

AGRITECH



Vol 2, Issue 2 (June), 2025

An e-magazine, bringing science to the public

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From the editor’s desk

India is a major exporter of horticultural produce, supplying fresh and processed fruits, vegetables, spices, and plantation crops to global markets. Its diverse agro-climatic conditions enable year-round production of crops such as mango, banana, grapes, pomegranate, onion, tomato, chillies, and okra, along with processed items like fruit pulps, dehydrated onions, pickles, and frozen vegetables. The Agricultural and Processed Food Products Export Development Authority (APEDA) plays a vital role in promoting exports by developing packhouses, cold storage facilities, and integrated packing lines, while also ensuring compliance with international quality and safety standards. Key export destinations include the Middle East, the European Union, Southeast Asia, and the United States. India’s adoption of Good Agricultural Practices (GAP), traceability systems, and residue monitoring has improved access to high-value markets. However, challenges remain in post-harvest management, cold chain logistics, and international branding, where competing nations often perform better. Strengthening farmer-producer organisations, contract farming, and value addition through processing can boost competitiveness. Initiatives like Geographical Indication (GI) tagging of unique produce, such as Alphonso mango and Nagpur orange, have enhanced India’s brand value. With rising global demand for organic, exotic, and sustainably grown produce, India has significant potential to expand horticultural exports, benefitting farmers and the national economy.

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Advanced Propagation Techniques in Spice Crops

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A spice is a seed, fruit, root, bark, or other plant substance primarily used for flavoring, coloring or preserving food. India is the land of Spices, the largest producer, consumer and exporter of the spices in the World. According to the Spice Board of India, sixty three spices are grown in the country. The spices continued to be one of the major foreign exchange earning items which necessitated expansion of area under these crops and hike in production because of its high enrich flavours and colouring agents for food. More than 90% of spices produced in India are used for domestic consumption and the remaining are exported in raw and value added forms. Lack of quality and insufficient planting material is a bottle neck for the productivity of spice crops. Under this context there is a need to develop advanced methods of propagation to meet the requirements of farmers for the planting material is need of the hour.

Conventional V/S modern propagation techniques

Conventional propagation needs a large quantity of planting material which results less sprouting ratio, more incidences of disease and pests and poor root development as well as field establishment. Modern propagation techniques are more advantageous over conventional one. Through

modern propagation techniques production of virus free, disease and insect pest resistant planting material with large quantities within a shorter space of time can be possible. These plants grow faster and more vigorously. Also gives higher yield as compare to conventional methods.

Advanced propagation techniques of spice crops

Black pepper

Black pepper (*Piper nigrum* L.) (Family: Piperaceae) (King of spices/ Black gold) is a perennial vine grown for its berries extensively used as spice and in medicine Black pepper can be propagated by seeds, cuttings, layering, and grafting. Seed propagation often results in genetic variation while other methods of propagation are slow and time consuming. So, there is a need to introduce efficient methods for rapid propagation of black pepper.

Rapid multiplication method

A propagation technique developed in Sri Lanka and modified for adoption in India for quick and easy multiplication of black pepper vines. A trench of 45 cm depth, 30 cm width and of convenient length is made. The trench is filled with rooting medium comprising of forest soil, sand and farm yard manure in 1:1:1 ratio. Split halves of bamboos are fixed at 45° angle by keeping split portion facing upward on a strong support on one side of the trench. The split bamboos are coated with tar or black paint to control the termite infestation. Rooted cuttings are planted in the trench at the rate of one cutting for each bamboo split. The lower portions of the bamboo splits are filled with rooting medium (preferably weathered coir dust-farm yard manure mixture in 1:1 ratio) and the growing vine is tied to the bamboo split in such a way to keep the nodes pressed to the rooting medium. Each single noded cutting with the bunch of

roots intact is cut and planted in polythene bags filled with fumigated potting mixture. Trichoderma @ 1g and VAM @ 100 cc/kg of soil can be added to the potting mixture. The buds start developing in about three weeks and the poly bags can then be removed and kept in shade till main field planting.

Advantages:

- (i)Rapid multiplication rate (1:40)
- (ii)Well developed root system
- (iii)Higher field establishment
- (iv)Vigorous growth as a result of better root system

Vertical column method

A novel method of intensifying quality planting material production has been standardized using vertical columns with soil-less media. The technique involves growing orthotropes on vertical column (2 m height, 0.3 m diameter) made of half an inch plastic coated welded wire mesh. The column is filled with partially decomposed coir pith and vermicompost @ 3:1 ratio fortified with bio-control agent Trichoderma harzianum. Growing the vine on vertical column can be effectively utilized for the production of three types of planting material i.e., single node cuttings, top shoots with lateral branch (use of top shoots for field planting is having advantage of producing fruit bearing branch from the base and start yielding early) and laterals or plagiotropes which can be used for production of bush pepper.

The hi-tech poly house (temperature of 25-28°C and relative humidity 75-80% with intermittent misting) is advisable for the above production system. Eight to ten cuttings can be planted around each vertical column. The cuttings are allowed to trail on the column ensuring that each node comes in contact with the medium. It takes about four to five months for the cuttings to reach the top of the column. At this stage each vine will have

around 20 nodes with few lateral branches (at 12th- 15th node). The top 5-7 nodes with lateral branches can be used as orthotropic shoots for field planting. In four to five months, about 150 single node cuttings, 10 – 15 laterals and 10 top shoots can be produced in this method. Two hundred such columns can be accommodated in a poly house size of 320 m². In a year, three harvesting cycles can be made. These cuttings can be rooted further for field planting using pro-trays.



Rapid multiplication method



Vertical column method

Cardamom

Cardamom (*Elettaria cardamomum* Maton) (Family: Zingiberaceae) (Queen of spices/ Green gold) originated in the Western Ghats of South India. It is one of the most highly priced and exotic spices in the world. The main reason for low cardamom productivity in India is the use of unselected and heterogeneous planting material raised from seed. Planting of propagules multiplied from elite plants could be used to raise cardamom productivity.

Rapid clonal nursery technique

A quick method of proliferation of suckers at IISR under controlled overhead shade to generate more number of planting units as well as high yield in a short time by restoring to HDP in trenches at close spacing.



High yielding plants free from pest and disease, with bold capsules marked and a part of clump uprooted leaving the mother clump in original site for further sucker development. Each planting unit consists of one grown up sucker and growing young shoot which are planted in trenches of 45cm width, 45 cm depth and of any convenient length may be taken across the slope or along the contour at 1.8 m apart which will accommodate 6800 plants/ha. The top 20 cm depth soil is excavated separately and heaped on the upper side of the trench. The lower 25 cm is excavated and heaped on the lower side of the trenches all along the line. The top soil is mixed with equal portions of top soil is mixed with equal proportions of humus rich jungle soil, sand and cattle manure and filled back by leaving a depression of 5 cm at the top to facilitate mulching for retention of soil mixture. Suckers, each consisting of one grown up tiller and a growing young shoot, are placed at a distance of 0.6 m distance in the trenches during March-October. Regular cultural operations are to be followed including high fertilizer dosed 100:50:200 kg NPK/ha in 6 split doses at 60 days interval. Irrigation should be provided atleast twice in a week. On average, 32-42 suckers per planting unit will be produced by 12 months after planting (after one year we get 16-21 planting units from one clump). In an area of 1 ha clonal nursery 1-1.4 lakh planting units can be produced after 12 months.

Turmeric

Turmeric (*Curcuma longa* L.) (Family: Zingiberaceae) (golden spice/ spice of life) is a tropical perennial rhizomatic spice crop. Turmeric is commonly propagated through rhizomes. Hence, large quantity of rhizome is required because of the low efficiency of vegetative propagation. The availability of quality planting material is also low during the cropping season (June - September). In order to overcome these problems, a technology on rapid multiplication of turmeric using single bud rhizome has been standardized at TNAU, Coimbatore. In this portray technique of turmeric, planting material requirement will be reduced; about 25 per cent of planting material requirement can be reduced.



Method of planting in portray

1. Select healthy turmeric rhizomes for seed purpose.
2. Treat the selected rhizomes with mancozeb (0.3%) and quinalphos (0.075%) for 30 min and store in well ventilated place.
3. One month before planting, the seed rhizomes are cut into single buds with small piece of rhizomes weighing 5- 7 g.
4. Fill the pro-trays (98 well) with nursery medium containing partially decomposed coir pith and vermicompost (75:25), enriched

with PGPR/Trichoderma 10g/kg of mixture.

5. Plant the turmeric bud sprouts in pro-trays.

6. Maintain the pro-trays under shade net house (50%).

7. Adopt need based irrigation with rose can or by using suitable sprinklers.

8. Seedlings will be ready within 30-35 days for transplanting

Conclusion

The major bottle neck of the spice production is due to unavailability of quality planting material. Keeping this constraints in mind the traditional methods of propagation in spice crops are following the advance techniques for rapid multiplication like split bamboo method, vertical column method, trench method in cardamom propagation and propagation of turmeric and ginger using single bud rhizomes as advance propagation techniques which has greater scope for multiplication of large quantity of planting material in small area.

Dual Role of P-Solubilizing Bacteria: Nutrient Mobilization and Plant Protection

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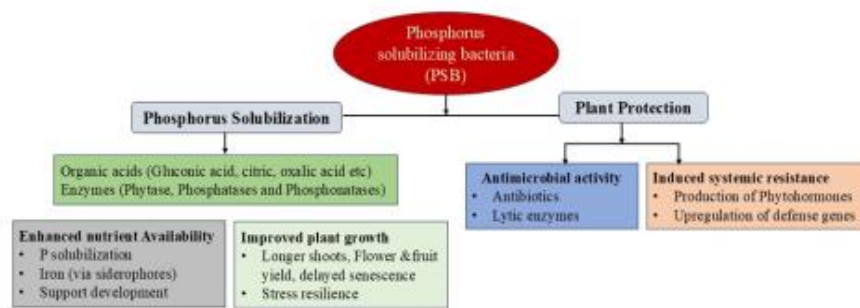
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Phosphorus (P) is one of the most essential macronutrients for plant growth, ranking just after nitrogen in importance. Phosphorus, a fundamental element in DNA, cell membranes, and energy-transfer molecules, plays a vital role in plant life by supporting cell division, root and stem strength, flower and seed development, crop maturity, and overall quality, while also integrating closely with nitrogen and carbon metabolism, as well as photosynthesis, to drive essential growth and energy processes. Yet, despite its abundance in soils, making up about 0.05% by weight, only a tiny fraction (around 0.1%) is actually available for plant uptake, as most of it exists in forms that plants can't absorb. This poor availability, caused by phosphorus becoming quickly locked up in the soil, makes it a major limiting factor in crop productivity. As a result,

ensuring plants get enough accessible phosphorus remains a key challenge in modern agriculture.

To tackle phosphorus deficiency in soils, modern agriculture has long relied on the heavy use of chemical phosphate fertilizers. These fertilizers initially flood the soil with soluble phosphate, yet plants manage to absorb only about 20% of what's applied. The rest quickly binds to soil particles, becoming unavailable to crops. Over time, the excessive and repeated use of these fertilizers has sparked serious concerns, degrading soil health, disrupting microbial communities, and polluting ecosystems.

Phosphorus-solubilizing microorganisms (PSMs) have been extensively explored as potential biofertilizers due to their natural ability to support plant nutrition and growth. These beneficial microbes, often found in phosphorus-rich zones, can be isolated and applied to crops to boost the availability of phosphorus, a nutrient that is often locked in insoluble forms in the soil. Beyond solubilizing phosphorus, PSMs enhance soil fertility, enrich phosphorus availability, and improve nutrient uptake. Among PSMs, Phosphorus-solubilizing bacteria (PSB) have emerged as particularly effective agents due to their re-



In many developing regions, the widespread and unchecked use of agrochemicals to boost yields has compromised soil fertility, biodiversity, groundwater quality, and food safety, posing a direct threat to long-term agricultural sustainability and planetary health. Furthermore, plants face a combination of challenges, from abiotic and biotic stresses to hormonal imbalances and nutrient deficiencies, all of which hamper growth and yield. Nature, however, holds a sustainable solution to this challenge. Recent advances highlight the potential of phosphorus-solubilizing microorganisms (PSMs) beneficial microbes that unlock soil-bound phosphorus, offering a sustainable and eco-friendly alternative to chemical fertilizers.

Phosphorus-Solubilizing Bacteria: Nature's Multifunctional Soil Engineers

markable efficiency in mobilizing soil-bound phosphorus. Many PSBs also produce phytohormones like IAA, gibberellins, and cytokinins, and synthesize ACC deaminase, which helps plants cope with stress. They generate siderophores that enhance iron availability and suppress pathogenic microbes (Fig. 1) in the rhizosphere (Misra and Chauhan, 2020).

Fig. 1: Role of Phosphorus solubilizing bacteria

A diverse group of soil microbes including *Pseudomonas*, *Bacillus*, *Azotobacter*, *Agrobacterium*, *Burkholderia*, *Rhizobium*, *Bradyrhizobium*, *Enterobacter*, *Erwinia*, *Achromobacter*, *Flavobacterium*, *Micrococcus* and *Aerobacter* have demonstrated the ability to break down insoluble phosphate compounds like dicalcium phosphate, tricalcium phosphate, and hydroxyapatite. These microorganisms, collec-

tively known as phosphate-solubilizing bacteria (PSB), are increasingly valued in agro-ecological systems for their capacity to enhance phosphorus availability, support plant growth, and sustain soil fertility (de Boer et al., 2019).

Pseudomonas species, in particular, are notable for their adaptability to diverse environments and exceptional metabolic versatility. These PSBs are capable of solubilizing both inorganic and organic forms of phosphorus and often exhibit strong antagonistic activity against soil-borne plant pathogens. This multifunctional nature makes them excellent candidates for eco-friendly, multi-purpose biofertilizers.

Mechanism of Phosphorus Solubilization by Soil Bacteria

Phosphorus solubilizing bacteria (PSB) help plants access phosphorus by breaking down both inorganic and organic phosphate compounds. Their primary strategy involves producing organic acids such as gluconic, citric, oxalic, lactic, and acetic acids. These acids lower soil pH and chelate metal ions that typically bind phosphorus, thereby releasing it into a form accessible to plants. Gluconic and 2-ketogluconic acids are particularly important and are commonly produced by bacteria such as *Pseudomonas putida*, *Burkholderia cepacia*, *Rhizobium leguminosarum*, and *Bacillus firmus*. This acid production is driven by enzymes like glucose dehydrogenase (GDH), which requires the cofactor PQQ (pyrroloquinoline quinone), and gluconate dehydrogenase (GAD). Genes such as *pqqABCDE*, which regulate PQQ biosynthesis, are critical for this function; their disruption significantly reduces phosphate solubilization capacity.

In addition to acid production, some PSBs release hydrogen ions (H^+) in exchange for cation

uptake, aiding phosphate release through ion exchange rather than pH alteration. When targeting organic phosphorus compounds, bacteria secrete specific enzymes like:

Non-specific acid phosphatases (NSAPs) – including acid and alkaline phosphomonoesterases that hydrolyze phosphoesters and phosphoanhydrides. Inoculation with PSB strains like *Klebsiella* RC3 and RCJ4, *Serratia* RCJ6, *Stenotrophomonas* RC5, and *Enterobacter* RJAL6 has demonstrated strong acid and alkaline phosphatase activity under phosphorus-deficient and aluminum-toxic conditions (Barra et al., 2018).

Phytases – which break down phytate to release inorganic phosphate (Pi). Phytases are especially significant for releasing phosphorus from phytate, one of the major forms of organic phosphorus in soils. Microorganisms such as *Citrobacter*, *Pseudomonas*, and *Rhizobium* are among the most active phytase producers (Kumar et al., 2017).

Phosphonatases and C-P lyases – which degrade complex organophosphonates.

Notable bacterial groups contributing to these processes include *Bacillus*, *Arthrobacter*, and *Rhodococcus* (Gram-positive), and *Pseudomonas*, *Rhizobium*, *Citrobacter*, and *Delftia* (Gram-negative). These mechanisms—acid secretion, metal ion chelation, and ion exchange—work synergistically to convert insoluble phosphorus into bioavailable forms. Among these, *Pseudomonas fluorescens* stands out for its plant growth-promoting potential, as demonstrated in tomato cultivation, where its application led to enhanced shoot length, increased flowering, higher fruit set, and greater total yield.

Biocontrol activity

Although the primary agricultural application of phosphorus-

solubilizing bacteria (PSB) lies in enhancing phosphorus availability, recent research highlights their broader ecological roles in the soil microbiome. PSB significantly influence rhizospheric microbial diversity and community composition by interacting with indigenous microorganisms. Such interactions often result in the enrichment of beneficial microbial taxa, thereby creating a favorable microecological niche for plant development. Importantly, PSB are increasingly recognized for their antagonistic potential against phytopathogens, a trait common among plant growth-promoting rhizobacteria (PGPR). Certain PSB strains exhibit biocontrol activity by producing antimicrobial compounds or competing for niche and resources, thereby reducing disease incidence.

Pseudomonas putida MTCC 5279 has shown remarkable ability to support plant growth under combined salt stress and phosphorus deficiency in *Arabidopsis thaliana*. This strain enhanced levels of IAA and ABA, increased phosphatase activity, and upregulated several stress-related genes—including those involved in DNA repair (*At3g32920*), jasmonate response (*At2g46370*), and NAC-domain transcription (*At5g39610*), resulting in delayed leaf senescence and improved stress resilience (Sonal and Suchi, 2020).

Recent work by Bouizgarne et al. (2023) has also highlighted the promising potential of *Pseudomonas* strain Bg32c as a biofertilizer and biopesticide. This strain not only improved growth and yield in cherry tomatoes but also suppressed *Clavibacter michiganensis* subsp. *michiganensis*, a serious pathogen in greenhouse-grown tomatoes.

For instance, *Serratia marcescens* Pt-3, isolated from tea rhizosphere, has demonstrated antifungal activity against a

broad spectrum of seven phytopathogenic fungi. Similarly, Burkholderia sp. strain N3 has shown the ability to suppress bacterial diseases, significantly lowering pathogen-induced plant damage.

Limitations

Various phosphorus-solubilizing bacteria play a significant role in plant growth and phosphorus mobilization, being well-known for their multifaceted contributions to plant growth promotion and biocontrol. They produce phytohormones, antimicrobial compounds, lytic enzymes, and siderophores, and can induce systemic resistance in plants. However, their effectiveness in real field conditions often falls short of the promising results observed in laboratory studies. One major limitation is their reduced survival and colonization in natural soils, where they must compete with a well-established native microbial community. To overcome this, careful formulation of the selected strain is crucial. Bioformulations, whether in liquid, powder, granular, or capsule forms, can significantly enhance the microbial shelf life, improve stress tolerance, and support successful field establishment, ultimately ensuring the desired plant protection and growth benefits.

Conclusion

Phosphorus-solubilizing bacteria (PSB) play a pivotal role in sustainable agriculture by improving phosphorus availability and contributing to disease resistance through their antimicrobial properties and influence on rhizospheric microbial communities. Their dual role as biofertilizers and biopesticides highlights their value in enhancing plant productivity and resilience. However, the transition from laboratory efficacy to consistent field performance remains a challenge due to their reduced survival and competitiveness in native soil ecosystems. This underscores

the need for optimized bioformulations—such as liquid, powder, granular, or encapsulated forms—that can extend shelf life, protect microbial viability, and support successful colonization under diverse environmental conditions. With proper formulation and field validation, PSB strains such as *Pseudomonas*, *Bacillus*, *Rhizobium*, *Erwinia*, *Agrobacterium*, *Micrococcus*, *Achromobacter*, and *Flavobacterium* can serve as eco-friendly alternatives to synthetic agrochemicals, offering a sustainable pathway to improved crop health and soil fertility.

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Carnivorous Plants

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Carnivorous plants have fascinated evolutionary ecologists, botanists, and horticulturists for centuries. Darwin (1875) provided the first detailed experimental evidence for carnivory in several plant genera, and established once and for all that true heterotrophy existed in an autotrophic kingdom. According to Juniper et al. (1989) a plant is defined as carnivorous through its ability to attract, catch, retain and digest preys into easily assimilated compounds and subsequently to absorb nitrogen products for its growth and reproduction. Carnivorous plants derive some or most of their nutrients from trapping and consuming small animals such as insects, spiders and some even use small animals like snails and frogs as their food. These plants use specialized trapping structures to attract, capture, digest and absorb nutrients from insect prey and other sources of nitrogen, phosphorus and minerals. Many traps lure prey with bright colours, extrafloral nectaries, guide hairs, and/or leaf extensions. Insect capture by plants is an adaptation to life in nitrogen-poor habitats such as acidic peat bogs and rock outcroppings considered as an additional pathway for acquisition of supplemental nutrients. Most carnivorous plants will grow without consuming prey but they grow much faster and reproduce much better with nutrients derived from their prey.

Carnivorous plants share mainly three attributes that operate to-

gether and separate them from other plants.

Carnivorous plants

1. Capture and kill prey
2. Have a mechanism to facilitate digestion of the prey
3. Derive a significant benefit from nutrients assimilated from the prey

Carnivorous plants grow on every continent except Antarctica. About 600 carnivorous plant species were recognized in 20 genera and 13 families, have developed fascinating morphological and anatomical features linked to carnivory. Carnivorous plants occur worldwide, but species richness and abundance are highest in wet, open, nutrient-poor habitats Guyana Highlands, the southeastern United States, and Western Australia.

Different trapping mechanisms

There are five types of carnivorous plants based on their trapping mechanism: pitcher, flypaper, snap, suction and lobster pot traps.

1. Pitcher

Pitcher plants trap prey in a rolled leaf that contains a pool of digestive enzymes or bacteria. Usually insects are attracted by bright flowerlike anthocyanin patterns in the leaves or by nectar bribes secreted by peristomes. They then fall into the pitcher due to slippery wax lining the inside leaves. The plants that produce attractants, like those in Nepenthaceae, are called pitcher traps and plants with no attractants, like those in Sarraceniaceae, are called pitfall traps.

2. Flypaper

Flypaper traps capture prey by using sticky mucilage and sun-dews (*Drosera*). *Pinguicula* and *Drosera* belong to this type.

3. Steel Trap

Snap traps (sometimes called steel traps) utilize rapid leaf movement to capture prey. Only two species, the Venus flytrap (*Dionaea muscipula*) and *Al-*

drovanda ceciculosa, belong to this type. These snap traps close rapidly when triggered to trap prey between two lobes. At the beginning of capture, hold on insects is just strong enough to prevent insect escape, but once plants detect protein, the hold becomes stronger. In this way, unnecessary snapping triggered by materials other than insects can be prevented. The prey inside the tightly closed leaves is digested over a period of one to two weeks. Leaves can be re-used 3 or 4 times before they become unresponsive to stimulation but usually leaves wither after one capture.

4. Suction Trap

Suction (bladder) traps are exclusive to the genus *Utricularia*. Suction traps suck in prey with a bladder that generates an internal vacuum by pumping ions out of the interior and allowing water to enter by osmosis. The bladder has a small opening, sealed by a hinged door. In aquatic species, the door has a pair of long trigger hairs. Aquatic invertebrates such as *Daphnia* touch these hairs and deform the door by lever action, releasing the vacuum. Then the invertebrates are sucked into the bladder, where they are digested.

5. Lobster Pot

Lobster pots are the trapping mechanism in *Genlisea*, the corkscrew plant. Lobster-pot traps force prey to move towards a digestive organ with inwardly pointing hairs.

Landscape utility of carnivorous plants

Carnivorous plants are a fascinating group of plants, and have long been the subject of popular interest. Due to the various shapes and sizes of leaves of carnivorous plants there are wide ranges of choice for landscaping purposes. Furthermore, their leaf colour variation as well as their beautiful flowers makes these plants ornamental materials with a high commercial po-

tential. For example, large and colourful Nepenthes and Sarracenia are recommended for garden plants.

Sarracenia is a cold-tolerant garden plant and many can be grown from parts of southern Canada to Florida, across most of the United Kingdom, much of Europe, and through most of non-tropical Australia and New Zealand. It is one of the easiest plants to grow in temperate climates, thrives best in open gardens, and usually shows the richest colour in full sun.

However, most carnivorous plants are not recommended for outside landscaping purpose because they require nutrient-poor and acidic soils. Accordingly, carnivorous plants can be used only for special outdoor landscaping such as swamps and bogs. Thus, carnivorous plants are utilized mostly for interior landscaping purposes. Their use as pot plants is most popular, and growing them in hanging baskets or terrariums is also gaining popularity. This is especially true because a terrarium is an excellent container for carnivorous plants.

Cultivation of carnivorous plants

In nature, carnivorous plants are propagated through seed or through suckers. For commercial propagation of carnivorous plants, not only seed propagation and cutting but also tissue culture technique can be used. Generally, the habitats of carnivorous plants are warm, sunny and constantly moist so the plants experience relatively little competition from other low growing plants. Therefore, a greenhouse is the ideal facility for commercial cultivation of carnivorous plants. Most carnivorous plants require bright light and most will look better under such conditions. So when growing inside, a fluorescent light supplement, 15-30 cm above the plants, is recommended.

The soils of carnivorous plant's habitats are characterized by very low nutrients such as nitrogen, phosphorus, and alkali ions, as well as high acidity. Since they obtain nutrients by consuming animal prey rather than absorbing via roots, the nutrient absorbing ability of roots is very limited. As a result, the roots of carnivorous plants will not tolerate nutrient-rich commercial horticultural mix. Nutrient-poor, acidic Sphagnum peat moss, or 3:1, or 2:1 mixture of peat moss to perlite are recommended as a growing media.

Most of the carnivorous plants are grow in bogs, so almost all are quite resistant to drying due to low humidity. For plants growing on bogs, watering done under surfaces with a complete change of water once every 3-5 days is recommended. To increase air humidity, frequent water spray is needed, except for flypaper trap type plants in which frequent spray will wash out digestive enzymes in the leaves, resulting in retarded plant growth.

Generally fertilization of carnivorous plants is not recommended. In rare cases, when mineral deficiencies do occur, foliar spray or under surface watering supplemented with water soluble fertilizers such as 19:19:19 or 20:20:20 are recommended. Dried leaves should be removed to maintain the appearance of the plant. As and when the plant becomes overcrowded in a pot, repotting is recommended.

Tree Transplanting (Burlapping): A Comprehensive Guide

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Transplanting a mature tree—commonly referred to as burlapping—is a complex and delicate operation, as it involves significant root removal due to the tree's extensive root system. Trees recover slowly from this process, and successful transplantation depends on the tree's overall health, structure, and ability to re-establish roots. Trees in poor health or with weak structure should not be considered for transplanting. Additionally, the expected lifespan and post-transplant health of the tree must be evaluated to determine whether the operation is cost-effective.

Timing:

Transplanting should ideally be done in early spring when the evapotranspiration rate is low. Summer is typically avoided due to the high water loss and stress on the tree.

Selecting Trees for Transplanting

• **Not Recommended:** Avoid transplanting invasive exotic species such as Poplar, *Eucalyptus*, *Prosopis juliflora*, *Leucaena leucocephala*, *Acacia tortilis*, and *Casuarina*.

• **Recommended:** Native and high-conservation-value trees should be prioritized, especially if they cannot be preserved in situ. Commonly transplanted species in India include heritage and culturally significant trees like Neem, Pungamia, Mango, Sacred Fig, Jamun, Ashoka, Jackfruit, Tamarind, Banyan, and Sandalwood.

• **Palms:** Species like *Oreodoxa regia*, *Phoenix sylvestris*, and *Wodyetia bifurcata* are also commonly transplanted.

Selecting the Transplant Site

- The receptor site should be close to the original location to retain landscape and amenity value.
- The site must accommodate a large root ball, following international standards with a root ball diameter to trunk diameter ratio of 8:1 to 10:1 for mature trees.
- The location should provide enough space, proper soil conditions, and stability for tree recovery.

Tools and Equipment Required

- Mechanical diggers and root pruners
- Lifting cables, chains, straps/slings
- Cranes, trolleys, and transport trucks
- JCB machines for pit preparation

Root Ball Preparation

Root ball size varies by species, size, and location, but should always be as large as practical to increase survival chances. Root balls are typically wider than they are deep, with depth rarely exceeding 1 meter.

Four-Stage Root Pruning Process (For Mature Trees):

1. Stage 1: Dig trenches on two opposing segments outside the marked circumference.

2. Stage 2 (After 1 month): Prune roots and dig adjacent opposing segments.

3. Stage 3 (After another month): Dig the remaining two opposing segments.

4. Stage 4 (After another month): Shape and cut the underside of the root ball, then uplift and transplant the tree.

Pre-Lifting Preparations

- Ensure the receptor site or holding nursery is fully ready before beginning.
- Water the tree before lifting.
- Loosen and shape the trench edge and taper the root ball inward.
- Wrap the entire root ball in hessian cloth and secure it with a metal mesh for transport.
- Provide temporary support such as guying or props to stabilize the tree before moving it.

Lifting and Transport

- Trees should be lifted using padded support attached to the root ball, not the trunk, to prevent damage.
- Improperly wrapped root balls risk collapsing during transit.
- Containerized root balls offer additional protection and ease of handling, promoting better post-transplant establishment.

Preparing the Receptor Site

- Avoid compacted soil; loosen the area widely to support new root growth.
- Provide adequate drainage in planting pits.
- The planting hole should be no deeper than the root ball and at least 1.5 times wider.
- Scarify the pit sides to encourage outward root growth.
- Avoid placing the root ball's top below the soil surface.

Planting Process

- Reorient the tree in the same direction it previously grew.

- Remove all wrapping and support materials before backfilling.
- Tamp the soil firmly around the root ball and water immediately to settle the soil.
- Create a soil saucer to retain irrigation and rainfall near the roots.
- Use appropriate staking or underground guying to stabilize the tree.

Post-Planting Care

1. Protection and Support:

- Protect the tree with fencing.
- Provide external support (e.g., scaffolding or staking) for 30–45 days until new growth begins.
- Remove supports as soon as the tree stabilizes to encourage strength development.

2. Mulching:

- Apply a 5 cm thick organic mulch around the root zone, avoiding direct contact with the trunk.
- Mulch retains moisture, regulates temperature, and adds nutrients.

3. Watering:

- Essential for root establishment, especially in the first two years.
- Keep the root zone clear of other plants to avoid competition.

4. Fertilization:

- Chemical fertilizers are not necessary unless deficiencies are confirmed.
- Decomposing mulch and organic matter typically provide sufficient nutrients.
- If needed, apply slow-release fertilizers only after the tree is established.
- Avoid fertilizer burn by ensuring adequate watering.

5. Monitoring and Adjusting Supports:

- Regularly inspect guys and ties.
- Adjust or remove them to prevent girdling or abrasion.