm. In certain locations, spacing of 60 cm x 60 cm or 45 cm x 30 cm is also adopted (Farooqi and Sreeramu, 2004). However, the preferred spacing is 60 cm x 30 cm, ensuring an optimal seedling population of approximately 55,000 per hectare (Namdeo and Ingawale, 2021). Notably, there is a noticeable variation in profitability due to different sowing methods. Regarding sowing techniques, the highest net return was observed with the raised bed method, followed by the ridge and furrow method, and then the flat-bed method (Ratre *et al.,* 2018).

In-vitro propagation

The substantial disparity between the demand and supply of *ashwagandha* cannot be addressed effectively through traditional propagation methods due to its low seed germination rate and seedling viability (Ameen *et al.,* 2023). *In-vitro* propagation emerges as the most suitable approach to overcome the constraints of conventional propagation and meet the commercial demands for *ashwagandha*. Numerous biotechnological interventions, including callus and suspension culture, hairy root culture, and others, have been developed to enhance the propagation process, as highlighted in Table 1.

Table 1. *In vitro* regeneration of *ashwagandha*

Mode of propagation	Explant used	Reference
Direct regeneration	Nodal explant	Tawade *et al*. (2023)
Multiple shoot differentiation	Nodal explant	Kaur *et al*. (2021)
Callus induction	Shoot explants (shoot tips, cotyledonary leaf, matured leaves, node, internode)	Sharada (2004)
Multiple shoots differentiation	Nodal explant	Govindaraju *et al*. (2003)
Multiple shoots differentiation	Nodal explant	Mir *et al*. (2014)
Direct regeneration	Nodal explant	Autade *et al*. (2016)

In contrast to callus culture, cell suspension culture offers the advantage of containing homogeneous cell populations and can be readily scaled up for large-scale cultivation (Ahuja *et al.,* 2021). In addition, it is noteworthy that somatic embryogenesis stands out as the swiftest method for generating a substantial quantity of clonal plants, given that somatic embryos encompass both shoot and root ends. Nevertheless, the utilization of synthetic seeds, including encapsulated somatic embryos or vegetative propagules such as nodes, axillary buds, and shoot apices, serves as a valuable strategy for preserving germplasm in elite medicinal plants (Verma *et al.,* 2010). Moreover, Singh *et al.* (2006) documented their successful production of synthetic seeds in *ashwagandha*. This was accomplished by encapsulating shoot tips from 4-week-old in vitro-cultured shoots using a mixture of sodium alginate (3.0%) and calcium chloride (75 mM). Similarly, Fatima *et al.* (2013) employed axenic nodal segments to create synthetic seeds in *ashwagandha*. These nodal segments were enveloped in a matrix consisting of 3% sodium alginate and 100 mM calcium chloride, then cultured on a Murashige and Skoog (MS) medium supplemented with BAP (6-benzylaminopurine) and NAA (naphthaleneacetic acid), aiming to facilitate the optimal transformation of encapsulated nodal segments into plantlets.

Propagation of Mulethi (Glycyrrhiza glabra L.)

Mulethi propagation can be accomplished through two methods: using seeds or employing root/stolon cuttings (Dastagir and Rizvi, 2016). However, the latter, involving 10-15 cm root/stolon cuttings, is more commonly chosen due to the relatively low seed set and germination rates (Bakhane *et al.,* 2014; Sharma *et al.,* 2010). The recommended variety for cultivation is 'Haryana Mulhatti-1,' released by Chaudhary Charan Singh Haryana Agricultural University, Hissar (Bhardwaj *et al.,* 2020). Planting is typically carried out in January and February in areas with irrigation facilities and during July and August in regions dependent on rain for sufficient soil moisture.

Propagation through seed

Variations in the germination capacity of *mulethi* were observed among seeds at different stages of maturation (Rao 1993). It is difficult to germinate seeds at the milky way ripe stages but seeds collected in July have the highest germination rates. It is advisable to plant the seeds at a depth of around 1/4 inch in soil. Furthermore, it is advisable to space the seeds at least 6 to 12 inches apart when planting to ensure that there is adequate room for the plants to grow (Öztürk *et al*., 2018).

Propagation through crown root

For optimal results, it is essential to plough and harrows the field thoroughly, ensuring a fine tilth and weed-free soil. During field preparation, it is recommended to apply Farm Yard Manure (FYM) at a rate of 10 tons per hectare to promote good underground root development (Tewari and Singh, 2019). Planting cuttings of the underground stolon, measuring 10-15 cm in length and possessing 2-3 eye buds, at a depth of six to eight cm and spaced at intervals of 60 x 45 cm or 90 x 45 cm is advisable (Akhtar and Anjum, 2022). Additionally, raising the rows 45-60 cm can facilitate irrigation. The stolon typically begins sprouting within 15-20 days after planting. Notably, *mulethi* propagation can also be achieved through a single root node cutting, which conserves planting material and promotes rapid germination (Fig. 3). During the initial phase, it is essential to provide light and frequent irrigation to support the establishment of the cuttings in the field. Once the plants reach a height of 20 to 30 cm, elevating the rows encourages healthy root expansion. To ensure optimal stolon growth and achieve a substantial yield, it is recommended to leave the crop in the field for a period of 3 to 4 years (Dastagir and Rizvi, 2016).

Fig. 3. *Mulethi* germination from single root node

In-vitro propagation

Traditional seed-based propagation faces economic challenges due to issues like poor seed set, low seed viability, and a slow growth rate (Jaiswal *et al*., 2017). As a result, the primary method for propagating the crop relies on valuable vegetative components such as stolons, rhizomes, or cuttings. However, vegetative propagation is not practical, especially for economic parts like roots that take several years to mature (Gupta *et al*., 1997). Tissue culture stands out as the viable alternative strategy, providing a large-scale *in vitro* propagation of *mulethi* germplasm. This approach enables the production of pathogen-free and season-independent clonal plants. This can be accomplished by utilizing different components of *mulethi*, including nodal buds, apical meristem, axillary buds, leaf segments, shoot buds or by employing somatic embryogenesis.

It can be achieved by using different parts of *mulethi* namely nodal bud, axillary buds, apical meristem, shoot buds, leaf segment or through somatic embryogenesis (Srivastava *et al*., 2019). Several biotechnological interventions have been reported in recent years to develop alternative strategies to meet industrial demands. Some of the *in vitro* study has been mentioned in Table 2.

Table 2. *In vitro* regeneration of *mulethi*

Mode of propagation	Explant used	Reference
Callus induction	Leaves and nodal segments	Rathi (2017)
Callus induction	Hypocotyl	Fu *et al.* (2010)
Multiple shoots differentiation	Nodal segment	Arya (2009)
Callus induction	Cotyledon	Wawrosch *et al.* (2009)
Callus induction	Young leaves	Mousa *et al.* (2007)

Considerable research efforts have been directed towards micro-propagation of *mulethi* using shoot tip and nodal culture techniques. *In vitro* rooting has proven to be most effective on full-strength MS medium enriched with IBA, with optimal levels ranging from 0.5 to 1.0 mg/l (Patel *et al.*, 2007). Yadav and Singh (2012) provided a detailed micro-propagation protocol involving the manipulation of growth regulators, cultural conditions, and external factors influencing *mulethi's in vitro* proliferation. Optimal results were achieved by selecting middle-order nodes, specifically the 3rd to 5th node from the apex, resulting in the highest bud-break rate (86.6%), longest shoot length (8.0 cm), and the greatest number of shoots (3.0). Similarly, Fu *et al.* (2010) conducted a study focused on enhancing the development of embryogenic callus and embryogenesis in *mulethi*. They observed that using hypocotyl explants led to the highest frequency of callus formation, reaching 93.3%, when cultured on MS medium supplemented with 2.0 mg/L 6-benzylaminopurine (6-BA) and 0.5 mg/L 2,4-dichlorophenoxyacetic acid (2,4-D).

Extensive research efforts have been dedicated to its micro-propagation using shoot tip and nodal culture techniques. *In vitro* rooting was found to be most effective on full-strength MS medium enriched with IBA at levels ranging from 0.5 to 1.0 mg/l (Patel *et al.*, 2007). Yadav and Singh (2012) detailed a specific micro-propagation protocol that involved the manipulation of growth regulators, cultural conditions, and external factors influencing the *in vitro* proliferation of *mulethi*. The most favorable outcomes were attained by selecting middle-order nodes (specifically, the 3rd to 5th node from the apex), which resulted in the highest bud-break rate (86.6%), longest shoot length (8.0 cm), and the greatest number of shoots (3.0). Similarly, Fu *et al.* (2010) conducted a study aimed at enhancing the development of embryogenic callus and embryogenesis in *mulethi*. They observed that using hypocotyl explants yielded the highest frequency of callus formation, reaching 93.3%, when cultured on Murashige and Skoog (MS) medium supplemented with 2.0 mg/L 6-benzylaminopurine (6-BA) and 0.5 mg/L 2,4-dichlorophenoxyacetic acid (2,4-D).

Propagation of Shatavari (Asparagus racemosus Willd.)

The National Medicinal Plant Board has identified *shatavari* as one of the 32 medicinal plants designated for conservation based on its extensive use (Thakur *et al.* 2015). Therefore, the preservation of this species is of utmost significance. They can be propagated through two main methods: seeds or divisions of rhizomatous discs (Sachan *et al.*, 2012).

Seed propagation

For sowing purpose seeds are typically harvested from March to May, specifically when they undergo a transition in color from red to black. As part of the pre-sowing treatment, these seeds can be soaked in water for duration of two days or subjected to gibberellic acid treatment for periods of 96 hours, which helps expedite the germination process (Gupta *et al.*, 2002). In the initial week of June, seed sowing takes place in meticulously prepared elevated nursery beds, as illustrated in Fig. 4. The seeds are planted at a depth of 2 cm beneath the soil surface within raised beds measuring 4.5 m x 1.2 m and standing at a height of 20 cm. With a spacing of 5 cm between seeds in rows, they are carefully positioned and lightly covered with fine sand. Regular watering with a rose cane is employed to sustain optimal moisture levels in the beds. Typically, germination occurs within a span of 15 to 20 days. Approximately 7 kg of seeds are required to cultivate enough seedlings for one hectare of the crop (Krishnamurthy *et al.*, 2004).

Transplanting

The soil ought to undergo thorough disc plowing, succeeded by harrowing and leveling processes. To facilitate irrigation management, the field is partitioned into separate plots with an irrigation channel positioned between every two rows of plots. About one month before the transplanting phase, it is advised to incorporate 10 tons of well-decomposed FYM into the soil, ensuring thorough mixing for optimal soil conditioning. August is ideal for transplanting. Seedlings are ready for transplantation about 45 days after sowing. Seedlings of 5 cm height are carefully removed from the beds, ensuring minimal root damage, and transferred to the field. During planting, they are placed into pits measuring 45 x 45 x 45 cm and spaced 1 meter apart (Saran *et al.,* 2020). In addition, seedlings are transplanted on ridges, maintaining a distance of 60 cm between plants, while ridges are 45 cm apart (Yadav *et al.,* 2022). The ridge method of transplanting is superior in comparison to a flatbed method. The ideal number of seedlings required per hectare is approximately 150,000 plants/ha.

Fig. 4. Nursery raising of Shatavari

Propagation with crown bud

The propagation of the plant can be done by taking the crown bud along with its root. After transplanting sprouting commence after 8-10 days of planting. The yield of the crop is influenced by the number of plants per unit area. The highest yield was achieved with a plant density of 1x0.5 meters spacing, resulting in a dry yield of 12.5 kilograms per 24 square meters in irrigated areas during the final harvest at 19 months. In contrast, a lower plant density of 1x1 meter spacing yielded 9-9.4 kilograms per 24 square meters under similar conditions (Krishnamurthy *et al*., 2004). The first harvest is usually done after 1.5-2 years of planting, and this can continue for 10-15 years (Saran *et al.*, 2019).

In vitro propagation

Shatavari can be grown from either seeds or other plant parts (like root cuttings) (Sachan *et al*., 2012). However, since the roots are the valuable part used for medicine, people usually prefer seeds to grow the plant. But multiplication through seed has its drawbacks such as low germination percentage, slow growth and existence of heterozygosity (Singla and Jaitak, 2014; Sharan *et al.,* 2011). Hence, the requirement for consistent and high-quality planting material is of utmost importance. In this context, *in vitro* techniques can prove advantageous. Numerous studies have documented the standardization of micro-propagation protocols for *shatavari*. A compilation of the *in vitro* propagation methods employed in *shatavari* is presented in Table 3.

Table 3. *In vitro* regeneration of *shatavari*

Mode of propagation	Explants used	References
Adventitious shoot bud regeneration	Nodal explant	Sulava *et al.* (2020)
Somatic embryoids formation through callus culture	Zygotic embryos	Chaudhary and Dantu (2019)
Somatic embryoids formation through callus culture	Nodal explant	Pant and Joshi (2017)
Adventitious shoot bud regeneration	Shoot apex and nodal explant	Sharan *et al.* (2011)
Indirect organogenesis via callus culture	Shoot explants (node, internode, shoot tips)	Pant and Joshi (2009)
Axillary branching	Nodal explant	Bopana and Saxena (2008)
Adventitious shoot bud regeneration through callus culture	Nodal explant	Kumar and Vijay (2008)

Kar and Sen (1985) pioneered the initial efforts to cultivate *Asparagus racemosus in vitro*. They successfully induced shoot proliferation from callus cultures of *shatavari* using stem discs as explants, with the aid of 2,4-D and kinetin.

Bopana and Saxena (2008) later devised a more effective protocol for axillary branching using nodal explants. Normally, *in vitro* rooting in *A. racemosus* is tedious and hormones are not enough to induce roots. However, this study successfully induced roots by employing phloroglucinol. The researchers utilized an MS medium supplemented with 3.69 µM 2-isopentyl adenine and 3% sucrose, leading to a multiplication rate of 3.5.

Post-planting care of tuberous medicinal plants

Caring for tuberous medicinal plants after planting is crucial to ensure their growth, health, and maximum medicinal yield. Here are some important post-planting care steps to follow:

Manure and fertilizer

Root crops generally do not demand heavy fertilization; however, applying a balanced fertilizer or compost during the growing season proves beneficial in providing essential nutrients. Organic manures like FYM, vermicompost, and green manure can be utilized based on the specific requirements of the species (Gupta *et al.,* 2011).

Ashwagandha crops exhibit excellent responsiveness to organic manures. For this crop, approximately 10 to 12 tonnes of well-decomposed FYM or 1 to 1.5 tons of vermicompost per hectare are recommended during plantation. In soils with average fertility, supplementing with 15 kg of nitrogen (N) and 15 kg of phosphorus (P) per hectare is advantageous for achieving higher yields (Tuteja, 2022). In cases of poor fertility soils, it is advisable to increase the application to 40 kg of nitrogen (N) and 40 kg of phosphorus (P) per hectare to optimize root yield. *Mulethi* crops generally do not require heavy fertilization, but the application of a balanced fertilizer or organic compost once or twice during the growing season can enhance growth. Applying compost or FYM at the rate of 12-18 tons per hectare is sufficient to meet the nutrient requirements of the plant. However, due to difficulties in obtaining organic manures in large quantities, a chemical fertilizer dose at the rate of 40:40:20 kg per hectare per year (urea, superphosphate, and chloride of potash) may also be considered. The full basal dose of superphosphate and potash is applied at the time of planting, while nitrogen is applied in three split doses: at planting, six months later, and one year after planting. Since the crop remains in the field for two and a half to three years, every year the same dose has to be applied (Farooqi, 2001). Further, *shatavari* cultivation demands a fertilizer dose of 60 kg nitrogen, 40 kg phosphate, and 40 kg potash per hectare to achieve optimal growth and enhance tuberous root yield (Parida *et al.,* 2018). It is recommended to place one-third of the nitrogen and the entire dose of phosphate and potash 10–12 cm deep in the rows before the transplanting process. This strategic placement ensures that the essential nutrients are available to support *shatavari* plants during their growth and development.

Irrigation

Tuberous medicinal plants are sensitive to excess water, and it is vital to avoid water-logging in the field. Stagnant water can result in problems like damping-off and root rot. To promote the successful establishment of seedlings in the soil, it is recommended to apply light irrigation at the time of transplanting. For optimal root yield, irrigation should be carried out at intervals of 8 to 10 days (Namdeo and Ingawale, 2021). However, during the dry summer season, the crop may require irrigation at intervals of 30-45 days, and in the winter season, one to two irrigations may be necessary to maintain root health. If there is regular rainfall, additional irrigation may not be needed. *Mulethi* plants, on the other hand, demand consistent moisture, especially during the growing season, typically requiring a total of 7-10 irrigations on average for successful crop cultivation (Zaidi, 2018). In contrast, *shatavari* requires minimal irrigation as it can thrive without frequent watering. An annual rainfall range of 800-1200 mm, distributed evenly, is generally sufficient for *shatavari* plants. During the initial establishment phase, plants may be irrigated weekly, and once they have firmly established themselves, light irrigation can be provided at monthly intervals (Saran *et al*., 2021).

Mulching

The mulching technique involves spreading a protective layer of organic materials, such as straw, leaves, wood chips, or compost over the soil surface around the base of the plants. It is an effective practice that offers multiple advantages. This practice aids in conserving moisture, regulating soil temperature, enhancing soil health, suppressing weeds, and mitigating erosion (Carrubba and Militello, 2013).

Weeding

Keep the area weed-free, as weed competition can impede their development. During the initial year of planting, it is essential to conduct three to four hoeing cum weeding sessions. In the following years, two hand weeding-cum-hoeing sessions prove adequate to maintain a weed-free field and enhance the overall well-being of the plants. Typically, the first weeding should occur within 21–25 days of sowing, with the second weeding scheduled after an additional 21–25 days following the initial one (Carrubba and Militello, 2013).

Staking

Ashwagandha, *mulethi* and *shatavari* may require support as they grow taller. Staking is crucial to counter potential damage from strong winds or heavy rainfall. *Ashwagandha* plants can grow up to 4 to 5 feet in height, and their branches may need some support. Consider staking or using a trellis to help the plants stay upright (Mathew *et al*., 2005). Likewise, *mulethi* plants can reach heights of 3 to 5 feet and may need support as they mature (Bakhane *et al.,* 2014). It is worth noting that *shatavari* crops, being climbers, also necessitate support for their optimal growth (Babu *et al.,* 2016). To facilitate this, 4-6 feet long stakes are commonly employed to provide the necessary support for the overall growth of the plants.

Pest and disease control

Major pests and diseases have not been reported in medicinal crops; however, early detection and timely intervention can effectively prevent any potential serious damage. It is advisable to employ natural pest control methods whenever possible. Bio-pesticides, either prepared individually or as a mixture from plant parts such as neem, chitrakmool, dhatura, and cow's urine, can be utilized for this purpose (Gupta *et al.,* 2011). Implementing this proactive strategy helps to ensure the overall health of root crops.

Harvesting

Ashwagandha roots are typically harvested between January and March, approximately 150 to 180 days after sowing, when they reach the desired size. The maturity of the crop is determined by the drying out of leaves and the presence of yellow-red berries (Moharana *et al.,* 2020; Saran *et al*., 2025). It is recommended to maintain adequate soil moisture during the digging process. Careful extraction of the tap root is essential to preserve the health of even the smaller lateral roots. A yield of 6.5 to 7.0 quintals per hectare can be achieved in fibrous type, with a preference for commercially viable root species with diameters ranging from 6 to 15 mm and lengths of 7 to 10 cm. DTWr-1 has maximum fresh root length (36-39 cm), fresh root girth (2-4 cm), dry root yield (5 t h^{-1}) and starch yield (2.70 t h^{-1}), as compared to all available checks as shown in Fig. 5 (Saran and Das, 2023; Saran *et al*., 2025). The alkaloid content in the roots varies from 0.13 to 0.31%.

Mulethi crops are ready for harvesting after 2.5-3 years of planting, just before fruiting, typically in November and December, when glycyrrhizin content is at its peak (Ahmed *et al.,* 2021). The plants are uprooted, and the aerial parts are removed, leaving clean roots. Herbage may be left in the field to recycle minerals and nutrients. The Haryana Mulhatti-1 variety yields 7-8 tons of roots with a 7.5 percent glycyrrhizin content (Zaidi, 2018). *Shatavari* crops mature within 12 to 14 months after planting (Saran *et al*., 2019) and are expected to yield approximately 4–5 tonnes per hectare, depending on soil and climatic conditions (Fig. 6). The optimal period for harvesting tuberous roots is in November to December, coinciding with the time when the above-ground parts of the plant begin to exhibit a pale-yellow color (Vel, 2017).

Fig. 5. Freshly harvested roots of starchy type *Ashwagandha*

Conclusion

The medicinal tubers are a vital group of medicinal plants. Their commercial value often leads to overexploitation, which threatens their natural populations. To address this issue, we have been exploring various propagation methods, including *in vitro* plant propagation. The review aims to provide a comprehensive overview of existing studies and investigations related to the propagation of medicinal tuber plants. This not only helps consolidate existing knowledge but also identifies research gaps that require further exploration. This approach aligns with a more holistic and forward-looking strategy to ensure the survival of these important medicinal plants for future generations. In this way, farmers will be encouraged to cultivate these medicinal plants for commercial use, which will curb overexploitation in the wild and thus complement the conservation process.

Fig. 6. Harvesting of *Shatavari*

Acknowledgements

The authors express their gratitude to the Indian Council of Agricultural Research (ICAR), New Delhi, and ICAR-Directorate of Medicinal and Aromatic Plants Research, Anand for providing the necessary facilities to conduct research and compile the information.

Author Contribution Statement

SWARAJYA LAXMI NAYAK: Writing original draft. Compilation; PARMESHWAR LAL SARAN: Compilation & manuscript editing; MANISH DAS: manuscript editing

Conflict of Interest

The authors have no conflict of interest.

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