Technical Bulletin No. 75

Production of Quality Seed and Planting Materials

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Contents

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FOREWORD

Inadequate availability of quality seed and planting materials are the important deterring factors in development of sound horticulture industry. During the past decade, significant achievements have been made for fruit and vegetable development and an area of 15.97 million hectare has been brought under both the crops that covers about 67.15 and 90 % of total horticulture area and production, respectively. The impact of investments in horticultural research can be realized only if farmers have better access to high quality seed and planting materials of the improved varieties at reasonable costs and at their production sites. Use of quality seeds and planting material of horticultural commodities of the recommended zones can ensure higher productivity and easy availability of the produce. In recent past a good number of crop genotype suited to hot arid agro-climate has been developed. However, the availability of their seed and planting materials are still in short supply. ICAR through its network on planting material production has intensified the work on production of quality seed and planting material of different plants. Although, the existing infrastructure facilities fulfill about 30-40 % supply of quality seed and genuine planting material, therefore need to strengthen it, so that the developed technologies can be commercialized for enhancing arid and semi arid fruits and vegetables production level.

This technical bulletin on "Production of Quality Seed and Planting Materials (Arid & Semi arid: Fruits & Vegetables)" covers all the important components for quality seed and saplings production through their proper selection of crop genotypes, sowing / propagation and multiplication techniques, intercultural operations, field management and resource utilization techniques. This bulletin would be beneficial to farmers, vegetable growers, students, technical officer's extension personals and persons engage in seed and plant multiplication.

I compliment ICAR-CIAH, Bikaner and the authors for this informative work.

Place: New Delhi
Date: 19 September 2018

(W. S. Dhillon)

PRODUCTION OF QUALITY SEED (Arid and Semi-arid: Vegetables)

1.1 Introduction:

Systematic vegetable crop production is limited in the hot arid region of north-western part of India and this is mainly due to unavailability of desirable crop-genotypes, seed-planting material and technologies suited to the prevailing agro-climatic conditions. The Indian arid zone can grow a large number of vegetables compared to any hot desert of the world (Samadia *et al.,* 2004), and some of well recognized and potential crop-plants having vegetable significance have been identified for diversification of dry-land horticulture.

In hot arid region, existing low productivity in vegetables can be enhanced by improving the crop-genetic make-up, adopting production technology and innovative approaches under integrated concept as crop-genotype-environment accepting. Here, special attention is needed to exploit native crop-plant genetic resources of horticultural significance species for developing systematic and viable vegetable culture. For this, systematic breeding approaches for the targeted crops should be taken-up for developing better genotypes with multiple-use attributes including processing quality and wider adaptability under abiotic stresses.

There is highest num*ber* (>50) of regional (kachri, snapmelon, mateera (watermelon), tinda, bottle gourd), traditional (tomato, chilli, brinjal, okra, early cauliflower, pea, cluster bean, cowpea, Indian bean, sword bean, velvet bean, palak, methi, coriander, cumin) and un-exploited (phog, khimp) vegetables in India and are cultivated under limited acreage and resource poor environment and for which appropriate genotypes and seed-chain is required. The indigenous and unique products from khejri, ker, kumat, lasora, sehjan, phog, khimp, ivy gourd, spiny gourd and aloe (guarpatha) can be exploited for fresh / value added vegetable products and for that quality seed-planting material is needed on top priority (Samadia, 2004 and Samadia and More, 2008).

1.2 Site management:

The yield of recommended crop-genotypes and productivity levels can be further enhanced manifold when due consideration are given to *in situ* rain water harvesting, moisture



conservation and adoption of improved practices and techniques in a strategic manner under the innovative concept - Horticulture based crop production site management approaches (HBCPSMA, Samadia, 2004).

Adoption and development of khejri based crop production sites as innovative tool for vegetable cultivation and to minimize the ill-effects from abiotic factors in hot arid areas and inter-linking of crop-commodity production sites with seed/planting supply agencies and storage, processing and marketing chain is highly beneficial and economically viable.

1.3 Cultivation practices

Standard agronomic and horticultural crop cultivation techniques and practices such as selection of commodity, varieties and their combinations at unit production site of defined location, selection and preparation of unit plot at identified production site, sowing time and techniques, plant spacing and population and other good management practices should be followed.

Table–1: Agro-techniques for vegetable seed production adopting channel or drip technology of crop cultivation under dry-land conditions of Rajasthan state.

Crop	Seed rate /ha	Plant-plant x row-row spacing	Time of sowing or transplanting	Remarks
Brinjal	200–250 g	50–60 cm x 75–100 cm	Nursery raising in January or June, and transplanting in February or July	
Tomato	200–250 g	50–60 cm x 75–100 cm		
Chilli	200–250 g	50–60 cm x 75–100 cm	Nursery in June and July transplanting	
Okra	10–15 kg	50–60 cm x 75–100 cm	February & July	1–2 seed / point, sowing manually
Pea	40–50 kg	50–60 cm x 75–100 cm	October	
Cluster bean	10–12 kg	15–20 cm x 25–30 cm	July	Line sowing
Cowpea	15–20 kg	50–60 cm x 75–100 cm	July	1–2 seed / point, sowing manually. Trellis system is developed for pole type beans Genotype
Indian bean (bush type)	15–20 kg	50–60 cm x 75–100 cm	July	
Indian bean (pole type)	12–15 kg	50–60 cm x 200–250 cm	July	
Sword bean	12–15 kg	50–60 cm x 200–250 cm	July	
Velvet bean	12–15 kg	50–60 cm x 200–250 cm	July	
Kachri	0.75–1.25 kg	50–60 cm x 200–250 cm	February & July	2–3 seeds at each sowing point, seedling thinning is done at 8–10 cm height or 18–21 days keeping one or two plants at each point. Hoeing and weeding, urea application and prophylactic spraying is done at 18-21, 30-35 and 45-55 days of crop growth.
Kakri	1.25–1.50 kg	50–60 cm x 200–250 cm	February	
Snap -melon	1.25–1.50 kg	50–60 cm x 200–250 cm	February & July	
Muskmelon	1.25–1.50 kg	50–60 cm x 200–250 cm	February	
Arya kakri & wanga	1.25–1.50 kg	50–60 cm x 200–250 cm	February	

Crop	Seed rate /ha	Plant-plant x row-row spacing	Time of sowing or transplanting	Remarks
Cucum*ber*	1.25–1.50 kg	50–60 cm x 200–250 cm	February & July	
Tinda	1.75–2.50 kg	50–60 cm x 200–250 cm	February &July	
Mateera / watermelon	1.75–2.50 kg	50–60 cm x 200–250 cm	February &July	
Tumba	2.25–2.50 kg	50–60 cm x 200–250 cm	July	
Bottle gourd	2.25–2.50 kg	50–60 cm x 200–250 cm	February &July	
Sponge gourd	2.25–2.50 kg	50–60 cm x 200–250 cm	February &July	
Ridge gourd	2.25–2.50 kg	50–60 cm x 200–250 cm	February &July	
Bitter gourd	2.25–2.50 kg	50–60 cm x 200–250 cm	July	
Pumpkin	2.50–2.75 kg	50–60 cm x 200–250 cm	July	
Kasuri methi	8–10 kg	15–20 cm x 25–30 cm	Octo*ber*	Line sowing
Palak	12–15 kg	30–50 cm x 60–100 cm	Octo*ber*	Line sowing
Moringa	300–400 g	400 cm x 400 cm	July–August	Perennial plant

To ensure genetic purity, good quality and high seed yield, in-depth emphasis should be given on isolation distances, rouging, monitoring, water management and crop maturity / ripen fruit harvesting. Requisite plant protection measures should be followed to raise healthy crop and quality seed production and recommended field preparation practices and prophylactic measures should be taken as per schedule to minimize the attack of various vectors, insect-pests and diseases.

1.4 Steps for quality seed production

The quality seed production is pre-dominantly influenced not only by genetic factors but also environmental conditions in which its multiplication is undertaken. Hence, emphasis should be concentrated on priority factors affecting seed quality and yield component. Important ones are selection of crop, sub-species and genotype, certification of basic seed source, selection of crop-field at production site, cultivation method and field inspections for roughing / monitoring in and around seed crop-field, harvesting, processing, packaging and marketing.

For maintaining genetic purity of crop-genotype, its basic seed production cycle should be lesser and more emphasis should be given on storage facility of breeder / foundation seeds in vegetable crops. Based on storability there are two forms *i.e.* orthodox and recalcitrant seed and most of vegetable crops belonging to orthodox in nature (5-8 % moisture) and can tolerate desiccation and stored for longer period without deteriorating viability.

1.5 Maintain isolation distance

For vegetables, isolation distance refers to separation of one crop-field-plot from other crop-field-plot of the same species, sub-species or varieties at defined level of minimum distance which varies from one crop-variety to the other for seed production. For self pollinated crop-genotype, low level of isolation distance of about 50 to 100 metre should be practiced. The isolation distance for often-cross and cross pollinated crops is much variable and it is from 200 to 3000 metre and further depends on mode of pollination and type of seed production. In cucurbits, isolation distance of 500 to 1000 metre is practiced for TFL, certified to breeder seed production.

1.6 Crop monitoring and rouging

For quality vegetable seed production, roughing-out or removal of off-type, variable and different plants / individuals (phenotypic level) from field of variety under seed multiplication is known as rouging. This is very essential and unique work which requires technical competency and dedication in particular to native and highly cross pollinated vegetable crops such as kachri, kakri, snapmelon, muskmelon, tinda, mateera / watermelon, gourds and palak. Roughing is not only done in seed production plot but also required at field site area of defined isolation distance for crop.

In self and often cross pollinated crops (tomato, brinjal, chilli, okra, cluster bean and beans), three to four field monitoring for rouging is done and the stages are defined i. e. first at early plant growth and before flowering (21-35 days after sowing), second at flowering and fruit / pod setting, third at first harvesting of fresh produce and last at seed crop maturity.

For native and cross pollinated vegetables (kachri, snapmelon, arya, wanga, kakri, muskmelon, tinda, mateera / watermelon, cucum*ber*, gourds, palak, carrot, radish, early cauliflower), intensive and regular monitoring is needed to produce genetically pure seed and this is due to wild and weedy nature of *Cucumis* and *Citrullus* group crop-plants spreading in fields of arid and semi-arid area, high level of out-crossing and grown with traditional cropping system in Rajasthan. Therefore, three to four field monitoring is done for rouging and stages are defined *i.e.* first at early plant growth and before flowering (21-25 days after sowing), second at flowering and fruit setting, third at first harvesting of fresh produce and last at harvesting of ripen fruits for seed.

In general, field monitoring and inspection is done by the crop curator, breeder, technical officers and inspectors of registered institutions / agencies involved in seed production of specific vegetable crops to examine the suitability for certification or quality seed for marketing.

Table–2: Crop monitoring and rouging stages for quality vegetable seed production

Crop	Field and crop monitoring stages (3–4 inspections)
Tomato	First before flowering, second during fruit setting and un-ripe fruit stage and third at mature / ripen fruit stage
Brinjal	First before flowering, second during fruit setting and tender fruit harvest stage and third at mature / ripen fruit stage
Chilli	First before flowering, second at fruit setting and immature fruit harvest stage and third at ripen fruit stage
Okra	First before flowering, second at fruit setting and tender fruit harvest stage and third at mature / seed fruit stage
Pea, beans & cluster bean	First before flowering stage, second during pod setting and tender / edible pod harvest stage, and third at mature / seed pod stage
Cucurbits	First at 2-4 true leaf stage and start of flowering, second at fruit setting and tender / marketable fruit harvest stage, and third at fruit maturity / ripen seed fruit harvest stage

1.7 Hybrid seed production

With present know-how, the public sector hybrids are as good or even better than hybrids marketed by a range of private seed companies in India, and this understanding is because its wider adaptability and stability for their performance at the production sites. The main reasons for non-spreading of public sector hybrids in India are

(a) Lesser weightage of seed production agencies, institutes and agricultural universities to produce bulk quantity seeds of F_1 hybrids and maintenance of their parental lines as desired,

(b) Unavailability of low-cost skilled staff on permanent basis as trained / specialized manpower needed for varietal maintenance breeding and bulk quantity F_1 hybrid seed production at public sector system and also to produce various types of vegetable hybrid seeds commercially,

(c) Lack of concern between institute developing hybrids and public sector seed producing agencies for their large-scale and regular production,

(d) Poor publicity of public sector hybrids with growers, and

(e) Rooted interest of multi-national company seed-chain in the country.

For promoting commercially accepted hybrids, large-scale F_1 seed production can be done adopting manual emasculation and pollination techniques under Indian perspective, and it is economically feasible in vegetables such as tomato, brinjal, bottle gourd, bitter gourd, sponge gourd, ridge gourd, pumpkin, summer squash, watermelon, muskmelon and cucum*ber* where large num*ber*s of F_1 seeds are obtained from one manually pollinated crossed fruit. Nevertheless,

in these vegetables very low seed is needed for one hectare planting and innovative techniques can be promoted like plug-seedling raising in nursery or single seed sowing of cucurbits under drip can be minimized cost of F_1 seed.

1.8 Quality control

Quality of seed in India is legally controlled by the Seed Act, 1966 and according to that, seeds of notified / popularized varieties sold to the farmers must meet the minimum standards of germination and physical purity. It should be packed in suitable container and must have requisite label on container / packaging. Information on crop, variety, germination, physical purity, date of testing, packaging lot and date, unit weight and price, name of seed producing agency / institution, and other requisite points is to be given on the label and packaging. The germination given on label is valid for nine month from test date and after which it has to be revalidated at six month period.

Table-3: Seed yield production potential of open pollinated vegetable crops

Crop	Seed yield (kg/ha)	Seed cost (Rs/kg)	Income** (Rs/ha)
Tomato	125	1000	125000
Brinjal	200	500	100000
Chilli	200	500	100000
Okra	1000	100	100000
Pea	1500	70	105000
Cowpea, cluster bean, Indian bean, sword bean	1200	70	84000
Kachri, snapmelon, *kakri*, muskmelon	250	1000	250000
Tinda, ridge gourd, bitter gourd	200	500	100000
Mateera, bottle gourd, sponge gourd, pumpkin	350	400	140000
Palak	600	150	90000
Sehjan (Moringa)	600	500	300000

** In vegetables, one or two pickings of tender fruits / pods or fresh produce helps in maintaining plant vigour, and this practice enhancing 25–30 % higher returns and is beneficial in seed crop.

PRODUCTION OF PLANTING MATERIALS (Arid and Semi-arid: Fruits)

2.1 Introduction

Nursery is the managed site, designed to produce seedlings, cuttings, layers, composite plantlets etc. grown under favourable conditions until they are ready for final planting. Nursery is the necessity for every horticultural crop growers. The development of seedlings in nursery not only reduces the crop span but also increases the uniformity of the crop as compared to direct sown crops. There is effective utilization of unfavourable period by preparing nursery under protected conditions. Seed cost of some crops like hybrid vegetables, ornamental plants, spices and some fruits can be economized through nursery sowing. Nursery production helps in maintaining effective plant stand in shortest possible time through gap fillings.

2.2 Types of nursery

Nursery types vary with size (small, medium, large), facilities, types of seedlings produced (fruit, ornamental, vegetable, landscape, forest) and operation. Based on facilities classified in following ways

(i). Hi-tech Nursery - fully controlled environment - Hi-tech nursery where the entire devices, controlling the environment parameters, are supported to function automatically. To propagate plants round the year the hi-tech nursery is used. The use of hi-tech nursery is also essential to mass multiply the plants through tissue culture. The main cause of promoting optimum growth in hi-tech nursery is high relative humidity and temperature control, adequate day length and light intensity. Hi-tech nursery is well equipped with elaborate structures and has precise control on temperature, light intensity and humidity (Singh & Sirohi, 2002).The size and type of hi-tech nursery, primarily depends upon the need of the plant propagator. Glass covered nurseries are expensive but have long life. However, for short-term benefits plastic covered nursery can also be made. Several types of sheets are available for their construction like UV stabilized polyethylene, polycarbonate and fiberglass. Plastic covered nurseries are lighter than the glass covered ones but there is very high increase in humidity in such houses, especially in winters which results in undesirable water drops on the plants. Major components of hi-tech nursery are as follows:

Temperature control- The thermostat can be coupled to water circulating pumps or exhaust fan for controlling the temperature inside the nursery. However, the lowest achievable temperature in fan and pad greenhouse is not below the wet bulb temperature in any case.

Relative humidity control- The humidistat can be coupled to water circulating pump or exhaust fan to control the relative humidity inside the fan and pad greenhouse. The maximum achievable relative humidity is 90% only in fan regulated (FR) nursery. The RH in Non-Ventilated (NV) GH can be increased by providing foggers.

Light intensity control- In certain areas where natural illumination is absent or very low, illumination for plants may be provided by artificial sources. Incandescent bulbs generate excessive heat and are unsatisfactory in most instances. Fluorescent tubes are useful as the sole source of light for fruit plant and vegetable seedlings, which grow satisfactorily at low light intensities. Excessive light intensity destroys chlorophyll.

Quality of light- Quality of light refers to its wavelength composition. Light in the orange-red portion of the visible spectrum from either sunlight or artificial illumination is most effective in causing the long-day response in plants. Far-red radiation appears to have the opposite effect. It is probable that the wavelengths activate some hormonal mechanism within the plant, which brings about the specific effect of light on growth and development of seedlings.

View of Hi-tech Nursery facilities

(ii). Net House- partially controlled environment - Nursery users prefers to have manually or semiautomatic control arrangement owing to minimum investment. This type of nursery is constructed using galvanized iron (G.I) pipes. The canopy cover is attached with structure with the help of screws. Whole structure is firmly fixed with the ground to withstand the disturbance against wind. Exhaust fans with thermostat are provided to control the temperature. Evaporative cooling pads and misting arrangements are also made to maintain a favourable humidity inside the nursery. As these systems are semi-automatic, hence, require a lot of attention and care, and it is very difficult and cum*ber*some to maintain uniform environment throughout the cropping period. These nurseries are suitable for dry and composite climatic zones (Singh & Shabir, 2012).

View of Nursery complex

***(*iii). Open field – Nature controlled-** Low cost nursery is a simple structure constructed with locally available materials such as bamboo, tim*ber* etc. Unlike conventional or hi-tech

nursery, no specific control device for regulating environmental parameters inside the nursery is provided. Simple techniques are, however, adopted for increasing or decreasing the temperature and humidity. Incorporating shading materials like nets can reduce even light intensity. The temperature can be reduced during summer by opening the sidewalls and covering by green plant branches. Such structure is used as rain shelter for growing seedling. Otherwise, inside temperature is increased when all sidewalls are covered with plastic film. This type of nursery is mainly suitable for where climatic conditions are normally favourable for the crops grown (Singh, 2010).

2.3 Site selection and layout of nursery

After selection of the nursery it is essential to start the preliminary works required for land preparation. These operations will improve the physical, chemical and biological conditions of the soil. The operations that have to be followed on the land are mentioned here under:

Survey of the land- After proper selection of the site, the nurseryman should first thoroughly survey the plot of land where the desired nursery is to be raised. This will help to go for preparation of layout of the nursery.

Cleaning of the land- Nursery preparation work starts with the cleaning of the land. It includes the removal of undesirable materials like stone, brick pieces and plastic and uprooting of weeds and other unwanted bushes or trees.

Ploughing- It is highly advantageous to plough the land thoroughly to loosen the compactness of the hard soil surface and also to bury the leaves and other materials under the soil. Ploughing will improve the soil aeration and water holding capacity, which is favourable for the plant growth.

Leveling- Ploughed land should be leveled properly by maintaining a slope in one way. It involves the shifting of the soil and therefore it is an expensive process. The land is divided into different sections and the leveling is done section wise.

Layout of Beds -Rectangular beds are preferred at the size of 10m x 1 m. The width of the seed bed should be kept such that weeding and hoeing can be accomplished without entering in the seed bed. To avoid flow of water outside the beds in dry areas usually 15 cm deeper than the normal ground level (sunken beds) are made and in high rainfall area raised bed are prepared.

Fencing- The nursery should be protected properly from outside. Therefore growing hedges or erection of walls can be done to build up fencing.

Construction of building- Construction of building for office, showroom, sale counter, staff quarters, etc. should be done well in advance.

Water harvesting and storage structure- It is essential to construct rain water harvesting or water storage structure at convenient place and size for collecting or storing run off water from nursery buildings and open area.

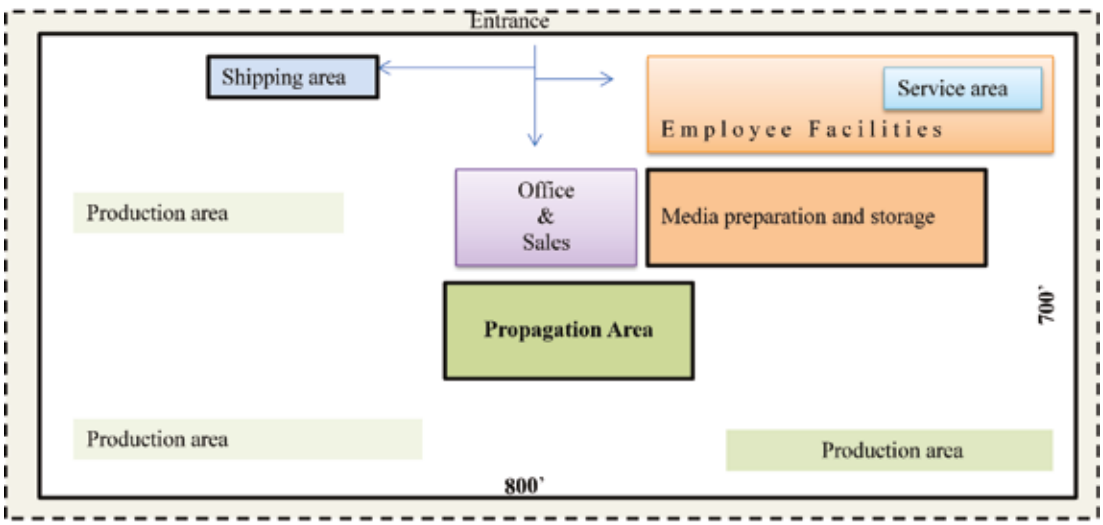
Planting of shady tree- To protect the nursery grown young and delicate plants from direct heat of sunlight and hot air, it is most urgent to plant shady trees well in advance.

Layout of model nursery- Many commercial nurseries begin as small backyard operations, with little thought given to initial or future layout design. Facilities or activity areas will vary with the types of nursery and specific production scheme employed. The area for model nursery production is prepared for effective utilization of inputs and to do things in proper manner. Nursery establishment as per their requirements design various location specific model, but there are some important components, which should be taken care during layout. The modern nurseries serve as an area where garden tools, fertilizers are also offered for sale along with planting material.

Propagation structures: Propagation structures useful for multiplication of grafts and seedlings. Generally 200 m^2 green house and poly house units with shade house of 400 m^2 and 15 m^2 mist cham*ber* are required for propagation of fifty thousand saplings annually.

Space for hardening of nursery plants: Small shade net houses are required for hardening of nursery plants. Open area under shade of khejri can also be used for the same. Hardening time depend on the type of plants grown and the temperature fluctuations

Store and office: An office-cum-stores is needed for effective management of the nursery. The buildings of suitable sizes are needed for keeping (all registers, notebooks and record etc.) and storing (garden tools, implements, raw materials, insecticides, fungicides, manures, media, fertilizers, boards, polythene bags etc.) materials use in plant raising and selling.



Layout of model nursery

2.4 Establishment of mother block and maintenance

Mother block of fruit plants is the most important components of plant nursery. Mother

plants provide bud sticks and scions for grafting and budding operations in nursery. Basic criteria require during the selection of mother plants *i.e.*,

1. Mother plants should be true to type, vigorous, healthy and high yielding.
2. It should be free from insect-pests, diseases and viruses.
3. They must be obtained from registered government nurseries.
4. Mother plants should be selected corresponding to the regional demand and mandate crops of the institute.
5. In nursery site maintain progeny plants of each fruit crop generally 50 plants of each commercial variety.

Progeny plants are planted according to the recommended planting distance. Progeny plant plantation must be well classified according to kind of crop and varieties.

Some Important Mother Plants and their cultivars for arid and semi arid region (Vision-2030, ICAR-CIAH, Bikaner)

1. Mango: Kesar, Mallika, Amrapali
2. Sapota: Kalipatti, Cricket Ball
3. Guava: Sardar (L-49), Allahabad Safeda
4. Pomegranate: Jalore Seedless, G-137, Bhagwa, Goma Khatta
5. Ber: Gola, Kaithli, Thar Sevika, Thar Bhubhraj, Umran, Goma Kirti, Banarsi Kadaka,
6. Khejri: Thar Shobha
7. Bael: Goma Yashi, NB-5, NB-9, Pant Sivani, Pant Sujata, Pant Aparna etc.
8. Sweet orange: Mosambi, Satgudi, Jaffa, Blood Red Malta
9. Mandarin: Kinnow
10. Lime/ lemon: Kagzi, Sai Sharbati, Pant Lemon
11. Jamun: Goma Priyanka, Thar Kranti
12. Mul*berry*: Thar Lohit, Thar Harit
13. Tamarind: Goma Prateek
14. Custard apple: Balanagar
15. Aonla: Goma Ashwarya, NA-7, Anand-2, Chakaiya, Banarsi
16. Lasoda: Thar Bold
17. Chironji: Thar Priya

18. Karonda: Thar Kamal
19. Khirni: Thar Rituraj
20. Mahua: Thar Madhu
21. Phalsa: Thar Pragti

Maintenance of Mother Plants

The success of any nursery depends on the health and vigor of its mother/ progeny plants. It is therefore necessary to obtain genuine mother plants to produce healthy and vigorous saplings. Not only selection of mother plants necessary, but also proper care and maintenance of these plants is essential to obtain healthy growth. Mother plants are irrigated regularly. Insect- pest and diseases are controlled by spraying fungicides (Carbendazim, Kerathan, Redomil, Copper oxy chloride) and insecticides (Monocrotophos, Imedacloprid, Thiomethaxam). After care and all operations are carried out so as to get healthy and vigorous bud sticks. Manures and fertilizers are given in July-August (as per package and practices). Only vegetative growth is permitted and maximum bud sticks are produced. Mother plants are kept healthy by regular testing of the plant material for viruses and other organisms. Register record about parents, pedigree and bearing habit is kept in office.



Mother plant blocks of sweet orange, pomegranate and bael

2.5 Plant propagation media and methods

(i) Media for propagation : Successful nursery production of container-grown plants is largely dependent on the chemical and physical properties of the rooting media. An ideal rooting medium should be free from weeds and disease inoculum, properly decomposed, light weight, porous, high cation exchange capacity. The media should also be well drained and yet retain sufficient water to reduce the frequency of watering. Other parameters to consider include cost, availability, consistency between batches and stability in the media over time. Selection of the proper media components is critical to the successful production of plants.

Table-4: General media for raising saplings

S.No.	Media	Use/Role	Comments
1	Sand	Improve drainage	Sand, a basic component of soil, ranges in particle size from 0.05 to 2.0mm in diameter
2	Coco peat	Moisture retention (5 times of its volume) improve	Eco-friendly biodegradable soil less sterile growing media prepare from natural coconut coir fibre, coir portion also content potassium but poor in nitrogen.
3	Perlite	Aeration & cation exchange capacity improve	White aluminum silicate mineral, heat-expanded volcanic origin, very light weight media use in mixed form.
4	Vermiculite	Porosity and trace elements Mg (9-12 %), K (5-8%) and iron etc.	hydrated magnesium iron silicate, light in weight and able to absorb large quantities of water (80 % porosity)
5	Sphagnum moss	Better water holding	Dehydrate residue of *Sphagnum papillosum, S. capillaceum* and *S. palustre* having better water holding capacity with acidic pH, which are used as soil substitutes

Nursery media treatment: Nursery growing medium may contain harmful disease causing organisms, nematodes, insects and weed seeds, so it should be decontaminated by heat treatment or by treating formalin, formaldehyde and other agrochemicals (Bhardwaj and Sarolia, 2011).

Table-5 : Nursery growing media treatment.

Agent	Method	Recommendation	Reference
Soil solarization	Summer deep ploughing, moist and covering with 200 gauge white polythene	Kill all stage insect, soil born fungus due to expose in open sun light and heat	Agropedia.iitk.ac.in/ content/nursery-management-vegetable
Formalin	20 ml/l of water (37%)	Apply 2 l/cu.ft. cover for 14 to 36 hr and aerate for at least 14 days.	Landis *et al*., 1994
Captan, Thiram, Ridomil- 72 WP	5-6 g/ m^2	Kill *Pythium, Fusarium, Rhizoctonia and Phytophthora like soil born fungus*..	Central Insecticide Board and Registration Committee (http://cibrc.nic.in/)
Chloropyriphos	2ml/l at 15-20 cm depth of soil	Kill insect's egg, larvae, etc stages	http://npic@ace.orst.edu/factshees/chlorpgen.html
Glyphosate	90 ml/15 l	Systemic non selective herbicide	Rana & Rana, 2015
Quizalfop ethyl 5% EC	30 ml/15 l	Against all grassy weeds	
Trichoderma	5-8 g/m^2	Against various soil fungus	Riad *et al*., 2010
Neem cake	400g/m^2	Against nematodes as repellent	Mbora *et al*., 2008

(ii) Methods for plant multiplication

(a) Propagation through seed

Conventionally seedling of horticultural crops are produced in seed beds or in poly bags of 150-200 gauge and different sizes *i.e.*, 25 x10 cm (ber, khejri), 15 x10 cm (Phalsa and pomegranate, karonda) and 30 x17 cm (Kinnow, mosambi, aonla, sapota, mango).

Rootstocks raising

Good varieties of fruits frequently may not perform well on their own roots, so rootstocks with proven performance are used. Just as scion varieties are selected for quality, colour and size of fruit, tree vigour, resistance to diseases and other desirable budding and grafting. Normally, seed propagation is not recommended in fruit crops owing to variability in growth and fruiting because of the cross pollination, long juvenile phase, chances of transmission of seed born diseases etc. but, where vegetative propagation is unsuccessful, difficult, expensive; for raising rootstock as clonal rootstock are not standardized in most of the fruits and multiplication of clonal materials is also expensive and time consuming, for evolving new varieties etc. the seed propagation is the feasible alternative. Still, the seed propagation is commercially practiced in case of papaya, phalsa, karonda, lasoda, lime etc.

Phalsa and Lasoda seedlings

Ber and Khejri rootstocks

Saplings raising in pro and plug trays:

The modern system of seedling production in portrays or plug production has several advantages over the conventional system which are as following.

This method is very useful in extending the growing season by producing seedling under protection and subsequently transplanted in either field (vegetable) or in polybags (fruit crops) as soon as the danger of frost, hails or low temperature is over.

1. This method also avoid environmental hazards of germination of seeds by providing optimum germination conditions under low tunnel, poly trench, green or glass houses for good germination and uniformity of plants.
2. No transplant sock occurs during field or container transplanting of plug seedlings.
3. Faster growth of seedlings achieved for field production or budding onto rootstock.
4. Seedlings become rapidly ready for outdoor planting or transfer within four to six weeks.
5. Protection from insect pests and diseases.
6. Allow precision crop scheduling and easy in post nursery handling and transplanting.

Pro/plug tray technique: Under this technique large num*ber* of vegetable seedlings and rootstocks of fruit crops can be produced annually in low cost poly houses, environmentally controlled greenhouses and under poly trenches by controlling optimum environmental conditions for seed germination and growth of the seedlings. A plug is a sapling which is produced in a small volume of medium in small individual cell or group of cells of different sizes ranging from 50 cc to 250 cc. Plug flats can be filled either manually or mechanically with a growing media and seeds are sown in to each cell. These plug trays are placed on stands in greenhouses under mist or fog conditions at optimum temperature and humidity. Plug trays can be initially put for 7-10 days in seed germinator or germinated seeds can also be sown in the plug trays filled with growing media. For production of plug transplants the seed of desired crop should be taken of high quality and vigour.

Pro-tray for raising vegetable seedlings

Plug-tray for raising of mulberry and pomegranate

Table-6: Methods of propagation in arid and semi arid fruit crops

S.N.	Name of fruit	Methods of propagation	
		Standardized	**Commercial**
1	Acid lime	Seed, budding, air layering	Seed
2	Aonla	Budding	T-budding/ Patch budding
3	Bael	Root cutting, budding, layering	Patch budding
4	Ber	Budding (T, I, ring and patch)	*In-situ* budding (T-budding) / Polytube budding method
5	Custard apple	Seed, Soft wood grafting (SWG), budding	T-budding/ inarching
6	Date palm	Seed, offshoots, tissue culture	Off shoot, tissue culture
7	Fig	Cutting, budding and air layering	Hard wood cutting
8	Grape fruit	Seed and budding	T-budding
9	Guava	Air layering and budding	Stooling, inarching, Soft wood grafting
10	Jamun	Seed and budding	Soft wood grafting
11	Ker	Seed and suckers	Suckers/ seed
12	Khejri	Seed and patch budding	*In-situ* Patch budding
13	Karonda	Seed and cutting	Seeds/ hard wood cutting
14	Lemon	Seed, cutting and layering	Air layering
15	Mandarin	Seed and budding	T/shield budding
16	Mango	Inarching, side and veneer grafting, budding	Inarching, softwood grafting
17	Mulberry	Cutting and budding	Stem cutting/ shield budding and cutting
18	Olive	Budding, grafting	T-budding, tissue culture
19	Papaya	Seed	Seed
20	Phalsa	Seed and cutting	Seed
21	Pilu	Suckers	Root suckers/layers
22	Pomegranate	Budding (chip, patch and forkert), layering (air, ground and pot),	Hard wood cutting, air layering & tissue culture
23	Pummelo	Seed and budding	Seed, T-budding
24	Sapota	Air layering, inarching and soft wood grafting	Inarching
25	Sweet orange	Seed and budding	T- budding
26	Tamarind	Seed and soft wood grafting	*In-situ* soft wood grafting
27	Wood apple	Root cutting, budding and seed	Seed/*In-situ* budding

Source : Resource book on Horticulture Nursery Management, NAIP, ICAR, 2012

(b) Vegetative propagation

There are different methods, which can be used for commercial multiplication of various fruit plants (NAIP-e publication). These include cutting (leaf, root, stem), layering (ground, air), budding, grafting, tissue culture etc.

(1). Propagation by cutting

Cuttings are the vegetative parts (leaf, root and stem etc.) of the plant used for propagation. On the basis of maturity of shoot, hard wood, semi-hard wood, soft wood and herbaceous cutting are categorized. The most commonly used are hard and semi- hard wood cuttings however, in greenhouse conditions apical herbaceous and soft wood cuttings also give good results. The major steps in cutting propagation are given below:

- It is simple and cheap method of clonal scion/rootstock multiplication.
- Hard and semi hard wood cuttings are easily handled and transported to the distant locations.
- Time of cuttings generally January-February and July-September (Pomegranate, mulberry, lemon, fig, phalsa). Weak as well as the fast growing shoots with longer internodes should be avoided
- Length should be 5-10 cm for soft wood, 7.5-15 cm for semi-hard wood and 15-25 cm. for hard wood stem cuttings.
- It should contain at least 2 buds.
- Just at the base of shoot below the node straight cut is given, while on the top of cutting, 1-2 cm above the bud a slanting cut is given. This helps to maintain polarity of the shoot and drain water.
- Base of the cuttings can be treated with plant regulators (IBA in the concentration of 1000-20000 ppm) in case of difficult to root species.
- Fruit plants such as pomegranate (Saroj *et al*., 2008), karonda, fig, citrus, mulberry, phalsa (Singh *et al*., 2014) and moringa can be propagated through cuttings.
- After proper rooting these should be transferred from portrays/root trainers to poly bag for further growth and development. After attaining appropriate length, these can be utilized for orchard plantation or for rootstock as the case may be.

Hard Wood Semi-hard wood Soft wood Herbaceous

Pomegranate cuttings in IBA Solution, nursery bed planting and Polybags shifting

Accelerated growth techniques (AGT)

Perennial fruit crops undergo cyclic growth and many species experienced dormancy during winters in order to speed up the growth and development of saplings propagated through seed, cutting, budding or grafting, a concept of accelerated growth system has become important aspect of commercial plant propagation to make available optimum size of saplings for field plantation within few months rather than years. Components of accelerated growth technique used in faster growth and development of *citrus* saplings propagated through soft wood cuttings are given below-

AGT Protocol for *citrus*

Induction of rooting in cutting protrays(cutting size 10-15 cm) after one month

↓

Transfer in poly bags of 4x10" size contains Sand+clay+ vermicompost (2:1:1)

↓

Put into protected structures in a plastic trays filled with sand and FYM(3:1)

↓

Programmed growth control throughout the growth period controlling using

- Light : 50000 lux
- Temperature : 30± 2 °C
- Mineral nutrient : NA
- Water-humidity : 60 ± 5%
- Growth regulators : NA
- Interaction of PGPR : Application of PGPR two application at 15 days interval
- Growing media : Sand+clay+vermicompost(2:1:1)
- Competition : Regular weeding
- Pest : Regular spray of pesticides

↓

Production of large rooted cutting plants(50-60 cm height) in 06 months age rather than years

↓

Acclimatization to natural condition for field plantation

(2) Propagation by layering-

Layering is a method of vegetative propagation, in which roots are induced on the shoots while they are still attached to the mother plants. This is an alternate method of propagation in fruit plants which do not root easily when detached from the mother plants. Most commonly used methods of layering are air layering, ground and mound layering in arid and semi-arid fruit crops.

Air layering (goottee/ marcottage/ chinese layering) - young, vigorously growing healthy branches are selected for layering. The leaves on selected branches should be exposed to light since these produce more food and will root faster. Selected branch in diameter ¼ to ¾ inch of it 3-4 inches above and below the point where the cut is to be made. Removing a ½-l inch ring of bark from the branch by making two circular cuts. After removing the bark or making the cut, enclose the injured area in a ball of moist sphagnum moss as soon as possible, making sure to squeeze out excess moisture before applying it to the cut surface. The ball should be wrapped snugly around the twig to ensure good contact and tied securely at both ends with rubber bands. Air layering can be practiced during February–March and July-August in guava (Ganesh *et al*.,2018), sapota, pomegranate, lime etc.

Plant (lime) propagation by air layering

Mound (Stool) layering- This method is used to propagate many of the thick stemmed or closely-branched plants especially when it is desirable to root all the branches. In this method, plant is headed back during dormant season from ground level. A ring of bark is removed from these shoots (IBA @ 1000-5000ppm with lanolin can apply) and they are covered with moist soil. The rooted stools of April stooling are separated during rainy season and those of August are removed in the following spring. Plants commonly propagated by this method eg. Guava (Saroj & Pathak, 1998), custard apple *etc*. This method is easy and plot of 4-5 m square can produce about 300 rooted shoots each year.

Guava propagation by stooling

(3) Propagation by grafting

Grafting is an art of inserting a part of one plant into another plant by exposing the actively growing tissue, so that they will unite and continue their growth as one plant. Where use shoot or small branch as a bud source called grafting and single bud as a source of scion called budding. Grafted plant also called composite plants, where lower part called rootstock and upper part as a scion (desired improved variety) and some time in between them uses inter stock also. The common methods of grafting are attached (inarching) and detached methods (veneer, soft wood, stone grafting etc.).

1. Inarching or approach or attached grafting: In this method root stock are raised in pots or poly bags and brought near the scion. Here, scion remains on mother trees grafted there. After 6-8 weeks, removed root stock the above graft union and scion below the graft union. Inarching can be performed by simple, tongued and inlay methods. Example mango, guava, tamarind and sapota, etc.

Inarching method in guava

2. Soft wood grafting: The top of rootstock are beheaded where the wood is soft and green with the help of a sharp knife and a slit of 5cm deep is made to accommodate the procured scion. The lower portion of the scion is made to a wedge shape with equal faces on both sides to a length of 5cm. After inserting the scion into the root stock, the union is tied with polythene strip. The scions are covered with a polythene bag of 100 gauge thickness and tied with a thread to keep the scions fresh till the union is completed. When the scions are sprouting (20-30 days after grafting) the polythene cover is removed. When the leaves on the graft are fully matured, the bandage is removed to prevent girdling of the graft. Examples mango, sapota, jamun (Singh and Singh,2006), chironji, tamarind, mahua and khirni (Singh and Singh, 2015) etc.

Important steps of grafting:

1. The scions and rootstocks should be preferably of the same diameter.
2. Grafting should be taken up where there is high humidity.
3. Grafts should be labeled after grafting so that varieties are not mixed.
4. Rootstock portion should be cut off after the leaves of the scion turns green.
5. Rootstocks of 1 year old age (0.50-0.75 cm. diameter) are used.
6. Grafting performed on rootstock at a height of about 20 cm from bottom.
7. The scion of similar thickness is selected having 3-5 buds and below 6 month old.
8. Terminal non flowering shoot should be preferred for multiplication.
9. Selected scion shoots are defoliated on the mother plant and bud swell stage gave better success.
10. For distant transportation of defoliated scion shoots can be wrapped with moist sphagnum moss, use of ice box and covered with jute cloth or polythene.
11. A same length cut on root stock and scion (bud sticks) should be made.
12. The scion is inserted in to the cut portion and graft union is tied firmly with transparent polythene strip and kept in mist house, later on shifted to shade net and then ultimately to open field for nurturing and sale.

(4) Propagation by budding

Budding saves bud wood as compared to grafting. This has been achieved successfully in propagation of aonla, bael, ber, sweet orange, kinnow mandarin and khejri *etc*. Under these crops the time of the budding can be significantly prolonged and budded plants can be developed within a short time for field plantation. It can be performed *in situ* and *ex-situ* ways. The important steps in T/Shield and patch budding are as under-

Preparing the rootstock

Rootstock can be grown in the nursery or field where it will be budded can be transplanted into the field and then allowed to grow under moderate fertility until they reach the desired caliper. Size and thickness of rootstock is depends on kind of fruit plants to be grafted or budded (Saroj *et al*., 2000 in aonla) *eg.* Ber require pencil thick like most of the fruit plants and khejri can be budded on refill thick.

Preparing the bud wood

Collect scion or bud wood when the plants are still fully turgid. The best vegetative buds usually come from the inside canopy of the tree on the current season's growth. Mature buds are most desirable; discard terminal and younger buds. Bud sticks are usually prepared in a cool, shaded area. Remove the leaves but keep the petioles intact to serve as handles when inserting a bud into the rootstock. Then cut the sticks to a convenient length, leaving three to five-six buds per stick. Bud sticks that will not be used immediately should be bundled, label and stored in moisture-retaining containers such as jute cloth or waxed cardboard boxes etc.

Time of bud wood availability depends on kind of fruit crops eg. May-August (Lasoda, ber, aonla, bael, Khejri, mulberry, mango, sapota, chironji, mahua) and August-Octo*ber* (Kinnow, mosambi, lime, lemon *etc*.).

Patch /T budding

A rectangular or square patch or shield shape of bark about 1.0-1.5 cm broad and 2.5 cm long is removed from the rootstock at about 15 to 20 cm from ground level. A similar patch with a bud on it is removed from the bud stick taking care not to split the bark beneath the bud. This patch/ shield is then transferred to rootstock and fixed smoothly at its new position and tied immediately with polythene strip. This type of budding is successful in aonla, bael, ber (Nath *et al*., 1998) khejri *(*Purohit *et al*., 2003*)*, jamun, lasoda (Singh *et al*., 2003) tamarind (Awasthi *et al*., 2005) *etc*.

Important steps involved in budding is given below-

- Select upright growing rootstock in which side shoots have been frequently removed and have attained thickness of 0.4-0.6 cm.
- Remove all leaves and thorn in case of ber and khejri rootstocks.
- Select 3-4 month old vigorous growing shoot on the mother plant for obtaining vegetative bud.
- The scion sticks should be wrapped in moist sphagnum moss or jute cloth with the help of polythene sheet and stored in cool place.
- Select fully developed swollen but not sprouted buds for budding.
- Remove rectangular patch/ shield shape of bark keeping bud in centre carefully.
- Make similar patch on the smooth portion of rootstock.
- Replace the scion, keep in right orientation and wrap firmly with polythene strip.
- After budding the young plantlets need to be kept continue in nursery bed until scion sprouts attain a height of 15-20 cm.
- Shift budded plants for proper hardening and acclimatization
- Remove the side shoots regularly from the rootstock.
- Allow only sprouted bud to grow, remove all other shoots regularly.

In-situ patch budding in bael

Ex-situ patch budding in ber

(5) Natural vegetative propagation: Plant propagation through specialized organs eg. Bulb, rhizome, tuber, corm, runner, suckers, offshoot are used for propagation in arid and semi arid fruit crops. Commercially propagation in date palm through offshoot, its detail is as under -

Off-shoots: Offshoots are axillary buds developed between the leaf base and the trunk during the juvenile phase of the palm. It arises near the base of the stem very intact. Per palm produce average 10-20 offshoots in life of mother palm (10-15 years). Offshoots of 3-5 year age and 8-10 kg weight should be removed by help of chisel and hammer, cut the joint without damage mother palm and offshoot. These offshoots treated with IBA @1000 ppm have improved the field survival per cent.

(c) Micro propagation or tissue or *in vitro* culture -

Micropropagation is defined as the true-to-type propagation of selected genotypes using *in vitro* techniques. Four basic methods are used to propagate plants *in vitro* depending on the species and cultural condition namely, enhanced axillary shoot proliferation (shoot tip, meristem tip, nodal culture, Stool shoot, proliferation of pseudocorms, mini tubers), adventitious shoot formation (internodal section, leaf pieces, fragmented shoot apices, immature inflorescence, bulb scale), micro grafting (Shoot/meristem tip) and somatic embryogenesis (cell, nucellus tissue, callus , shoot tip) of suitable explant.

Stages in micropropagation

Based on the various research informations, it is now established that there are five major stages (0 to 4) are critical for execution of successful plant regeneration *viz*.

Stage 0: Donor plant selection and preparation

Stock plants are maintained in clean, controlled conditions that allow active growth but reduce the probability of diseases. Explant quality and subsequent responsiveness to *in vitro* are significantly influenced by the phyto-sanitary and physiological conditions of the donor plant. Numerous practices are employed to increase explant responsiveness by modifying the physiological status of the stock plant. These include: (1) trimming to stimulate lateral shoot growth, (2) pretreatment sprays containing cytokinins or gib*ber*ellic acid and (3) use of forcing solution containing 2% sucrose and 200 mg/l 8- hydroxyquinoline citrate for induction of bud break and delivery of growth regulators to target explant tissues (Read, 1988).

Stage 1: Establishment of aseptic cultures

Initiation and aseptic establishment of pathogen eradicated and responsive terminal or lateral shoot meristem explants are the major goals of this stage. The success of Stage I establishment of meristem explants depend upon explant time, position of the explant on the stem, explant size and polyphenol oxidation. Obviously there is no one universal culture medium for establishment of all species. However, modifications to the Murashige and Skoog (Murashige and Skoog, 1962) basal medium formulation are most frequently used. Cytokinins or auxins are most frequently added to Stage I media to enhance explant survival and shoot development. The types and levels of growth regulators used in Stage I media are dependent on the species, genotype, and explant size.

Stage II : Proliferation of axillary shoots

Stage II propagation is characterized by repeated enhanced formation of axillary shoots from shoot tips or lateral buds cultured on a medium supplemented with a relatively higher cytokinin level to disrupt apical dominance of the shoot tip. A subculture interval of 4 weeks with 3 – 8 fold increase in shoot num*ber* is common for many crops propagated by shoot culture. Given these multiplication rates, conservatively, more than 4.3×10^7 shoots could be produced yearly from a single starting explant. Stage II cultures are routinely subdivided into smaller cluster, individual

shoot tips, or nodal segments that serve as propagules for further proliferation. Addition of auxin in the medium often mitigates the inhibitory effect of cytokinin on shoot elongation, thus increasing the number of usable shoots of sufficient length for rooting. This benefit must be weighed against the increase chance of callus formation.

Stage III: Pre-transplant (rooting)

This step is characterized by preparation of Stage II shoots or shoots clusters for successful transfer to soil. The process involves:

(1) Elongation of shoots prior to rooting

(2) Rooting of individual shoots or shoot clumps

(3) Fulfilling dormancy requirements of storage organs by cold treatment

(4) Prehardening cultures to increase survival.

Estimated costs for Stage III range from 35 to 75 per cent of the total production cost. This reflects the significant input of labour and supplies required to complete Stage III rooting considerable cost saving can be realized if Stage III is eliminated. Furthermore, it is often observed that *in vitro* formed root systems are largely nonfunctional and die following transplanting. Elongated shoots may be further pretreated in an aqueous auxin solution prior to transplanting. Usually, Stage III rooting of herbaceous plants can be achieved on medium in the absence of auxins. However, with many woody species, the addition of an auxin (IBA or NAA) in Stage III medium is required to enhance the adventitious rooting. Optimum auxin concentration is determined based on percent rooting, root number and length. It is critical that the roots not be allowed to elongate to prevent root damage during transplanting.

Simple tissue culture protocol for fruit crop species

At CIAH, Bikaner simple tissue culture protocol for fruit crops like citrus, mulberry and lasora has been developed by eliminated sub-culturing requirements. Several problems of *in vitro* culture system such as hyperhydricity of cultures, frequent subculturing for shoot proliferation, poor morphogeneic responces of explant from mature tree, contamination in culture either systemic infection or infection during long term culturing process, problem of somaclonal variation due to repeated subculturing process, poor root formation and low rate of servival during acclimatization of the plantlets *ex-vitro* are associated with *Citrus* species. Keeping in view these inherent limitaions of micropropagation of citrus, a new concept of micropropagations of lemon variety Pant Lemon-1 has been developed using single or double node explants from the mature trees. Direct morphogenesis of shoot and root formation was achieved in *Citrus limon* using single or double node explant having physiologically active axillary buds. Under this *in vitro* system, two media were used- one for shoot induction in pre-existing axillary buds and another for formation roots at the basal of the original explant. Under this experiment, influence of BA (0, 3, 6, 9 mg /l) and NAA (0, 0.1, 1 mg /l) and their combinations were tried for shoot induction. For root formation several concentration of IBA (0, 0.5, 1, 2, 3 mg/l) were used

with MS medium fortified by 30 g/l sucrose 7.5 g/l agar and 3 g/l actvated charcoal. Maximum shoot length 9.5 cm was recorded with 6 mg/l BA without NAA, whereas minimum shoot length and leaf size was low with devoid of growth regulators. Various concentrations of IBA were found to influence rooting in cultures and 1 mg/l IBA was found superior as compared to other concentrations for induction rooting.

In another important study with this cultivar of *Citrus limon*, direct shoot and root formation was achieved in double node explant within 35 days of culture period. These results conform the production of plantlets within a short period eliminating subculturing process completely. Thus, using this technique of micropropagation, the *Citrus limon,* mulberry, lasoda (Krishna and Singh, 2013) *and Aloe vera* have been multiplied *in vitro* with minimizing inherent problems of tissue culture in greater way to obtain a large num*ber* of genetically identical from a mother plant, physiologically uniform and normal plantlets preferably with high photosynthetic or phototrophic potential to survive the harsh *ex-vitro* condition.

Micro propagated citrus plantlets

Micropropagated mulberry plantlets

Micropropagated *Aloe vera* micro sucker

Hardening of plants

The main climatic features of Indian hot arid agro-ecosystem is high wind speed, sand storm, high temperature during summer up to 48 ^{0}C and during winter season temperature sometimes goes up to 0 and even -2 ^{0}C, low atmospheric humidity *i.e.* 20-30 per cent during maximum period of the year. These climatic parameters create detrimental effect not only on micro-propagated plantlets, but also the vegetatively propagated plants are seriously damaged. Therefore, gradual hardening of plantlets is an important and this is challenging part of the micro-propagation of horticultural crops in arid ecosystem. Problems related to tissue culture plants are:

- Heterotrophic mode of nutrition
- Poor control of water loss.
- The *in-vitro* formed roots are often thick and lack of root hairs and good vascular connection.
- Poor formation epicuticular wax on the leaves *in vitro* condition leading to poor transplantation rate.
- Excessive diffusion of water from *in vitro* formed leaves.

- Poor anatomical differentiation of leaves, greater stomatal frequency and impaired stomatal structure and movement in micropropagated plants.
- Structural changes in guard cells as accompanied by lower level of cellulose, pectins and cutin.
- Leaves of micro-propagated plants show poor mesophyl differentiations and weak vascular system.
- The chloroplasts are poorly developed with low chlorophyll and protein contents and the enzymes responsible for photosynthesis are inactive or absent.
- The stem of *in-vitro* developed plant is hypo-lignified, cells are thin and there are large intercellular spaces with limited development of vascular tissues and considerably less collenchyma and sclerenchyma.

Hardening facilities

For hardening of tissue cultured plants, maintenance of mother stock plants and micro-propagation of plants and clonal propagation of root stocks of arid fruit crops and induction of multiple suckers in date palm and *Aloe vera*, a three steps cham*ber* facilities consisting of two cham*ber* of glasshouse and one shade house was established in nursery in lieu of enhancement of propagation efficiency under extreme climatic conditions of arid eco-system.

Hardening chamber: The plant hardening cham*ber* was developed for primary hardening of plantlets. This chamber was made of double brick wall filled with course sand and duly covered with polycarbonate sheet for receiving natural light in the cham*ber*. In order to maintain desired temperature and humidity regimes the cham*ber* was fitted with air conditioner and intermittent fogging device. Hardening chamber was found to maintain 25-30 ^{0}C temperature and relative humidity up to 99%.

Glass house cham*ber* I :Favourable environmental conditions such as 28-35^{0}C temperature and 70-80% relative humidity were observed during second step of hardening process under glasshouse cham*ber* shaded by agronet of 50% light intensity. The chamber was fitted with dessert coolers and fogging system. These devices of glasshouse cham*ber* was found to regulate temperature and humidity inside the chamber as per plants requirements.

Glass house cham*ber* II : This cham*ber* was developed with the objective of gradual hardening of plantlets under increased temperature and decreased humidity level. This glasshouse cham*ber* shaded by agronet of 50% light intensity. The chamber was fitted with dessert coolers and fogging system. These devices of glasshouse chamber was found to regulate temperature, light intensity and humidity inside the chamber as per plants requirements.

Shade house : This facility was developed for growth and development of plants under extreme summer season and favourable environment conditions for plants are maintained by operating cooling pad and misting system.

Mist chamber: The mist propagation involves spraying of water in the form of mist, which is either done continuously or intermittently to maintain high humidity. The excessive loss of water from leaves of cuttings and from the tender tissue culture plants can be prevented by use of misting.

Inside view of hardening chamber

Low cost energy efficient hardening technology

This technique include, covering of pots by perforated poly ethylene bags, use of polyhouse or glasshouse equipped with fan/pad and fogging/misting devices, application growth retardant such as paclobutrazole or ancymidol have been reported to improve acclimatization of plantlets. However, these techniques are either inefficient or capital and energy intensive and not applicable to all agroecological conditions.

Looking in to the inherent hardening problem of tissue culture plants, a three step low cost energy efficient hardening facility for tissue culture plants for arid agro ecosystem was developed at Central Institute for Arid Horticulture, Bikaner. In the present study, a three step plant hardening facility involving primary hardening in acclimatization hood made of plastic tray covered with polycarbonate sheet with ventilation device inside culture room for 7-10 days and subsequent transfer to evaporative cool cham*ber* for 7-10 days thereafter acclimatization of plantlets either in shade house or low cost polyhouse (depending on ambient environment) equipped with intermittent fogging device. The first step of plant hardening achieved under acclimatization hood utilizing existing environmental controlled facilities of culture room of the laboratory without use of extra energy for creating favourable environmental conditions. In culture room, acclimatization hood found suitable to maintain 25-27^{0}C temperature and relative humidity up to 90 per cent. Favourable environmental conditions such as 25-30^{0}C temperature and 70-80 per cent relative humidity were achieved during second step of hardening process under zero energy evaporative cool chamber by covering insect proof plastic net, thatches of local grass and shaded by agronet of 50 per cent light intensity. These three covers of cool cham*ber* was found to regulate temperature and humidity inside the cham*ber* significantly. Under third step of plant hardening, low cost polyhouse/shade house with energy efficient intermittent fogging device (250 watts capacity) was used for further growth and development of plantlets in pots. Under this low cost three step hardening facility, acclimatization of tissue cultured plants of *Cordya myxa, Capparis decidua* and cactus pear (*Opuntia ficus-indica*) have been successfully achieved.

Table-7: Major environmental regime under three step hardening system

S.No.	Steps of hardening	Temperature range (°C)	Relative Humidity (%)	Light intensity range (lux)
1	Acclimatization hood made of polycarbonate sheet with ventilation device kept inside culture room	25±2	75-95	3000-5000
2	Evaporative cool chamber covered by insect proof net, thatches of local grass and shaded by agronet of 50 per cent light intensity.	25-30	70-80	5000-10000
3	Low cost polyhouse /shade house equipped with intermittent fogging device (250 watts capacity).	25-35	60-80	10000-20000

Table-8: Potting substrate and their combination under different hardening steps

S.No.	Steps of hardening	Vermiculite (%)	Coco peat (%)	Perlite (%)	Vermicompost (%)	Soil (sandy) (%)
1	Acclimatization hood	60	30	10	-----	-----
2	Evaporative cool chamber	60	-----	-----	40	
3	Low cost polyhouse /shade house	-----	-----	-----	30	70

2.6 Quality Standards of Nursery Plants

Grafted plants should be healthy, vigorous and equal in size of scion – rootstock, proper in shoot: root ratio, free from disease, weed, insect-pests and proper in morphological standard of scion according to varieties and species.

Table-9: Specific quality standards of fruit plant in nursery

S.No.	Crop	Propagation method	Quality standard
1	Aonla, ber	Patch /I budding	6-12 month old saplings
2	Custard apple	Soft wood grafting	1 year old graft
3	Kinnow, sweet orange, bael	Patch/I budding	1-1 ½ year old sapling at 75-90 cm height
4	Pomegranate	Cutting	20-25 cm height of sprouts
5	Guava	Layering	6-9 month old layers
6	Mango	Grafting (Veneer, soft wood)	1 year old grafts
7	Jamun	Soft wood grafting	1-1 ½ year old graft
8	Lime	Seedling	1 year old seedlings
9	Lasoda	Seed, budding	4-6 month old sapling
10	Mulberry	Cutting, budding	20-25 cm long height sprout and bud 10-15 cm height 4-6 month old sapling

S.No.	Crop	Propagation method	Quality standard
11	Sapota, Tamarind	Grafting (Inarching, soft wood)	60-70 days after removal from mother plants & 1-1 ½ year old graft
12	Chironji	Soft wood grafting	1 year old grafts





Fruit crops	Ber	Khejri	Sweet orange	Date Palm	Lasoda/ mulberry
Standard height of scion	30-35 cm	20-30 cm	30-50 cm	60-100 cm	30-35 cm

2.7 Management of diseases, insect-pest & weed

The integrated concept in diseases and insects in nursery involves integration of cultural methods, mechanical methods, use of natural products and application of need based chemicals. The cultural methods include raising of resistant and tolerant cultivars; summer deep ploughing of mother plant block, soil solarization of nursery media, clean cultivation and removal of crop residues and appropriate sowing time; nursery seed bed's media change after every production cycle and sequence of cropping; optimum plant spacing; use of trap crops & barrier crops and avoiding excessive irrigation and nitrogenous fertilization. Management of diseases and insect-pest effectively by following approaches:

Integrated Disease Management

- Integrated diseases management (IDM) combines chemical, cultural and biological control techniques to address disease problems by:
- Selection of apparently healthy seeds/propagules for seedling production
- Seed dressing with 0.2% Carbendazim/Methyl thiophanate/Benomyl/Thiram
- Sowing in sterilized/fumigated, clean beds and adequate watering
- Using sterilized budding knife, secateurs, and scissors during budding and grafting
- Transplanting seedling after root dip for 3-5 min. in 0.02% Carbendazim solution
- Healthy planting material maintenance by keeping them under proper sunlight,
- Watering and clean environment

- Frequent examination of seedling health and removal of diseased stocks
- Foliar spray of 0.2% Carbendazim/Dithane M-45 at regular interval

Integrated Insect-Pest Management

Integrated pest management (IPM) combines chemical, cultural and biological control techniques to address pest problems. Good sanitation and plant health reduce insect-pest problems. The following procedures make up an effective IPM programme:

- Mapping the nursery by identifying plants which are most susceptible to insects and disease problems. Note which species and cultivars are affected first.
- Monitoring nursery at least once a week. Pay particular attention to sensitive species.
- Identifying pests and beneficial insects, noting life cycle stages and population levels.
- Making a decision on appropriate control from collected information.

Table-10: Management of insect, pest and diseases in nursery

S.No.	Particulars	Management
Insects & Pests		
1	White grub, caterpillars, worms	Methyl Parathion -50EC, Phosalone35EC, Quinolphos-25EC -1.5% powder @ 25 kg ha^{-1} & Phorate 10G 10kg ha^{-1}
2	Aphid, Jassid, White fly, Thrips & other sucking insects	Systemic insecticides Dimethoate, Metasystox, Rogar , Acephate, Profenofos50EC @ 1-1.5ml $litre^{-1}$ or Imidacloprid 17.8SL @ 1 ml per 3 litre water
3	Leaf minor, leaf roller	Sanitation , neem cake or NSKE @ 5% and insecticide Imidacloprid 17.8SL @ 1 ml per 3 litre water
4	Butter fly (lemon, pomegranate)	Nuvacron or Rogar @ 1-1.5ml $litre^{-1}$
5	Inderbela or bark eating caterpillar	Clean the site and apply Dichlorvos100EC in kerosene and pour in hole then cover it
6	Termite	Regular irrigate & apply Chloropyriphos -25 EC, Fipronil 5%SC @1-1.5ml $litre^{-1}$
7	Nematode	Soil treatment prior to seedling raising with Carbofuran @ 5-7 g/sqm or DD mixture @ 200 ml/ sqm or neem cake 400g/sqm and grow trap cropping eg marigold
8	Mite	Propargite 75% EC, Ethione, Abamectin @1 ml $litre^{-1}$
Diseases		
1	Damping off (Fungus *Pithium* sp & *Phytopthora* sp.)	Soil treatment with Formaline 2 ml l^{-1} and seed treatment with Captan-50WP or Thiram @ 2-3 g kg^{-1} seed
2	Wither tip/dieback (Fungus *Colletotricum* sp.)	Cut portion apply bordeaux paste (1.0%) or blitox @ 0.3-0.4% with proper drainage
3	Malformation(Complex)	Use healthy scion and apply NAA @ 200 ppm
4	Wilt (Fungus *Fusarium* or *Rhizoctonia* sp.)	Proper drainage, crop rotation and improve soil condition through amendments (lime) and Carbandazim-50WP apply as foliar (0.1%) and drenching (0.2%) method

S.No.	Particulars	Management
5	Powdery mildew (Fungus -*Oidium* or *Uncinula* or *Erysiphe* sp.)	Sulfex or Dinocap 80%EC (Kerathane) spray @ 0.1 %
6	Downey mildew (*Peronospora* sp)	Bordeaux mixture (0.8%) & Dithane Z-78 @ 0.1%
7	Die-back, blight	Dithan M-45, Copper oxy chloride @2g/l
8	Anthracnose, fruit rot	Tebucanazole 26% (0.05%)
9	Blight Fungus *Alternaria* sp.	Difolatan & Mencozeb @ 0.2%
10	Virus	Control vector and use disease free scion

Weed management:

Unwanted plants self grow in seed beds, nursery beds, mother orchards and other open space of nursery. Especially during initial growth stage give tough competition to the nursery plants due to their faster growth. Follow prevention measures that included cleaning of seed properly, use well rotted manure, control weeds on field bunds and irrigation channels, screening irrigation water etc. New hand-tools (chisel (khurpi), hand hoe, spades, weeding sword, brush cutter, weeder) and implements (rotovator, harrow) have also been designed to assist in weed management in nursery.

2.8 Marketing and record management

Marketing of nursery plants is a problem in India as there is no proper marketing system in our country. Nurserymen do not get good price from their products because the price in the market depends on demand and supply of the products. Nurserymen should give emphasis on the following points to get higher price from his products.

- Nurserymen should give emphasis on production and quality of the planting materials.
- Plants to be sold should be uniform in size and high in vigour.
- Graded saplings require proper packing and it should be looked appealing.
- Plants that are to be sold should be healthy and free from pests and diseases.
- Nursery grown plants should be nicely labelled and displayed attractively at the sale counter.
- Plants should be handled carefully during transport to avoid damage to the planting materials. It will also help plants to reach in the hands of the customers in a better condition. This will help to fetch better price in the market.
- The nursery should supply the catalogue or pamphlets containing the detailed information related to planting, handling and management of the plants offered for sale.

Disposal of nursery plants and planting materials

Disposal of propagated plants and planting material also requires skillful management, otherwise whole efforts are futile. It requires timely action so that users may get quality planting materials at proper time and at the same time, producer may gain the desired returns. Sometimes, planting materials remain unsold if they are produced delayed in the season. Further, keeping them for longer period in the nursery may not only involve additional expenditure but the quality of planting materials reduced due to coiling of the roots and over growth of plants. The nursery

manager must contact the users and even he should also do advance booking. The planting materials raised either in beds or in polybags should be lifted properly. Unwanted foliage should be removed to minimize transpiration losses. Plants should be graded based on size, age, vigour etc. and packed in such a way that roots remain moist. For wrapping of the planting stocks, grasses, straw, perforated polythene, gunny bags, moss grass etc. are generally used as packing materials. Now a day's wooden or perforated paper boxes and plastic tray are used for long distance transit. There should be minimum time gap between lifting of the stock from the nursery and planting at desired site (Sarolia *et al*., 2017).

Record management

Records of all purchases (seed, agro-chemicals, media, *etc*.), observation of data (sowing, germination dates and germination per cent, growth, *etc*.), labor engagement and attendance, sales, pest and disease outbreaks, permanent and temporary stocks (including species wise seedling stocks) and movement register are required to be maintained up to date (Singh *et al*., 2017). Various records of expenditure and income are recorded in different book *viz*., purchase book, sales book, ledger, cash book, dispatch register, nursery calendar, seed & plant identification etc. It is advisable to maintain books of accounts for the following reasons:

1. They provide up-to-date nursery business information and guideline for planning
2. They help to analyze the performance of the nursery activity.
3. Ensure the efficient management of a nursery.

2.9 Nursery accreditation

Online Application Form and attach the required documents (Refer Checklist down load www.nhb.gov.in) required as part of the application and submit the application to National Horticulture Board for accreditation (Recognition and Renewal) detail procedure as under:

- Lay out of Nursery showing location of infrastructure component
- land utilization plan
- details of technical qualified staff
- major farm machineries
- operational manual prepared
- process followed for production of planting material
- management of inventory of planting material
- details regarding source of Mother Plants used for propagation
- register for sale of horticulture plants

Assessment criteria: system of graded certification

- Different from licensing of Horticulture Nurseries under provision of some Act or administrative orders.
- It is based on
  - continuous evaluation of source of parent material,
  - propagation in disease free condition
  - adoption of Good Nursery Management Practices
  - reliable record keeping
  - training of staff.
- Each parameter will be critically examined by assessment team as per laid down criteria

Grading systems

- Following grading shall be provided
  - Outstanding * * * * *
  - Excellent * * * *
  - Very Good * * *
  - Good * *
  - Satisfactory *

Other:

1. Procedure for application to higher grade
   - Nursery can apply for a higher grade from existing lower grade
   - Shall be considered for fresh assessment.
2. Renewal of recognition
   - Application should be made on prescribed format
   - Based on the satisfactory performance reported by inspection teams
   - If required nursery may have to go in for fresh assessment
3. Assessment and assessment committee

Assessment Committee may have representatives from:

- State Agriculture University in the State concerned
- Apex Horticulture Institute. NRC or Regional Station of ICAR
- Nursery men Association
- National Horticulture Board
- State Directorate of Horticulture/Agriculture.
- Nominated by NHB

Check list

List of the documents required to furnish along with physical application under the scheme "Nursery Rating System".

1. Application Form in prescribed format.
2. Application Fee of Rs. 5000/-.
3. Layout of Nursery showing Location of infrastructure components and land utilization plan.
4. Details of Technically Qualified staff in the nursery.
5. Major Farm machineries & Operational manual prepared by nursery for selection and maintenance of mother plants.
6. Process followed for production of planting material & management of inventory of planting material.
7. Details regarding source of mother plants used for propagation of Horticulture plants in prescribed Format.

ICAR-CIAH Nursery being accredited 3 star (***) by NHB team

ANNEXURE

Table-11: Dos and don'ts in nursery activities

S.No	Do's	Don't
1	Proper filling of polybags with media mixture in appropriate ratio and make holes for good drainage and saplings growth.	Use improper media mixture ratio and without holes and half filled polybags.
2	Place polybag in upright position for stopping stem curvature.	Place polybags in zigzag position.
3	Change the soil of seed beds after every production cycle.	Use the same germination media every year due to increase fungus inoculums.
4	Sowing of seed at proper depth for proper germination.	Sow seed too shallow and deep.
5	Handle transplant seedlings at root collar region.	Handle transplant seedlings by foliage as it may damage the saplings.
6	Remove air space around the root of young saplings during field planting.	Leave air space around the root of transplanted saplings.
7	Clean properly sprayer after applying weedicide/ fungicide.	Use same sprayer without proper clean to apply agrochemicals.
8	Budding/ grafting on physiological mature shoot.	Perform budding/ grafting on too young seedling, fail to survive.
9	Hardening off process at appropriate time for better field survivability of saplings.	Neglect or too late hardening off process.

S.No	Do's	Don't
10	Removal of side sprouts of rootstocks in grafted plants.	Leave sprouts of rootstocks in grafted plants for better development of scion part in it.
11	Plant wind breaks in nursery for providing protection to the young saplings from harsh environment.	Plant too many trees in nursery cause unnecessary shade.
12	Remove all cut parts of mother plants after pruning.	Keep diseased, dead, dried wood portion after pruning in field may cause inoculums for diseases, insects etc.
13	Sale saplings as per quality standard according to crop and its varieties with a bill for genuineness.	Sale too young, without hardening, diseased and none descript planting material without bill.
14	Give detailed protocol of planting and after care of grafted plants for better field survival (if needs).	Supply wrong planting material without guidance in case of new specific requirement.

Table-12: Economics of 50,000 (30,000 Khejri & 20,000 Ber) sapling production

Particulars	Ber	Khejri	*Total*
Material cost			
No. of polybags required	30 thousands	55 thousand	85,000
(i) Quantity of seed	8 kg=28000	15 kg=12000	40,000
(ii) Poly bags cost (Rs.) Approx. Rs.1/-	30 thousands	55 thousand	85,000
(iii) Mixture cost (FYM+ pond silt/clay) (Rs.0.25/-)	7.50 Thousands	13.75 thousands	21.25 thou
(iv) Insecticide- pesticide (Soil/ plants)	8,000	10,000	18,000
(v) Labour cost			
Labour cost (initial to final) up to successful plants	7.10/- plant	8.0/- plant	3,82,000
Rootstock preparation (@20%)	28400	48000	76,400
Successful budding (@30%)	42600	72000	1,14,600
Final submission (@50%)	71000	120000	1,91,000
(vi) Miscellaneous cost			
Shifting/ tagging/ spraying etc. (Rs.1/-)	20,000	30,000	50,000
Due stock maintenance (for next year)			
(vii) Plant protection (spray, frost, hot winds), shifting, hoeing etc. Rs.1/-			25,000
(viii) Sprout removal time to time Rs.1/-	15,000	10,000	25,000
(ix) Shifting and grading			25,000
(x) Labour engaged for watch & ward			50,000
Material procured from contractor	15,680	30,000	45,680
Out come	@30/-	@35/-	

Particulars	Ber	Khejri	*Total*
A. Same year sale out (8,000 each)	2.4 lakh	2.8 lakh	5.2 lakh
Mortality 15 % (during shifting twice & other natural cause)	4,544	16,000	
b. Next year sale out	1.96 lakh	6.55 lakh	8.51 lakh
x. Gross income (Rs. A+B)			13.71 lakh
y. Total cost (i to x)			7.22 lakh
Expected Net income (x-y)			6.49 lakh

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