# Training Manual
# on

# Dissemination of Climate Smart Horticultural Technologies for Socio-Economic Upliftment and Livelihood Security of Farmers in Arid and Semi- Arid Regions of India

**(11-13 December, 2024)**


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**ICAR- Central Institute for Arid Horticulture, Bikaner- Rajasthan**

in Collaboration with
National Institute of Agricultural Extension Management (MANAGE)
Hyderabad, Telangana

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# Contents

# PREFACE

The horticulture crops play an important role in economic and nutritional security of the inhabitants of the hot arid and semi-arid regions of the country. In India, 12% of the total geographical area, accounting to 31.71 Mha. is under hot arid ecosystem which are threatened by desertification and other climatic challenges such as extreme temperature in summer and extreme cold in winter, drought, dust storms, heat waves, water stress, erratic and low rainfall, etc. Even in such extreme climatic conditions, the hot arid regions have potential for cultivation of arid horticultural crops owing to its strength such as enormous land resources, low humidity, low incidence of pest and diseases, expansion of irrigation facility, easy availability of cost-effective labourers. The arid fruit crops such as *ber*, date palm, aonla, bael, pomegranate, kinnow, lasoda, and arid vegetables such as cucurbits, legumes and solanaceous crops; spices, medicinal and aromatic plants *etc*. are tolerant to biotic & abiotic stresses. Thus, they can be cultivated successfully by adopting good management practices for the same. Traditional crops have a limited scope for sustaining with high growth rate of agricultural production; while horticulture sector particularly, fruit and vegetable has potentiality for high production and productivity, if followed their improved production technologies and required inputs.

However, one of the major constraints in development of horticulture sector in India, is non-availability of quality seeds & planting materials. Therefore, production of quality seeds and planting material through hi-tech propagation techniques at reasonable price will improve the adoption and production of arid horticultural crops. Application of site specific agro techniques with improved genotypes may help in advancement of horticultural production in hot arid regions. Arid horticulture crops are found suitable for multi-cropping/multi-story cropping system for optimum utilization of available natural resources i.e. land, water, labour and farm resources. This training manual covers various aspects of hi-tech production of fruits and vegetables in arid and semi-arid agro ecosystems such as genetic diversity and improvement of fruit and vegetable crops, vegetative and hi-tech propagation, nursery management, production technology of arid fruits and vegetables including water, nutrient and integrated pest and disease management and post harvest management and value addition etc. The compiled information, guidelines and pictures in this manual will be useful not only for horticulture growers but also for nursery growers, researchers and students and will encourage a better horticultural production system, especially in hot arid and semi-arid regions of the country.

**Authors**

# Arid vegetable production technologies for climate resilient farming

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## Inroduction:

In-spite of environmental, bio-physical and resources constraints in the Rajasthan state, the geographical area can be defined into the three distinct climatic zones viz., hot arid, semi-arid and sub-humid for the horticultural perspective. These diverse zones have an excellent vegetable production potential with wide range of crop-plants and varied opportunities for resources utilization. However, extremes of high (March–October) and low (December–January) temperature situations in-together associated abiotic stresses in the arid region restricting the choice of crops and their genotypes, quality of produce and productivity level. Thus, the vegetable production with adaptive and native crop-plants, in general, found to be the most productive, cost-efficient and stable under the dry-land climate of the state which receives 150–650 mm of rains and having problems from abiotic factors owing to climatic variability, extremeness of temperature, drought, frost, hot and cold winds, soil and water quality (Samadia, 2016).

Vegetable production in the country is largely un-even and concentrated mostly into the limited states and areas where climate is much favourable and mild for their promotion. In addition, emphasis is given only to the few numbers of vegetables and that too grown with high inputs and irrigations. To meet-out the increasing vegetable demand and utilization of indigenous resources, now, there is utmost need for the massive and integrated efforts with native, un-conventional, under-scored and perennial vegetable crop-plants. The increased vegetable production can be achieved firstly by developing high yielding crop-genotypes suited to the prevailing conditions of the targeted zones and resource based production technologies under the climatic variability. The second approach is through exploitation of native resources i.e. varied and un-tapped land-area and under-scored horticultural species having vegetable potentialities. In this way, desert and tribal dry-land area of north-western India is a vast and un-tapped resource where a large numbers of common, well-adapted and native crop-plants having horticultural significance can be exploited for organized vegetable farming (Samadia, 2017).

### Strategies for arid vegetables

In the state of Rajasthan, systematic vegetable cultivation is very limited and productivity is also low, and this is primarily because of lack of requisite crop-plant genotypes suited to the

climatic variability zones and environmentally stressed production sites. Besides, non-availability of quality seed-planting materials of recommended crop-genotypes according to varying growing situations and lack of crop-genotype-climatic matching vegetable production technique are also chief limiting factors. Therefore, there are essentially two complementary requirements for obtaining higher vegetable production and productivity i.e. improvement in the genetic make-up of prioritized crops and development of favourable micro-climate at the production sites (Samadia, 2018). Since, the arid vegetable crop-plants provide an opportunity to produce quality harvest, rich in nutraceutical and medicinal values, and excellent for low-inputs and nature's resilient farming.

The Indian arid zone can grow a large number of vegetable crops compared to any hot desert of the world and some of well recognized and potential vegetable crop-plants have been identified for diversification of dry-land horticulture (Samadia *et al*., 2004). Based on region specific surveys in the hot arid, semi-arid and tribal areas of Rajasthan and Gujarat and field research work over 30 years, the extent of restrictions and opportunities have been assessed in respect to the horticulture perspective and recommendations are carved out for vegetable production. In addition, innovative and resource based conceptual approaches have been suggested for cultivation of vegetables under rainfed, limited or assured irrigated conditions with three distinct agro-climate in the state (Samadia and Haldhar, 2019).

The importance of eco-significance native trees and shrubs having the potentialities of regional, traditional and un-common vegetables both fresh and dehydrated or processed forms have also been highlighted for promoting the resource based native or intensive production models under the climatic adversity. By incorporating the un-exploited and indigenous perennial floras at the production sites as component of wind-break, boundary-side, bio-fence, hedge-row, field-divider, strip-block or planting model would not only helps in the creation of favourable micro-climate for cropping system but also ensure the regular income from the socio-welfare species as monsoon supported harvest (Samadia and Haldhar, 2017).

Owing to the variable and to some extent the manageable climatic conditions, availability of limited irrigation facilities and potentials for different types of production systems (rainfed, limited or assured irrigation) in vast spread arid farm-land, a careful selection of crops and their genotypes for a specific zone could be advantage for success in vegetable production. The peculiar arid agro-climatic conditions impart unique quality in kachri, kaakdia, mateera, bottle gourd, muskmelon, chilli and seed-spices. An enormous scope to promote large-scale seed production in cucurbits, tomato, chilli, brinjal, okra, early cauliflower, pea, cluster bean, cowpea, Indian bean, palak, methi, coriander, cumin, and truck gardening for distance market in particular to cole crops, onion, carrot, melons and chillies is do exists with irrigated farm-land.

The indigenous products from khejri, ker, kachri and kaakdia can be exploited for processing industry. Dry vegetable products have a lot of market potential as concentrated vegetables (dehydrated paan-methi, palak, sehjan, mint and curry-leaf). The conditions of high temperature and low humidity promoting solar-drying and this practice is already adopted for dehydration of pods of sangri and guar-phali and fruits of kachri, kaakdia, tinda, chillies, ker and lasora (Samadia, 2018).

**Technological intervention for arid vegetables**

It is, now, well recognized that the majority of adaptive vegetables can successfully grown under three distinct agro-climatic zones classified for horticulture development in Rajasthan state and improved production could be achieved through careful selection and slight modification in the crop-genotypes and adopting appropriate technique and site management practices. Hi–tech vegetable production does not means that the cultivation is only with the greenhouses or controlled conditions. In my opinion, definition of hi-tech crop production is very wide and still there is ample scope to recast it in relation to produce is to be desired, technology required to be modified for improving productivity of available resources and minimizing ill-effects of the environmental adversity at production sites. Thus, it is an integration of improved, modern and innovative techniques for enhancing the productivity of resources and obtaining better quality marketable yields.

Therefore, the prime aspect needs to be improved on priority for arid zone vegetable cultivation consisted are of better crop-genotypes for high quality marketable yield under the defined production system of sub-zone; modification in time and sowing / planting techniques and plant population/unit area; integration of crop management and protection practices and on-farm value addition and post-harvest criteria. The modern ways needs to be understand are on water utilization through drip / mini-sprinkler for vegetables; crop-plant architecture, use of bio-regulators, crop mechanization and trellis for vertical harvesting and protective techniques for nursery-raising; surface covering, zero-energy and low-cost structures for off-season raising and to escape from the ill-effects of winter temperature. The innovative concepts which need special attention are on development and management of khejri based production sites (HBCPSMA) to minimize the ill-effects from abiotic and biotic restrictions and inter-linking crop-commodity production sites together with reliable seed-planting material supply agencies and storage, processing and marketing chain for promotion of commercial vegetable farming and entrepreneurship.

**(A) Nature's resilient crop-genotypes**

In-spite of a large number of varietal wealth and progress in vegetable improvement in national net-work, very few crop-genotypes exhibiting their superiority with varying environmental situations across the region as targeted. Thus, specific breeding work for developing varieties, trait-specific lines and value-added genotypes is needed on under-utilized and native crop-plants of regional significance and also on under-scored, un-exploited and adaptive vegetables for cultivation with low-input, dry-land and abiotic stressed situations (More *et al*., 2018).

**(1) Conservation and maintenance of vegetable germplasm**

Land-races and local-cultivars are source of genes for stress tolerant, adaptability, quality and thus, their collection and evaluation is the pre-requisite for potentially utilization of genetic resources. At CIAH, systematic research on genetic resource management was taken under the mission mode programme from the year 1994 to 2005, and several crop-specific and multi-crop explorations were made for the surveys and collection of vegetable germplasm from arid, semi-arid and tribal areas of Rajasthan and Gujarat. As a result, 1725 accessions were collected and evaluated in the prioritized vegetables under dry-land conditions at Bikaner, and out of them 1060 germplasm were deposited at NBPGR for safe-conservation. For germplasm collection and characterization studies, major emphasis is given on kachri (591), kaakdia (120), kakri (32), muskmelon (74), mateera (217), tinda (26), gourds (156), chillies (217), brinjal (78), tomato (125), cluster bean, cowpea and beans (90) and native perennials.

On the basis of intensive field-crop evaluation studies over the seasons and years (1994–2023), the potential vegetable crop-plant germplasm were identified and developed genetic material from the basic genetic resources is being maintained as active breeding lines (>500) for use in the improvement programmes. The maintained material is consisted of kachri (68), kaakdia (65), kakri (18), muskmelon (60), mateera (65), tinda (10), bottle gourd (20), ridge gourd (20), sponge gourd (15), bitter gourd (04), chillies (45), brinjal (30), tomato (14), khejri (15), India bean (30), sword bean (01), cluster bean (02), cowpea (02) and others (15) including perennial vegetables.

**(2) Utilization of vegetable germplasm**

To promote profitable vegetable farming under arid environment, systematic crop improvement work-plan was formulated first-time by me as PI of programme and started during 1994 at NRCAH, Bikaner. During first five-years of project, the prime emphasis was on drought tolerating un-exploited crops viz., kachri, kaakdia, kakri, mateera, tinda and guar-phali. From 2000, the mission mode work on khejri, sehjan and beans, and heat tolerant breeding in melons,

gourds, chilli, tomato and brinjal was taken considering the requirement of the varieties for the dry-land areas of Rajasthan. This prioritized research work resulted to recommendations of high yielding and trait-specific genotypes and these are in mateera (AHW-19, AHW-65 and Thar Manak), kachri (AHK-119 and AHK-200), kaakdia (AHS-10 and AHS-82), arya-kakri (AHC-2), salad-kakri (AHC-13), bottle gourd (Thar Samridhi), sponge gourd (Thar Tapish), ivy gourd (Thar Sundari), palak (Thar Hariparna), brinjal (Thar Rachit), cluster bean (Thar Bhadavi), Indian bean (Thar Kartiki and Thar Maghi), sword bean (Thar Mahi) and khejri (Thar Shobha and Thar Amruta).

The promising lines of bottle gourd (AHLS-24), ridge gourd (AHRG-1 and AHRG-8), sponge gourd (AHSG-4, AHSG-5 and AHSG-16), round melon (AHRM-1 and AHRM-2), muskmelon (CIAH-1, AHMM-17, AHMM-26, AHMM-32 and AHMM-46), chilli (HRM-1), brinjal (CIAH-22, CIAH-12 and CIAH-16) and moringa (AHMO-1-4s) were used in breeding programme and developed material is under large scale trials. In addition, trait specific breeding and valuation of old-cultivar was done to develop desirable material in the targeted vegetable crop-plants and evaluated over the seasons and years (2005–2023) under high temperature and abiotic stressed conditions. The most promising consisted of kachri (AHK-411, AHK-564 and AHK-572), snap melon (DKS/AHS-2011/2), tar-kakri (AHC-1), mateera (AHW RSS-1 and AHW BSM-1), ridge gourd (AHRG-15-4-1), bottle gourd (AHLS Oblong-1, AHLS-Long/2015/F6/1 and AHLS-17), bitter gourd (AHBT-2), chilli (Mathania Selection-1), brinjal (AHB-1 and AHB-2), tomato (AHSL-1 and AHSL-2), cowpea (AHCP-1-4-1 and AHCP-2-3), Indian bean (KSB-66), cluster bean (AHG-23), velvet bean (AHVB-1), paan-methi (AHLM-1), bathua (AHLB-1), carrot (AHDC-1), guarpatha (AHAB-S-1 and AHAB-B-1), phog (CIAH-PHOG-1) and khejri (CIAH Selection-3).

**(B) Apposite production technology**

To standardize production techniques and good management practices for vegetable cultivation in the sandy soils of hot arid climate, a series of crop specific and combination experimental trials were conducted adopting check-bed, channel or drip and sprinkler method of cultivation either rainfed or minimal irrigations, &/or under khejri based production approaches at ICAR-CIAH, Bikaner during 1997 to 2023 period. The experimental results and recommendations are promoted as (SOP's) practical aspects of crop management and agro-techniques for nature's resilient farming. For agro-technique standardization and developing packages of practices, native and potential vegetables such as cucurbits, brinjal, tomato, pea, cowpea, cluster bean and beans, palak, cole crops, seed spices, sehjan and khejri were studied with HBCPSMA concept.

Most of vegetables are shallow roots and a short-spell of moisture deficit (3-7 days) affecting the plant growth, flowering, fruit-set, marketable quality and yield under high temperature and abiotic stressed conditions of dry-land climate. The common irrigation method is flow (check-bed) since it is low-cost but inefficient causing water conveyance and percolation losses. Among controlled method, bubbler or hose-pipe up to crop-field for channel or deep-furrow and pressurized (drip and sprinkler) is improved, and studied at CIAH. For irrigated crops, experiments were combined with the rain-water harvesting practices and water management through controlled pipe-line and pressurized method. This resulted to diggi-water based advancement is demonstrated at CIAH to promote farming adopting the channel and drip technology for water efficiency, and described as "No–pole electricity–water resource utilization concept" and here inclusion of solar-pumping is most beneficial (Samadia, 2016).

**1) Khejri based crop production site management approach**

Khejri is versatile tree of the *Thar* Desert and an important perennial component compatible to any companion crop-plants in the long-established farming systems of the north-western parts of India. Budded khejri plants grow luxuriously under extremes hot and dry conditions. This eco-restoring plant is not only helping in soil fertility build-up but also minimizing the ill-effects from high solar radiation, extremes of temperatures and hot winds at developed production site. Systematic plantations of khejri varieties in high-density or paired-rows at wider-space exhibited needful effects in creating favourable micro-climate at the production site. In addition, organized planting helped in promotion of pollinising agents (ants, bees, flies) in the farm-land.

Under changed scenario, now, the horticultural focus is shifted from sustenance to measurable economic farming but the mono-cropping is much risky for developing dry-land vegetable production systems. Therefore, the traditional systems pre-dominantly mixed cropping needs multi-dimensional interventions through prioritized vegetables, native crop-plants and newer technological advancements and now, it could be performed with HBCPSMA concept and khejri based crop production site management approach as innovative tool for doubling income (Samadia, 2016).

The region and crop specific long-term research findings under the HBCPSMA concept (1994 to 2020) enables me to conclude it with recommendations and based on that some principles have been suggested for development and management of khejri based crop production sites. The production sites should be developed in accordance to topography of sand-dune landscape and soil conditions of dry-lands. Fencing of production site and development of multi-tier rows of seedling plantation with desert tree species (khejri, lasora, rohida, kumat, bordi, ker, pilu) and shrubs (jharber, phog) all-around the field block is the prime consideration for creation of favourable micro-climate and it is must for protection of crop production sites

from the extremes of hot, cold and high wind conditions. The four-side field area of production site is developed as multi-tier rows of seedling plantation (single or paired, 4mx4m) with the directions for the khejri and lasora or rohida, kumat (south), khejri and lasora or ker, rohida (west), khejri and kumat or rohida, bordi (north) and khejri and ker or rohida (east) in the arid zone of Rajasthan.

The innovative practices / techniques under HBCPSMA includes selection and development of khejri planting model based on available resources at production site, preparation and maintenance of production site for *in–situ* rain-water harvesting and soil-moisture conservation, and crop cultivation. Adoption of pre–monsoon deep ploughing in June prior to crop sowing and post–monsoon ploughing after crop harvest in November month as techniques resulted into more *in–situ* rain-water harvesting, moisture conservation and weed free-fields. Keeping of crop field fallow for 1–2 months either April–June or October–November, and is an essential practice for soil health security and fertility build-up. Besides, seed / plant selection, sowing / planting time and techniques, maintenance of crop plant population and prophylactic protective measures are good management practices essentially required for improving yield and productivity of resources, and it is only worthy when the best suited genotype is selected for vegetable cultivation at the production site.

Based on crop potentialities and critical analysis over 15 year period, so far, three horticultural combinations are suggested for development of khejri based crop production sites. The first two are primarily with rainfed or limited irrigations, and namely are organic *Panchkuta* production technology (khejri, ker, lasora, kumat and kachri) and native crop production technology (khejri + native vegetables) where khejri planting model KM–1 (4mx4m) & KM–3 (8mx8m) is practiced, respectively with hectare block lay-out. For prioritized vegetable cropping sequence and irrigated cultivation, wide spacing planting model (KM–9 & KM–11) is most appropriate and here 4mx4m paired row khejri plantation is practiced at 24m or 44m distances, respectively with four hectare block layout and it is intensive crop production technology. For systematic block planting, single or paired rows of khejri var. Thar Shobha should be lay-out in the east-west direction and wider space is developed fields for vegetable crop cultivation.

For studding khejri planting and cropping models adopting HBCPSMA concept, five hectare virgin field area of sandy-sand-dune land-scape was developed through *in situ* orchard establishment technique under rainfed conditions at CIAH, Bikaner. From 2007 to 2016, annual growth and development observations were recorded periodically in response to the tree-plant establishment and training–pruning techniques. No much difference is observed in respect to the growth parameters under investigation in Thar Shobha plantations with varying planting models and it was up-to economic yield stage i.e. $6^{th}$ and $7^{th}$ year tree age-group during 2015-16 and 2016-17. It is also observed that close spacing and paired rows (4m x 4m) khejri planting

exhibited maximum canopy at about 6$^{th}$ years age and thus this age-group plant growth from which normal pruning is recommended for the economic and annual harvesting of pod, loong and fuel-wood as highest bio-mass/year.

The annual observation data were compiled on growth, yield and bio-mass production in khejri with varying planting models (12), and based on three years of mean of economic yield, variety Thar Shobha recorded tender pod (sangri) yield of 6.58 kg/plant under KM-1, KM-9 & KM-11. Similarly, marketable fruit yield of kachri var. AHK-119 (56.58 q/ha) and tender pod yield of cluster bean var. Thar Bhadavi (54.34 q/ha) was recorded as monsoon supported inter-crop with khejri, and this was by adopting recommended techniques of HBCPSMA concept from 2014-15 to 2016-17 period at Bikaner.

For developing desert horticulture, promotion of KM-1 and KM-9 planting model as khejri based crop production site is found to be most successful under resource constraints arid environment for vegetables and this should be with the highest remunerative crop-genotype such as kachri (AHK-119), cluster bean (Thar Bhadavi), snap melon (AHS-82), mateera (Thar Manak), bottle gourd (Thar Samridhi) and Indian bean (Thar Kartiki). The khejri based crop combinations resulted into higher family employment and regular income @ Rs 75,000–2,25,000 per ha/year in comparison to the conventional cropping (Rs. 23,000–42,000 ha/year), respectively under rainfed or limited irrigations. The crop yield, bio-mass and income stabilizes from 4–5 years and further in increasing order with time period and doubled at 8–10 years of establishment of HBCPSMA as integrated concept.

**2) Channel technology of vegetable cultivation**

Channel system of cultivation as standardized at CIAH, Bikaner under the sandy soils is found most practicable for arid vegetables viz., cucurbits, brinjal, tomato, chilli and beans. This technology save valuable inputs such as irrigation water (30–50%), manure and fertilizes (30–35%) and labour cost (25–30%). The channel technology helps in better care of young seedling, ease in inter-culture, irrigation, sprays and harvesting and permitting mechanization for weed management. This technology also reduces pre-harvest losses of fruits by restricting water-flow only in the channels. Under channel system, total irrigation water requirement and water losses are lesser than the check-bed method. The water distribution in root zone of crop is uniform. Labour and time requirement for irrigation is also lesser. This system of vegetable cultivation offers an additional opportunity to harvest maximum rain-water within the channels and it is even on scanty rainy-day (10–15 mm) and directly available nearby root-zone of crop-plants.

After selecting proper field at production site, marked area should be cross-ploughed followed by planking or use rotawator, and it should be started prior to 10–15 days of crop sowing. About 50–60 cm wide and 20–25 cm deep furrows (channels) are made at 1.5–2.5 m distances depending upon the crop, cultivar and season for cucurbitaceous vegetables. For

solanaceous crops, channels of about 50–60 cm wide are made in a continuous manner. With trellis system of beans and gourds, distance between the channels should be 2.0 meters. For uniform water distribution, maximum length of crop-sown channels should not be more then 25 m on-one side of supply-line. Field plot of 50x50m size should be developed keeping one meter wide water delivery channel in centre area. Application of basal doses of manures and fertilizers is done only in channels. The seeds are sown at 50 cm distances only on down-side of the northern slope of each channel for ground storey cucurbitaceous and also for trellis system of cucurbits and beans. At each sowing point, 1–3 seeds are dibbed. When the seedlings are 8–10 cm in height, thinning should be done keeping one or two plants at each point. In solanaceous crops, seedlings should be transplanted at 50 cm distances in the centre area of the channels.

**3) Drip technology of vegetables cultivation**

Irrigation water management is very essential to ensure that crop-plant needs can be meet-out without under or over watering. The increasing crop-yield level obtained with drip irrigation can be attributed to the several factors such as high water use efficiency because of the precise application directly to the root-zone of plant and less water losses due to the reduced evaporation, run-off and deep percolation, and less fluctuations in the soil-water content resulting into avoidance of water-stress. The principle of drip irrigation is to supply water at the very low-rate and in the region of maximum root activity and thus, there is considerable saving in the water consumption. Surface or sub-surface drip irrigations do not wet plant foliage and thereby reducing disease spread significantly. Drip irrigation maintains crop rhizosphere almost at field capacity so that the plants do not experience moisture stress conditions. Therefore, drip technology is the most efficient method of irrigation when it comes to the water saving and its productivity. For technological advancement adopting pressurized irrigation and crop cultivation, a series of experimental trials were conducted for water management studies under sandy soils of arid climate from 2002–2012 at CIAH, Bikaner and it was in particular to assess the feasibility of different combinations of drip and micro-sprinkler system and also find out practical recommendations for vegetable production with limited irrigation water.

The R&D studies with drip technology led to conclude that single lateral pipe lines (16 mm) at 2.0 m distances with in-line drippers (4 lph) at 50 cm distances is found to be the most appropriate for cucurbitaceous crops such as kachri, snap melon, round melon, kakri, mateera, muskmelon, bottle gourd, sponge gourd and ridge gourd under limited irrigation water in sandy soils of hot arid climate. Similarly, with trellis system of crop cultivation, the laterals at 2.0 m and drippers at 50 cm distances is also found to be the optimum in Indian bean, sword bean, ivy gourd and bitter gourd. Drip technology has also given excellent results in brinjal, tomato, cowpea and cabbage (laterals at 1.0 m apart and drippers at 50 cm) at CIAH, Bikaner. In conclusion, with limited water these crops should be irrigated for 1–2 hours at 2–3 days intervals

by assessing the age of crop-plants, growth phases and seasonal weather conditions. About 15–50 per cent higher yield with better marketable quality was obtained in the above said crops with limited water under drip technology in comparison to the channel system of production. For better water distribution and crop management, one side length of lateral lines should not exceeds 25 m and unit plot with control valves should be of 50x50 m size, and 4 ha block area can be controlled with a drip system as unit at diggi-site.

**4) Surface-channel, tent or arch-type covering technology of protected cultivation**

Based on environmental and vegetable production constraints analysis, two prime limiting factors were identified in particular to protected cultivation and these are strong wind velocity with sand-storms and continuous high temperature range for the prolonged period (March–October) in arid region of Rajasthan. Therefore, prior to recommendations on protected technology for production sites of dry-land areas, complete analysis is to be done on structures type (low-tunnels, poly-houses, shade-houses or controlled green-houses), crop-genotype and cultivation season (Samadia, 2004). Based on preliminary work, systematic studies on low-cost protected crop cultivation (tomato, chilli, capsicum, summer squash and bottle gourd) was done at CIAH, Bikaner from 2007–2010. The plant growth, fruit-set, quality and yield potential were much inferior in tomato, capsicum and chilli under green shade-net (50 and 75 %) and insect's proof shade-net covering structures as summer and rainy season crops. Similarly, extremes of high temperature and high wind conditions affecting poly-tunnel cultivation of cucurbits as complete crop from sowing to harvesting in the arid climate. Thus, above experimental results on protected vegetable cultivation here discouraged me over the open-field hi-tech crop production practices as standardized at Bikaner.

However, movable or folding structure (modification in low-tunnel to surface-channel or arch, coat & tent-type) and polythene as covering material is found to be the best for early cucurbits sowing under the protection and to save the crop from low temperature and frost conditions during the peak winters of December and January. Followed by removal of polythene covering is done in-between last week of January to first week of February and the crop is allowed to grow as early spring-summer season in open-field. Indigenous design arch, tent and channel covering protected cucurbits cultivation methodology as standardized at CIAH is a innovative technological advancements for early harvesting, and bottle gourd was test-crop and this practice is now commercially popularized in the arid region.

The adversity of extremes of low and high temperature conditions in the north–western parts of Rajasthan restricting the quality fruit yield, period of crop harvesting and productivity in cucurbits. In this part, winter is very severe and starts from November, and continuing to the end of January and some times it extends up to the second week of February, and therefore, sowing

of cucurbits under open-field is performed in the middle of February for spring-summer season crop. In this part, high temperature picks up very fast with the end of March and extremes of high temperature conditions is continuing from April to June month. The high temperature and aridity situations in May and June month is severely affecting development of female flower, fruit-set and marketable quality fruits in cucurbits and thereby very low productivity and benefits to growers. Under this situation, it is the only possibility to sow the crops at the earliest under protection from the severe winter in January and then allowing the crop under open-field condition after risk dates or with rising temperature from first week of February for plant growth and fruiting (Samadia and More, 2010)To standardize this technique, a series of experiments on low-cost and zero-energy protected methods alongwith drip technology of cucurbits cultivation were conducted from 2007–2016 at CIAH, Bikaner as winter–spring–summer season crop. Different types of structures and surface channels were designed considering environmental situations, crop feasibility and transparent polythene or nylon-net was used as covering material to protect from winters. Seed sowing was done on 21$^{st}$ December, 01$^{st}$, 15$^{th}$ and 25$^{th}$ January and 5$^{th}$ February with varying covering practices. Besides, open-field sowing on 15$^{th}$ and 25$^{th}$ February and 5$^{th}$ March was done for the study. Tent-type structures and channel covering with polythene and where sowing on first January exhibited earliness of about 30 days for first marketable harvesting (15 March) in comparison to normal (16 April). This technology exhibited improvement for high yield potential of 30–35 % alongwith better fruit quality. In addition, channel covering is much beneficial for cucurbit sowing in second week of January and it is very simple, highly remunerative and promoted "Surface-channel, tent or arch type tunnel technology of protected cultivation" of CIAH.

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# Hot arid climate resilient production technologies of arid fruit crops

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## Introduction

India has approximately 16% of its land under arid soils and climatic conditions, distributed across 10 states. In these regions, the interaction of various edaphic and climatic factors often leads to limited soil moisture, which restricts plant growth for most of the year. The total area classified as typical arid land is estimated to be around 20-22 million hectares, of which 6-7 million hectares are considered wasteland (Anon., 1998).

Fruit trees offer a valuable opportunity for the productive utilization of these physically and physiologically stressed lands. Cultivating fruit trees in such areas not only holds economic significance but also contributes to the ecological rehabilitation of the region. The arid climate is conducive to the development of certain high-quality fruits that are distinguished by their excellent color and taste, providing further potential for both ecological and economic benefits.
Several drought-hardy native and exotic fruit crops are highly suited for arid ecosystems but remain underutilized. Native Fruits:Lesser-known indigenous crops like bordi, ker, gondi, phalsa, wood-apple, karonda, khejri, wild date palm, pilu, and black mulberry thrive in harsh climates and provide good economic returns.Exotic Fruits:Exotic species such as argan, black sapota, Abyssinian gooseberry, marula nut, cactus pear, carob, pineapple guava, Chinese jujube, oyster nut, quandong, and ye-eb nut also show great potential for commercial cultivation in these regions.

Hot arid climates present significant challenges for fruit production, but resilient technologies have been developed to optimize the cultivation of arid fruit crops. These technologies focus on improving water-use efficiency, managing soil conditions, and enhancing crop resilience to environmental stress.

resilient production technologies: challenging environments have different mechanisms for crop production. crop-plant-genotype interactions play a key role in the success of any system. some factors very important for crop production in such vulnerable ecosystem

1. **Water management**:

   Most precious input for crop production in arid region. Moisture conservation and basin slope management are the important components and advance management aspect required as

- **Drip Irrigation and Mulching**: Efficient water delivery systems like drip irrigation, coupled with plastic or organic mulching, help conserve moisture and ensure water reaches the root zone. This reduces water wastage and improves productivity under drought conditions.
- **Rainwater Harvesting**: Collecting and storing rainwater in ponds or farm reservoirs allows farmers to supplement irrigation during dry periods.
- **Water Recycling and Reuse**: Treated Sewage Water and grey water use in irrigation in peri-urban area

1. **Soil Management**: Soil of arid region low in fertility require amendment regularly to achieve desired production of the grown crops.
    - **Organic Amendments**: Adding compost, manure, or biochar improves soil structure, enhances water retention, and supports plant growth in low-nutrient arid soils.
    - **Contour Bunding and Terracing**: These techniques help reduce soil erosion and increase moisture infiltration, making arid land more productive for fruit cultivation.
    - **Bio-fertilizer consortium use:** For build up soil microflora or beneficial biota in nursery growing media, plant establishment and in growing site.
2. **Crop and its varieties**: Considering ecologically suitable crops and its genotypes for higher production. Apart from improved scion some desirable rootstocks may help in better way

**Table-1 Recommended varieties of climate resilient fruit crops**

| S.N. | Crops | Varieties |
|---|---|---|
| 1 | Ber | Gola, Seb, Umran, Mundia, Kaithali, Banarasi Kadaka, Thar Bhubharaj, Thar Sevika, Goma Kirti |
| 2 | Bael | NB-5, NB-7, NB 9, Pant Aparna, Pant Sujata, Pant Shivani, CISH B-1, CISH B-2, Goma Yashi, Thar Divya Thar Neelkanth |
| 3 | Pomegranate | Ganesh, Jalor seedless, G-137, Mridula, Bhagawa, Phule Arakta, Super Bhagava |
| 4 | Aonla | NA-7, NA-6, NA-10, Kanchan, Krishna, Balwant, Laxmi-52 |
| 5 | Custard apple | Arka Sahan, Balanagar, Mammoth, Island, Gem, Red Sitaphal, APK (Ca)-1 |

| | | |
|---|---|---|
| 6 | Jamun | Goma Priyanka, Paras, Thar Kranti |
| 7 | Date palm | Halawy, Barhee, Medjool, Shamran, Khuneizi, Khadrawy, Zahidi |
| 8 | Fig | Poona Fig, Dianna, Dinkar, Conadria, Excel, Chalisgaon |
| 9 | Tamarind | PKM 1, Pratisthan, Yogeshwari, Goma Prateek |
| 10 | Khirni | Thar Rituraj |
| 11 | Phalsa | Thar Pragti, Sharbati |
| 12 | Lasora | Thar Bold, Karan Lasoda, Maru Smardhi |

**Brief description of native and exotic fruits suitable for arid region:**

## A. Native arid fruits

| S.N. | Crops | Description |
|---|---|---|
| **1** | ***Boradi*** *(Ziziphus mauritiana* var. *rotundifolia)* | *Boradi* is drought hardy shrub or tree.The fruits are used fresh as well as after sun drying. Young seedlings are commercially used as rootstock for *ber.* |
| **2** | ***Jherber*** *(Ziziphus nummularia* Burm. F.*)* | It is a bushy plant. Fruit small mature in October month and dried fruit powder can be use and air dried leaves excellent fodder for sheep and goats |
| **3** | ***Karonda*** *(Carissa carandas* L.) | Multipurpose bush of dry areas (bio fence, fruits, dye). Fruit colour i.e., green, pink and white. The mature fruits are processed into quality pickle and candies |
| **4** | ***Ker*** *(Capparis decidua (* Forsk. ) Edgew.) | A small tree having green, zigzag, thorny stem. Fruit tender stage use for pickle and dried it a principal component of pachkutta. |
| **5** | **Pilu** (*Salvadora spp.*L.) | Also called as mustard or salt bush or tooth brush tree mostly suitable as for aforestation of ravines, saline and alkaline lands, as windbreak and in shelterbelts. Small fruit much have processing value. |
| **6** | ***Goondi*** *(Cordia gharaf)* | It is a tall, erect, branched shrub or tree. Fruits small mucilage rich and tree produce gum, both are edible. |

| | | |
|---|---|---|
| **7** | ***B*lack mulberry** *(Morus nigra)* | The edible fruit is dark purple, almost black, when ripe, 2–3 centimetres (0.8–1.2 in) long, a compound cluster of several small drupes; |
| **8** | ***Phog (***Calligonum Polygonoides) | A woody shrub producing quality fuel wood, foliage for camel and other animals and flower buds having economic value as various preparation. |
| **9** | ***Manila Tamarind (***Pithecellobium dulce***)*** | MADRAS THORN or JUNGLE JALEBI, drought-tolerant tree produce pods in summer months and leaves use for fodder. |

. **B: Exotic less known arid fruits**

| **S.N.** | **Crops** | **Description** |
|---|---|---|
| **1** | **Argan** *(Argania spinosa)* | Thorny with gnarled trunks tree species, fruit takes over a year to mature, oil contains 80% unsaturated fatty acids, is rich in essential fatty acids as substitute of olive oil and cosmetic industries. |
| **2** | **Black sapote** (*Diospyrus digyna*) | A drought hardy dioecious fruit tree produced edible fruits can be used for preparation of value added products . |
| **3** | **African dove plum** (*Dovyalis abyssinica* (A. Rich.) Warb.) | Abyssinian gooseberry belong to the family Salicaceae. A dense, thorny plants, containing several small seeds. They are very juicy and with anacidic flavour. Ripe fruit is used to make a very agreeable jelly and fruit punch. |
| **4** | **Marula nut** *(Sclerocarya birrea)* | Medium-sized dioecious tree, The fruit is used to make the cream liqueur Amarula, sold as a frozen puree used in juice blends like Marula Mania, and marula oil is used as an ingredient in cosmetics. |
| **5** | **Cactus pear** ***(****Opuntia ficus-indica Mill****.)*** | Prickly pear or *tuna, a* xerophytic C4 plant, it was considered as a potential crop species for the water scarce arid regions as animal feed and value added products. |

| | | |
|---|---|---|
| **6** | **pineapple guava** (*Feijoa sellowiana* O. Berg) | A perennial shrub or small tree. The fruit pulp resembles the closely related guava, having a gritty texture, used in some natural cosmetic products. |
| **7** | **Carob (*Ceratonia siliqua*)** | Fabaceae family member widely cultivated for its edible pods, energy-rich feed for livestock. Other products like syrup, drinks etc. can be prepared |
| **8** | **Chinese jujube (***Zizyphus jujube***)** | Cold hardy bushy plant, used for processing and value added products. Frost tolerant and very less infestation of fruit fly in arid region |
| **9** | **Oyster nut** (*Telfairia pedata*) | A climbing plant produce large edible nut like seeds yielding an oil similar to olive oil |
| **10** | **Quandong** (*Santalum acuminatum* ) | A hemi-parasitic plant belongs to *Santalaceae* family, fruit as an exotic flavouring, one of the best known bush foods, the hard and wrinkled nuts have been used ornamentally, for necklaces and shirt buttons, and were used as marbles on chinese checkers' boards. |
| **11** | **Ye-eb nut** (C*ordeauxia edulis* ) | Plant in the Fabaceae family bush serves forage for livestock, firewood and dye. The seeds are eaten dried, boiled, roasted or raw. |
| **12** | **Hingota** (*Balanites aegyptiaca* (L.) Delile) | Thorny tree, the fleshy pulp of both unripe and ripe fruit is edible and eaten dried or fresh. The fruit is processed into a drink and sweetmeats and soup |

3. **Integrated Pest and Disease Management (IPDM)**: Generally arid ecology less of infestation with insect-pest and infestation of diseases complex. So by adopting good management practices automatically reduce load below ETL. However some IPM and IDM aspects better for commercial as well as natural /organic protocol use in crop production.

   **Following steps essentially important**:

   - Orchard site should be well protected through fencing and wind breaks.
   - Bird net, bird scaring ribbons and keep clean and cultivate farm area regular.

- Remote Sensing & Drones equipped with multispectral and thermal cameras
- GMPs namely Soil solarisation,
- Use tolerant/ resistant root stocks & varieties (if available),
- Balance nutrition, strictly follow field and machines sanitization measures,
- Crop regulation, weed management, harvest produce at proper stage & time,
- Grow compatible intercrops,
- Conserve native beneficial insects
- Apply microbial consortia
- Deploy solar-powered light traps
- Fruit wrapping/ water sprout removal / traps
- Use of bio-pesticides or biocontrol formulations
- Use semiochemicals and Mass-rear and release parasitoids for insect
- Apply nano-encapsulated pesti-fungicide & slow-release formulations

4. **Fruit based cropping Systems**: Arid region hostile climate and complex diverse risk prone situation. Our aim through system approach subsistence farmer can get at least some yield in this situation. Arid region sole crop not fit and in place of that to create ameliorating effect this system give dual benefit to the crops and improve regular cash flow for the given piece of land. Components for diversification need to be followed compatible crop selection criteria, due regards to farmers wisdom, site improvement approach (HBCPSMA ). Combining fruit trees with other drought-tolerant plants like legumes or grasses promotes biodiversity, improves soil fertility, and creates microclimates that reduce heat stress on crops. Area specific fruit model can be designed with consideration of allelopathic effect and round the year ( time to time) cash flow.
5. **Post-Harvest Technologies**: Arid region have higher solar radiation. That energy can be used for drying of fruit-vegetable part for safe storage. Some local level a good market of these commodities particularly ker, lasoda, jharber, bordi, ker, goondi, pilu and phog etc. Some advance planning and bridging require through:

    - Infrastructure: solar dryers help extend the shelf life of fruits, reducing post-harvest losses. Other storage (cold), road net work for transport, cool chain facility boosts this crop cultivation at commercial level.
    - Apart from this product branding & marketing intelligence help not only product popularization but also for demand driven to different categories of population.

- Processing Units: Developing local fruit processing units for products like dried products (ker, lasoda,), jams (pillu), and gum (goondi), oils (pomegranate, olive, jojoba) can enhance economic returns for farmers.

| **Proc. product** | **Name of arid fruits** |
|---|---|
| Jam | Jamun, karonda, aonla, tamarind, sitaphal, bael, ber, mulberry,wood apple etc. |
| Jelly | Tamarind, jamun, karonda, barbados cherry etc. |
| Preserved | Ber, aonla, bael, ker, sangari, karonda etc. |
| Candy | Aonla, ber, karonda,datepalm,tamarind etc. |
| Glazed fruits | Tamarind, aonla etc. |
| Juice/beverage/squash | Tamarind, bael, jamun, karonda, phalsa, ber, aonla, pomegranate, mulberry, wood apple etc. |
| Wine | Mahua, wild apricot, datepalm, karonda, ber, Indian fig etc. |
| Chutney | Karonda, tamarind, ker, aonla, wood apple etc |
| Sauce | Karonda, tamarind, wood apple, pomegranate |
| Pickle | Aonla, karonda, ker, lasoda, sangari, ber, tamarind etc. |
| Dehydration | Bael, karonda, ker, phalsa, ber, kachari, sangari, khimp, mulberry, date palm, lasoda, tamarind, aonla, custard apple etc. |
| Frozen puree | Tamarind, bael, karonda, ker, phalsa, tamarind, custard apple etc. |
| Canning | Ber, aonla, jamun, ker etc. |
| Confectionary | Aonla, tamarind etc. |

**Conclusion**

Fruit crops have potential possibilities in this adverse arid condition. Therefore, cultivation of suitable species and varieties of fruit in different horticulture cropping models will offer the bio diversity in hot arid desert ecosystem for livelihood and nutritional as well as income security to the farmers. Having a wide degree of adaptability with high degree of tolerance, they can thrive well under adverse climatic and edaphic conditions. These fruits also serve a potentiality in sustainable horticulture. Hence, research and development work, farmers awareness and feasibility for cultivation of these fruits are to be given due consideration. By

adopting these resilient technologies, arid-region farmers can significantly improve the sustainability and profitability of fruit production in hot, challenging climates.

***Future challenges and research needs***

To increase the productivity of arid fruit some of the general strategies suggested are as

- Natural variability in majority of the arid fruits still to be collected, conserved and evaluated.
- Genetic improvement is required for drought hardiness, disease resistance and fruit quality in arid zone fruits.
- Effective water and nutrient management need to be investigated and standardized.
- Studies on physiological adaptation for drought and salt resistance.
- Utilization of brackish water for date palm, ber and pomegranate.
- Ber based farming system.
- Research work is needed on bio-control techniques for management of diseases and pest with minimum use of chemicals.
- Identification of source of fruitfly and powdery mildew resistance in ber and use of these sources in further breeding programmes.
- Processing and value addition.
- Rapid methods of multiplication.
- Transfer of technology. The technologies should reach to the farmers field after desired refinement.

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# Hi- Tech Propagation: A Climate Smart Technique of plant multiplication of arid fruit crops

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## Introduction

The climatic elements such as solar radiation, temperature, precipitation, humidity, evaporation, evapotranspiration and wind velocity affect growth and development of saplings. These climatic factors are not favourable for successful propagation of various horticultural crops in arid region. The main climatic features of Indian hot arid agro-ecosystem is high wind speed, sand storm and high temperature during summers up to 48-50$^0$ C and during winter season temperature falls to the 2-3$^0$C, low atmospheric humidity i.e. 20-30 % during maximum period of the year. Moreover the relative humidity goes down to below 10 per cent during summer months. These climatic factors are detrimental for vegetative propagation of arid fruit crops and the technique of vegetative method of budding, grafting and stem cutting gives poor result. Moreover , under open field condition the water requirement for plant propagation is 20-25 times more as compared to propagation under controlled environment conditions. The growth and development of root-stocks are slow and difficult to achieve buddable size during current season under open condition. Propagation of horticultural crops in arid zone is limited because of the short span of the favourable temperature and humidity, inadequate water supply and sudden change in wind velocity. There are frequent weather aberrations which favour incidence of physiological disorder in the saplings of fruits and vegetabes.

## Facility of Hi-Tech plant propagation

For Hi-tech propagation of fruit crops three important facilities are required, one is greenhouses/protected structures for development of root-stocks during unfavourable conditions, adventitious root formation in cuttings and providing congenial environment for budding and grafting operations. Another facility of tissue culture laboratory is also becoming an integral part of Hi-tech nurseries to improve the propagation efficiency and quality of saplings. Third is the hardening facility under which young saplings are subjected for gradual acclimatization by passing them to different environmental regimes. The importance and applications of these facilities are given as following:

## Factors affecting propagation of fruit crops

Propagation of fruit crops affected by several factors such as :

- Microclimatic conditions (light, water-relative humidity, temperatures and gases).
- Edaphic factors (propagation medium or soil, mineral nutrition and water).
- Biotic factors-interaction of propagules with other organisms (such as beneficial bacteria, mycorrhizal fungi, insect pests, pathogens, etc.).
- Physiological conditions of mother stock plant.
- Physiological conditions of scion plant.
- Hardening and post propagation care.

Among these factors, the importance of microclimatic conditions is described.

**Microclimatic conditions**

Several environmental factors such as light, intensity, water quality, temperature, and photoperiod remarkably influence propagation of saplings and young nursery plants. These factors need to arrange at optimum level for better response of multiplication. Young nursery plants requires protection from high and low temperature, hot winds, excessive rainfall and protection from pathogens and pests. The salinity level of media and water is also controlled for better growth and development of saplings. Thus, these factors are managed through protected structures, Hi-tech equipment and micro-irrigation devices.

**Light**: Light is important for photosynthesis and proper growth and development of the saplings. It increases temperature of plants aerials and soil zone. For example, extreme high temperature can rapidly desiccate and kill cuttings and newly emerged scion shoots grafted plants. The management of light is critical for rooting of cuttings, growing seedlings or shoot multiplication of explants during *in vitro* condition. Light can be manipulated by controlling light quality, intensity and duration through protected structures fluorescent lamp.

**Light intensity**: Intensity of light can effect organogenesis of shoot and root formation in the cutting and also scion sprout in budded plants. Furthermore, it is also important in raising quality and healthy rootstocks. For instance high light intensity is required for development of vigorous rootstock of arid fruit crops such as ber, aonla, bael and khejri.

**Photoperiod**: Photoperiod is normally controlled or induction of rooting in cuttings or bud union in graftage. This is also useful for increasing faster growth and development of saplings.

**Light quality**: light quality also affects quality of saplings and organogenesis for shoot-root in the cutting and growing nursery stocks. Far red light can promote bulb formation in onion whereas blue light enhances *in vitro* bud sprouting. This has also found to control the height and greenhouse grown plants rather than depending on PGPR application for height control. This has application for round the year propagation, liner production and tissue culture systems.

**I. Green houses/protected structures acility**

**Hi-tech green house for plant propagation**

**Type of greenhouses/protected structures**

**Greenhouses:** Commercial greenhouses are usually independent structures of even span gable roof construction, proportioned so that the space is well utilized for convenient walkways and propagating benches.. All metal prefabricated GI/ aluminum greenhouses are also widely used. A means of providing air movement and air exchange is necessary in all greenhouses to aid in controlling temperature and humidity. A ridge ventilator is almost always used and in some cases side ventilators are also used. Automatic, thermostatically operated controls are available to open and close the ventilators as the temperature fluctuates during the day and night. Forced air ventilator is usually used in large installations. Greenhouses can be mechanically cooled in the summer at low cost by the use of large evaporative cooling units. It is best, if possible, to have the greenhouse heating self-opening ventilators and evaporative cooling systems controlled by thermostat.

**Plastic covered greenhouses-** Lightweight frames covered with various types of plastic film are popular for small home garden structures as well as for large commercial installations. Plastic houses are usually of temporary construction, except when the more permanent high cost covering such as fiberglass panels are used.

**Polyhouse:** This is the least expensive covering material but has shortest life. It breaks down in summer and must be replaced once a year or oftener this is generally done in the fall for use during the winter. Ultraviolet ray resisting polythene lasts longer but cost is somewhat more. A thickness of 200 micron is recommended.

**Fiberglass:** Rigid panels corrugated or flat of fiberglass sheets embedded in plastic are widely used for greenhouse construction. Fiberglass is strong, long lasting, lightweight and easily applied coming in a variety of width, lengths and thicknesses. Only the clean material specially, made for greenhouse should be used.

**Poly carbonate sheet:** Now a day UV stabilized poly carbonate sheets are becoming popular for covering of greenhouse structures because of their longer life up to 10 years and more resistance to high wind velocity and rains. Poly carbonate sheets are available in different sizes ranging from 5 mm to 10 mm size.

**Shade house:** These structures are useful in providing protection to grown nursery stock especially in areas of high summer temperatures and high light intensity. For tender species the shade house is used as an intermediate step between the polyhouse and field planting. More commonly, wood or pipe supports are used set in concrete with the necessary supporting poles. Shade is provided by agro-net of different shading intensity, depending on the need. The sides as well as the top are usually covered.

**Table : Comparison of conventional and Hi-tech propagation**

| Conventional system | Hi-tech propagation system |
|---|---|
| • Season dependent<br>• Low efficiency<br>• Less control on quality<br>• Poor control on insect-pests<br>• Poor control on disease<br>• Less capital requires<br>• Running cost is low<br>• Per unit production is low<br>• Labor requirement is high<br>• Low skill worker is require<br>• Problems of weed<br>• Slow growth of saplings<br>• Water requirement is high<br>• High environmental risks | • Season independent<br>• High propagation efficiency<br>• Control on quality<br>• Control on insect-pests<br>• Control on disease<br>• High capital requires<br>• Running cost is high<br>• Per unit production is high<br>• Labour requirement is less<br>• Highly skilled workers are require<br>• Problems of weed is very less<br>• Rapid growth of saplings<br>• Water requirement is less<br>• No environmental risks |

**Methods of Hi-tech propagation**

**1. Development of seedling under protected conditions**

Conventionally seedling of horticultural crops are produced in seed beds or in poly bags of different sizes which require more and frequently watering. The modern system of seedling production in portrays as plug production has several advantages over the conventional system which are as following.

- The water requirement for seed germination and sapling growth is very less.
- 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.
- 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.
- No transplant sock occurs during field or container transplanting of plug seedlings.
- Faster growth of seedlings achieved for field production or budding onto rootstock.
- Seedling become rapidly ready for outdoor planting or transfer within four to six weeks.

- Protection from insect pests and diseases.
- Escape from environmental injuries.
- Initial irrigation for outdoor establishment is very low.
- Allow precision crop scheduling and easy in post nursery handling and transplanting.

**2. Plug production technique:**

Under this technique large number 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 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.

**Morphological growth stages of plug saplings:** There are four important growth stages of plug seedlings such as initial development stage (Stage I), cotyledon unfolding stage (Stage II), development of leaves (Stage III) and more than four leaves (Stage IV). Each stage of seedling growth requires precise environmental condition. High moisture or watering can cause oxygen deficiency and leads to poor germination to seedlings mortality. For proper initial emergence, warm temperature and consistent moisture is essential, however, these can be reduced at Stage II of saplings development. Light and supplemental liquid fertilization can be important in Stage III. The fertilizer should be given under close monitoring. At the Stage IV saplings become ready for outdoor plantation. Hardening of saplings is required at this stage by putting plugs in moderate ambient environment.

Ammonium fertilizer should not be given at this stage. Application of calcium or potassium nitrate as nitrogen source should be given rather than ammonium nitrate or urea.Saplings should be removed from plug tray after 2-3 hours of watering.

Care should be taken in production of seedling saplings or rootstock of fruit crops like ber, aonla, phalsa, lasora and khejri. The healthy seeds of such crops should be sown initially in plug tray after germination at Stages III and IV. The seedlings are transferred to polybags or other container for further growth and development either in greenhouse condition or open environmental conditions. In this system, root pruning is essential to avoid root coiling and to induce well branched root system. Delay in transplanting at any stages or omission of root pruning will increase the incidence of poor root system.

## 3. Propagation by cutting

Cutting propagation is the most important means of clonal propagation of cultivars and rootstocks of many horticultural crops. Adventitious root formation is a prerequisite to successful cutting propagation. Rooting efficiency of many horticultural crops can be improved by hi-tech systems of plant propagation such as tissue culture facility, green houses, intermittent mists and fog systems and light manipulation. The formation of adventitious roots is dependent on plant cells to differentiate and develop into root system. The process of dedifferentiation in the capability of previously developed, differentiated cells to initiate cell divisions and form a new meristematic growing point. Those characteristics are more pronounced in some cells and plant parts than in others. Therefore, there is need to do some manipulation to provide the proper conditions for plant regeneration. A sound understanding of physiology and biology of regeneration is essential particularly in case of difficult to root species. There are two types of adventitious roots, one is preformed roots, and another is wound-induced roots.

Three steps procedure occurs in root regeneration in wound-induced roots.

1. The outer injured cells are killed and form a necrotic plate, a necrotic plate formed, the wound is sealed with a corky material (suberin) and xylem may plus with gum. This plate protects the cut surfaces from desiccation and pathogens.
2. Living cells behind this plate begin to divide after a few days and a layer of parenchymatous cells form callus which develop into a wound periderm.
3. Certain cells in the vicinity of the vascular cambium and phloem begin to divide and initiate *de novo* adventitious roots.

**Stages of *de novo* adventitious root formation**

1. Dedifferentiation of specific differentiated cells.
2. Formation of rooting initials from meristematic dedifferentiation cells near vascular bundles or vascular tissues.
3. Development of root initials into organized root promordia.
4. Growth and emergence of root promordia and formation of vascular tissue.

**Major steps in cutting propagation**

Cuttings are the vegetative parts of the plant used for propagation. On the basis of maturity of shoot, hard wood, semi-hard wood and soft wood cutting are categorized (Figure 8). The most commonly used are hardwood cuttings however, in greenhouse conditions semi hard wood and apical soft wood cuttings also give good results (Figure 9). The major steps in cutting propagation is given below :

- It is simple and cheap method of clonal scion/rootstock multiplication.
- Hard wood cuttings are easily handled and transported to the distant locations.

- Weak as well as the fast growing shoots with longer internodes should be avoided
- Length should be 10-12 cm for soft wood, 15-20 cm for semi-hard wood and 20-25 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 in case of difficult to root species.
- Fruit plants such as pomegranate, karonda, fig, citrus, mulberry and moringa can be propagated through cuttings in greenhouse round the year.
- 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.

**Use of plant growth regulators in propagation**

In plant multiplication, plant growth regulators are used to improve and enhance seed germination, seedling growth and particularly to improve root formation and accelerated growth in saplings. For enhancing seed germination gibberellic acid, thiourea and sometime NAA are used in different concentrations depending upon the hardiness. Auxins particularly IBA in concentration range of 100-10000 ppm is used for rooting. In principle, lower concentration of IBA ranging from 100-500 ppm is used for soft wood cutting, 500-2000 ppm for semi- hard wood and from 2000-10000 ppm for hard wood and difficult to root cuttings and layers. Number of commercial formulations such as Seradex, Keradux, etc. are available in the market for common use.

**4. Propagation by budding**

Under Hi-tech propagation system, the improvement in technique and fficiency of the budding and grafting technique are possible using several approaches and alternate use of different facilities for faster development of rootstock and sprouting of budded scion. This has been achieved successfully in propagation of aonla, bael, ber and khejri. 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. The important steps in T/Shield and patch budding are as under-

**T/Shield budding**

Most of the arid fruit crops such as ber, aonla, khejari, bael and mulberry are commonly propagated by T/Shield budding method. As the name indicates shield is the shape which is similar to a boat. T is the shape of the cut given on the rootsrock for placement of the bud. Plants

with thin bark and sufficient sap flow like Citrus, peach, plum, apricot, cherry, apple, pear, ber etc. are propagated by this method. In Citrus, budding should be done along with wood to avoid rupture of the bud. In case bud is placed without making T cut, it is known as shield, and with inverted T it is known as inverted T budding.

**Patch budding**

Important steps involved in patch method are 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 khejari 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 of bark keeping bud in centre carefully.
- Make similar patch on the smooth portion of rootstock.
- Replace the scion patch, keep in right orientation and wrap firmly with polythene strip.
- After budding the young budlings 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.
- Manage pest and disease if noticed in the plants.

**5. Propagation by grafting**

The common method of grafting is inarching or approach grafting. Veneer grafting has also been found to simple and successful method. For citrus species micro budding has been utilized commercially. Likewise CIAH, Bikaner has developed micro grafting technique in mulberry using one month old clonal rootstock and defoliated scion wood containing 2-3 buds. For veneer grafting the scion must be taken from one month old shoot duly defoliated for forcing the buds. About 3-4 cm long shoots with one or two buds is used for grafting. The percentage success during July has been recorded as 80 %. In places where humidity is more than 70 % or where mist chamber facility is there soft wood grafting and stone grafting can be practiced.

**Important steps of veneer grafting:**

1. The scions and rootstocks should be preferably of the same diameter ( for veneer).

2. Grafting should be taken up where there is high humidity.
3. Grafted plants are to be kept in mist if possible.
4. Grafts should be labeled after grafting so that varieties are not mixed.
5. Rootstock portion should be cut off after the leaves of the scion turns green.
6. Rootstocks of 1 year old age (0.50-0.75 cm diameter) are used.
7. A slanting downward and inward 30-40 mm long cut is made on smooth area of the stock at a height of about 20 cm from bottom.
8. At base of the cut, a smaller shorter cut is given to intersect so to remove the wood and bark.
9. The scion of similar thickness is selected having a length of 2.5- 10 cm and 4-5 months old.
10. Terminal non flowering shoot should be preferred for multiplication.
11. Selected scion shoots are defoliated on the mother plant 7-10 days prior to detachment.
12. For distant transportation defoliated scion shoots can be wrapped with moist sphagnum moss and covered with polythene.
13. A long cut is given at one side of the scion and short cut on the other side to match cut on the ootstock.
14. 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.

**Important steps of micro- grafting in mulberry:**

1. Develop clonal rootstock in greenhouse using terminal shoots from wild type morus.
2. After one month of root formation in terminal shoots are used as rootstock for micro grafting operation.
3. Make a horizontal cut at 10-15 cm height of rootstock. Thereafter make a cut vertically making a wedge of 2 cm depth on the decapitated rootstocks.
4. Insert scion wood which was defoliated 7-10 days prior to grafting on to the rootstock.
5. After grafting graft union zone is wrapped by polythene strip and covered grafted stock by polythene tube to avoid direct contact of water to union zone.
6. Sprouting takes place within 10-15 days and then polytube should be remove from the grafted plant.

After attaining 4-5 leaves in the grafted scion, the plant should be transferred to bigger container for further growth and development

## 6. 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 upto 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 micropropagated plantlets, but also the vegetatively propagated plants are seriously damaged. Green house propagated plants, although green in colour are poor photosynthesizer. Further, because of high relative humidity inside the green house (over 85%), they lack proper mechanism to control water loss and photosynthesis process. The plants, if transferred directly to the open environment show, very poor survival. Therefore, gradual hardening of plantlets is an important and this is challenging part of the propagation of horticultural crops in arid ecosystem. Hardening or acclimatization refers to the physiological adaptation of plants to change in climate or environment such as light, temperature and relative humidity. Hardening of plant is a gradual procedure in which light intensity, temperature and relative humidity need to be altered and other factors such as nutrient supply, watering frequency, container substrate components and use of growth regulators and pesticides are maintained precisely which favors plants to become conditioned before being placed in field condition. The ultimate success of commercial propagation depends upon the ability to transfer plantlets from green house environment on a large scale at low cost and with high survival rates.

**Table 2. Comparative advantages of Hi-tech propagation over conventional propagation of arid fruit plant**

| Sl. No | Name of crops | Important cultivars | Conventional Method of propagation | Time | Hi-tech method |
|---|---|---|---|---|---|
| **1.** | Ber (*Ziziphus mauritiana)* | Gola, Seb, Kaithli, Mundia, Umran, Banarasi Karaka | Budding | June-July | May-September (by developing rootstock in greenhouse) |
| **2.** | Pomegranate (*Punica granatum*) | Ganesh, Jallore Seedless, Mridula, G-137 | Hard wood Cutting | July-September | Round the year with microcutting, semi and hard wood cutting |
| **3.** | Aonla (*Emblica officinalis*) | Kanchan, Krishna, Chakaiya, NA-6, NA-7, NA-10 | Budding | June-July | May-September (by developing rootstock in greenhouse) |
| **4.** | Date palm (*Phoenix dactylifera*) | Medjool, Zahidi, Barhee, Halawy, Khadrawy | Suckers | February-March, August-September | |
| **5.** | Fig (*Ficus carica*) | Puna Fig, Brown Turdey | Hardwood cutting | December-February, June-July | Round the year, soft wood, semi and hard wood cutting |

| | | | | | |
|---|---|---|---|---|---|
| **6.** | Phalsa (*Grewia subinaequalis*) | Sharbati and Local | Seed, Hard wood Cutting | April-June | April-October in protrays |
| **7.** | Tamarind (*Tamarindus indica*) | PKM-1, Pratisthan | Seed, Budding | February-March, June-July | |
| **8.** | Lasora *(Cordia myxa*) | CIAH Sel.-1, CIAH Sel.-2 | Seed | May-June | May-December in greenhouse condition |
| **9.** | Citrus (lime/lemon) | Pant Lemon, Baramasi | Seed | July-August | Round the year, soft wood, semi hard wood cutting in mist propagation unit |
| **10.** | Karonda (Carissa congesta) | Pink Fruited, Green Fruited, Red Fruited | Seed | August-September | Round the year, soft wood, semi and hard wood cutting in green house condition |
| **11.** | Bael (Aegle marmelos) | NB-5, NB-6, NB-9, Pantnagar Selection | Budding | June-July | May-September, round the year propagation of seedling rootstocks in greenhouse condition |
| **12.** | Mulberry (Morus sp.) | Local | Cutting | June-July | March-September through budding, round the year clonal root stock propagation in greenhouse condition |
| **13.** | Ker (Capparis decidua) | Local | Seed | June-July | Stem cutting in September in green house condition |
| **14.** | Khejari (Prosopis cineraria) | Thar Shobha | Budding | June-July | May-September, round the year propagation of seedling rootstocks |
| **15.** | Aloe vera (Aloe barbadendasis) | CIAH Sel.-1, CIAH Sel.-2, CIAH Sel.-3 | Sucker (2-3 suckers/plant/ year | March-September | Round the year in green house condition (20-25 suckers/plant/year |

**Plant propagation through cutting in Hi-Tech glass house**

| S.No | Crops | Types of cutting | Length of cuttings (cm.) | Diameter of cuttings | Days taken in root initiation | % success |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | Pomegranate | Semi hard wood/ apical shoot | 12-18 | 0.3-0.5<br>0.1-0.3 | 25-30 | 75-80 |
| 2 | Lime/Lemon | Apical shoot with leaves | 10-15 | 0.2-0.3 | 20-25 | 85-90 |
| 3 | Karonda | Apical shoot with leaves | 10-15 | 0.2-0.3 | 40-45 | 60-70 |
| 4 | Mulberry cultivar | Apical shoot with leaves | 10-15 | 0.2-0.3 | 40-45 | 60-70 |
| 5 | Mulberry (clonal rootstock multiplication) | Apical shoot with leaves | 15-20 | 0.1-0.3 | 15-20 | 95-100 |
| 6 | Aonla (clonal rootstock multiplication) | Apical shoot with leaves | 15-20 | 0.2-0.3 | 45-50 | 60-70 |
| 7 | Drum stick | Apical shoot with leaves | 15-20 | 0.5-0.6 | 35-40 | 60-70 |
| 8 | Ficus panda | Apical shoot with leaves | 15-20 | 0.1-0.3 | 25-30 | 85-90 |
| 9 | Clerodendron enermi | Apical shoot with leaves | 10-15 | 0.2-0.4 | 15-20 | 85-100 |
| 10 | Rose | Semi hardwood | 10-15 | 0.2-0.5 | 25-30 | 75-80 |

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# Quality seed production of arid vegetable crops

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## Introduction

Vegetables play an important role in nutritional security, economic viability and fit well into the predominant intensive cropping systems prevailing in different parts of our country. Because of varied agro-climatic conditions in India, more than 60 kinds of vegetables are grown in tropical, subtropical and temperate zones. The desert has diverse agro-climatic conditions (arid, semi-arid and sub-humid tropics) and the nature has imposed some restrictions which limits the scope for diversification through vegetable crops. However, these conditions favour successful cultivation of several vegetable crops like *Kachri* (*Cucumis callosus*), snapmelon/ *Phoot* (*Cucumis melo* var. *momordica*), watermelon/ *mateera* (*Citrullus lanatus*), longmelon/ *Kakri* (*Cucumis melo* var. *utilissimus*), round melon/ *Tinda* (*Praecitrullus fistulosus*), bottle gourd (*Lagenaria siceraria*), ridge gourd (*Luffa acutangula*), cluster bean (*Cyamopsis tetragonoloba*), *etc*. Other vegetable crops like solanaceous (tomato, brinjal, chilli), bulb crops (onion, garlic), root crops (carrot, radish), cole crops (cabbage, cauliflower, knol-khol), leafy (palak, *Chenopodium*, fenugreek, *Amaranthus*), legumes (cowpea, Indian bean) and okra also have good potential under limited irrigation water facility by adopting suitable production and protection technologies. The vegetable crops like *arya* (*Cucumis melo* var. *chate*), *mathkachar*, spine gourd (*Momordica dioica*), *jhaar karela* (*Momordica balsamina*), ivy gourd (*Coccinia grandis*), *etc*. are naturally grown in different parts of arid zone particularly on neglected places and possess wide genetic diversity. The institute is preserving a vast collection of germplasm for various arid vegetable crops. This germplasm has been systematically evaluated, characterized, and purified, enabling its effective use in crop improvement programs. These efforts have led to the development of several climate-resilient varieties well-suited to arid ecosystems.

**Table 1. Improved vegetable varieties developed by ICAR-CIAH, Bikaner**

| Crop | Variety |
|---|---|
| Kachri | AHK-119, AHK-200 |
| Snap melon | AHS-10, AHS-82 |
| Mateera | AHW-19, AHW-65, Thar Manak |
| Long melon | Thar Sheetal |
| Ridge gourd | Thar Karni |
| Muskmelon | Thar Mahima |

| | |
|---|---|
| Watermelon | Thar Tripti |
| Sponge gourd | Thar Tapish |
| Bottle gourd | Thar Samridhi |
| Ivy gourd | Thar Sundari |
| Brinjal | Thar Rachit |
| Palak | Thar Hariparna |
| Cluster bean | Thar Bhadvi |
| Dolichos bean | Thar Kartiki, Thar Maghi |

Seed is a fundamental and crucial input in vegetable cultivation, directly influencing the returns from all other agricultural inputs. The successful cultivation of vegetables depends on raising healthy seedlings, which requires high-quality seeds, appropriate cultural practices, and optimal environmental conditions. However, the inadequate availability of quality seeds remains a significant factor contributing to low productivity and substandard vegetable produce. To address this challenge and enhance vegetable production and productivity, it is essential to prioritize and expand the production of high-quality vegetable seeds. Currently, there is a significant gap between the actual seed requirement and the production of vegetable seeds in India. The seed replacement rate for vegetables is steadily increasing each year, driven largely by the adoption of improved varieties and hybrids. However, the primary factors contributing to low vegetable productivity in the country are the limited availability of quality seeds for improved open-pollinated varieties, and the prohibitively high cost of hybrid seeds.

The production of quality seeds for arid vegetable crops is a specialized task that demands skilled and trained manpower. This process involves meticulous planning, precise agronomic practices, and careful management of genetic purity, all tailored to the unique challenges of arid ecosystems. Developing a pool of well-trained personnel is essential to ensure the production of high-quality seeds that meet the standards required for sustainable cultivation in these regions. The success of seed production largely depends on effective crop management practices, starting from sowing and continuing through to harvest. Every aspect of agronomic management plays a critical role in influencing the outcomes of the seed production process, including the quality attributes of the seeds. Meticulous attention to factors such as soil preparation, sowing techniques, nutrient management, pest and disease control, and harvesting practices is essential to achieve high-quality seed production and ensure the overall success of the program.

Isolation, rouging, timely harvesting, and proper seed extraction procedures are critical components of quality seed production for arid vegetable crops. To ensure the production of high-quality seeds that can thrive in arid ecosystems, it is essential to strictly adhere to the standard methods developed for these processes. These practices help maintain genetic purity,

seed health, and overall quality, making them indispensable for successful seed production programs in challenging arid conditions.

**Table 2. Isolation distance required for quality seed production**

| Crops | Isolation in metres | |
|---|---|---|
| | Foundation | Certified/ TFL |
| Brinjal | 200 | 100 |
| Capsicum (chillies) | 400 | 200 |
| Tomato | 50 | 25 |
| Okra | 400 | 200 |
| Cluster bean | 50 | 25 |
| Cowpea | 50 | 25 |
| Indian bean | 50 | 25 |
| Spinach | 1600 | 1000 |
| Cucurbits (All crops) | 1000 | 500 |

**Field inspection**

Field inspection for seed production is a critical process to ensure that the seed lot meets the required standards of purity, quality, and health. The process is usually divided into several stages, with inspections conducted at different times during the growing season.

- **pre-planting inspection (field selection):** to ensure that the field selected for seed production is suitable for producing high-quality seeds.
- **vegetative stage (early growth phase):** to ensure that the crop is growing properly and that there are no early signs of disease or pest infestation.
- **flowering stage (pollination and fruit set):** to monitor the pollination process and ensure the genetic purity of the seed lot.
- **mature plant stage (pre-harvest):** to ensure that the crop is approaching maturity, and the seed is ready for harvest.
- **harvest stage:** to ensure that the crop is harvested at the right time for optimal seed quality.

- **post-harvest (seed processing):** to inspect the seeds after they have been harvested and processed, ensuring their quality for sale and planting.

Field inspection ensures that only high-quality seeds reach the market, helping to maintain the genetic integrity and health of the crop.

**Rouging**

Rouging is the process of removing unwanted, non-true-to-type, and diseased plants from a seed field to maintain the purity and quality of the seed crop. This practice is essential to ensure that the seeds produced are genetically pure, free from disease, and true to the desired variety. Rouging should be performed throughout the life cycle of the crop, but it is especially critical at key stages when the unwanted plants have the potential to contaminate the seed crop. The key points for effective rouging are described below:

- **Early stages:** At the initial growth stages, rouging helps in removing any off-type plants (those that do not conform to the desired characteristics of the variety) or any early signs of diseases.
- **Flowering stage:** During this stage, any off-type or cross-pollinated plants that could affect the genetic purity of the seed crop should be removed. Special attention is needed to prevent cross-pollination with other varieties.
- **Maturity stage:** Just before and during the maturity stage, rouging ensures that any remaining undesirable plants are removed to avoid contaminating the seed lot.

By carefully managing rouging at different stages, the quality of the seed can be maintained, ensuring high germination rates and healthy plants in the next growing cycle.

**Harvesting for seed purpose**

The timing of harvesting mature fruits varies across different vegetable crops, depending on their specific growth and development patterns after pollination. The stages of harvest for some important crops are given below:

**Table 4. Harvesting stage of different vegetable crops for seed**

| S.N. | Crop | Harvesting time |
|---|---|---|
| 1 | Tomato | 60-65 days after pollination. Fruit colour completely red. |
| 2 | Brinjal | 50-55 days after pollination. Fruit skin colour yellow/ yellowish brown |
| 3 | Muskmelon | Full slip stage or when cracks develop at the junction of fruit peduncle. 30-35 days after pollination. |

| | | |
|---|---|---|
| 4 | Watermelon | 30-35 days after pollination. The tendril nearest to the fruit is dried up to the base. The fruits also produce dull sound when tapped with knuckles. |

**Seed extraction and drying**

In seed production, proper extraction techniques are critical to ensure seed quality and viability. Below are the methods for seed extraction in some important crops:

Watermelon and muskmelon: Seeds are extracted using the fermentation method. Under warm conditions, fermentation is completed within 24 hours. At 25°C, the process takes about two days. The pulp is stirred several times a day to ensure uniform fermentation and to prevent seed discoloration.

Tomato: The fermentation method not only facilitates seed extraction but also helps control seed-borne bacterial canker. Alternatively, chemical treatments are used:

- Hydrochloric Acid (HCl): 10 cc of 36% HCl is added to 4 kg of tomato pulp and treated for 15 minutes.
- Sodium Hydroxide (NaOH): 30% NaOH solution is applied similarly. After treatment, the seeds are thoroughly washed with clean water to remove residual chemicals.

Brinjal and chilli: Fully ripe fruits are crushed, and the seeds are separated by washing.

Seed Drying: After extraction, seeds are dried using dry air at a controlled temperature of 28-30°C to maintain their viability and quality.

**Seed standards**

Seed standards refer to the set of criteria or guidelines established to ensure the quality, viability, and purity of seeds for planting. These standards are designed to ensure that seeds meet the minimum requirements for factors such as germination, physical purity, and health, which ultimately affect crop productivity. Below are the key components typically covered by seed standards:

**Germination percentage:** the percentage of seeds that successfully germinate under controlled conditions. a higher germination rate is essential for good crop establishment.

**Purity:**

**Physical purity**: The percentage of pure seed in the seed lot, excluding weed seeds, inert matter, and seeds of other crops.

**Genetic purity:** Ensures that the seed is of the correct variety and free from contamination by off-type plants.

**Seed health:** refers to the absence of seed-borne diseases, pests, or pathogens. seeds are tested for diseases such as fungal, bacterial, or viral infections to ensure they do not spread to crops upon planting.

**Moisture content:** the moisture content of seeds affects their storage and germination potential. ideal moisture levels are typically between 7% and 12%, depending on the crop species. Excessive moisture can lead to mold or fungal growth, while low moisture can result in poor seed viability.

**Physical characteristics:**

**Size and Shape:** Seeds should have uniform size and shape for consistent planting.

**Colour:** The colour of the seed should be consistent with the variety and indicate good quality.

**Test for weeds and foreign matter:** the seed lot should be free from weed seeds and foreign matter that may hinder crop growth or contaminate the environment.

**Vigour:** this refers to the overall health and energy of seeds to sprout quickly and produce Strong seedlings under field conditions. seeds with high vigour are more likely to perform well in suboptimal environmental conditions.

**Pest-free:** the seeds should be free from insect infestation, which could compromise their viability or lead to the spread of pests in the field.

**Storage conditions:** seed standards also specify optimal conditions for storing seeds to maintain their viability. seeds should be stored in a cool, dry, and well-ventilated environment, away from light.

By following these standards, seed producers can ensure that their seeds are suitable for planting and capable of producing high-quality crops.

**Table 5. Seed standards of different vegetable crops**

| Crop | Minimum | | | | Maximum recommended limit | | | Humidity (%) | |
|---|---|---|---|---|---|---|---|---|---|
| | Pure seed (%) | Germin-ation (%) | Inert matter (%) | Other crop seed (number / kg) | Weed seed (number / kg) | Other variety seed (number / kg) | Unwanted seed (number / kg) | Normal Packing | Air tight packing |
| Brinjal | 98 | 70 | 2 | None | None | - | - | 8 | 6 |
| Tomato | 98 | 70 | 2 | 10 | None | - | - | 8 | 6 |
| Chilli | 98 | 60 | 2 | 10 | 10 | - | - | 8 | 6 |
| Bottle gourd, pumpkin | 98 | 60 | 2 | None | None | - | - | 7 | 6 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Watermelon | 98 | 60 | 2 | None | None | 10 | 10 | 7 | 6 |
| Cucumber, longmelon, muskmelon | 98 | 60 | 3 | 10 | None | - | - | 7 | 6 |
| Ridge gourd, sponge gourd | 98 | 60 | 2 | None | None | 10 | 10 | 7 | 6 |

***"Subeejam Sukshetre Jayate Sampadhyate"*** **(Good Seed on Good Land Yields Abundantly)**

**"Care with the Seed-Joy with the Harvest**"

**"As You Sow -So Shall You Reap"**

# Scope of Organic and Natural Horticulture Production in hot Arid Climatic Conditions: Problems and Prospects

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## Organic Farming vs. Natural Farming

Despite the rapidly growing market for organic food and beverages, organic farming remains a contentious practice, often criticized as an inefficient approach to food production. While the global demand for organic products continues to rise steadily, periodic shortages have been observed. These shortages primarily stem from the inability of organic food supply chains to keep pace with escalating demand (Dimitri and Oberholtzer, 2009).

India is home to 30% of the world's total organic producers but accounts for only 2.59% (1.6 million hectares) of the total global organic cultivation area, which spans 57.8 million hectares, according to the World of Organic Agriculture 2018 report. Organic products are typically 3-4 times more expensive than conventional products, due to higher labor costs, certification expenses, specialized handling requirements, and comparatively lower yields. Additionally, transitioning to organic farming involves a three-year conversion period during which farmers must practice organic farming without being allowed to market their produce as organic. This poses significant financial risks for farmers, as yields tend to be lower during this transition period.

In contrast, Natural Farming (NF) offers a less restrictive pathway for farmers. If recognized as a chemical-free production system, farmers practicing NF can sell their produce as "Green Products" from the first year itself, often at slightly higher prices. This advantage helps offset potential yield losses during the initial years. According to TechSci Research, the global organic food market was valued at $110.25 billion in 2016 and is projected to grow at a CAGR of 16.15%, reaching $262.85 billion by 2022. In India, the organic food market has been expanding at a CAGR of 25% and was expected to reach ₹10,000-₹12,000 crore by 2020, up from ₹4,000 crore. India exported organic products worth ₹5,151 crore in 2018–19, a 50% increase from the previous year. Presently, 1.78 million hectares of cultivated land in India are under organic farming. However, the steep prices of organic food make it inaccessible to much of the middle-class population. These high prices are attributed to factors such as input costs, labor expenses, certification fees, and the logistical challenges of sourcing and distributing organic products.

Organic farming does offer notable health benefits. Organically grown foods have higher concentrations of antioxidants, lower cadmium levels, and fewer pesticide residues. Antioxidants like polyphenolics in organic foods are associated with reduced risks of chronic diseases, including cardiovascular diseases, neurodegenerative conditions, and certain cancers (Baranski et al., 2014).

However, organic farming faces criticism for its limited scalability. Some argue that its global carrying capacity supports only 3–4 billion people (Connor, 2008), far below the current world population of 6.2 billion and the projected 9 billion by 2050. In contrast, Badgley et al. (2007) suggested that organic agriculture can not only enhance productivity in developing countries but also feed the global population. Barbieri et al. (2019) estimated that transitioning to organic farming could result in a 31% decrease in harvested land area for primary cereals like wheat, rice, and maize, offset by increased areas for fodder crops (+63%), secondary cereals (+27%), and pulses (+26%). This shift, paired with lower yields, could lead to a 27% gap in energy production from croplands compared to conventional farming.

Additionally, critics like Searchinger et al. (2018) argue that organic farming may have a larger climate impact than conventional farming due to the increased land required to produce equivalent yields. This expansion contributes to greater carbon emissions, despite organic farming being perceived as more environmentally friendly by consumers.

In the Indian context, Sh. Subhash Palekar asserts that organic farming may harm agriculture more than it helps. Organic farming often demands large quantities of organic matter, such as farmyard manure (FYM), which many Indian farmers cannot readily access. Purchasing cow dung in substantial quantities increases costs, rendering organic agriculture economically unviable. Consequently, organic produce has become a luxury product, affordable only to the wealthy. Furthermore, the use of vermicompost, which relies on surface-feeding earthworms like *Eisenia foetida* (redworms), is another limitation. Unlike native earthworms, these redworms do not burrow into the soil to improve its mineral content, making them less effective for Indian farming conditions.

Given these challenges, Natural Farming practices may be more suitable for smallholder farmers in India. NF avoids the high input costs associated with both organic and conventional farming, offering a more viable and sustainable alternative for chemical-free agriculture. According to the FAO, global food production must increase by 70% by 2050 to meet the demands of a growing population and the changing consumption patterns driven by an expanding middle class. Simultaneously, India is projected to become the world's most populous country by 2030, with an estimated population of 1.51 billion. In such a scenario, ensuring food security for the population will be one of the nation's most critical challenges.

Adopting large-scale farming practices or production technologies that are not scientifically validated or that negatively affect crop yields could undermine the national goal of achieving food and nutritional security. The Green Revolution of the mid-1960s, which relied heavily on high-yielding variety (HYV) seeds, chemical fertilizers, and intensive irrigation, successfully addressed food shortages in India. However, the intensification of agriculture has resulted in significant environmental challenges, including soil degradation, eutrophication of land and water bodies, greenhouse gas (GHG) emissions, and biodiversity loss (Evenson and Gollin, 2003; Canfield et al., 2010; Smith et al., 2013; IAASTD, 2009; Pingali, 2012).

In contrast, Natural Farming (NF) offers a unique, chemical-free approach to agriculture. It is an agroecology-based, diversified farming system that integrates crops, trees, and livestock, fostering functional biodiversity (LVC, 2010; Rosset and Martinez-Torres, 2012). Zero Budget Natural Farming (ZBNF), a subset of NF, was introduced in the mid-1990s by agriculturist Sh. Subhash Palekar, who was honored with the Padma Shri, one of India's highest civilian awards, in 2016 for promoting these alternative farming practices (Khadse et al., 2017; Mishra, 2018; Niyogi, 2018; Economic Survey, 2019). ZBNF has been widely adopted across several states, including Andhra Pradesh, Karnataka, Maharashtra, and Himachal Pradesh.

ZBNF significantly reduces production costs by replacing chemical fertilizers and pesticides with home-grown products such as Jeevamritha, Beejamritha, and Neemastra, and by incorporating practices like intercropping and mulching (Palekar, 2005; 2006). According to Palekar, this method requires only one indigenous cow for every 30 acres of land. It is believed to enhance soil health, increase soil organic carbon without the extensive use of farmyard manure (FYM), as in organic farming, and promote sustainable agriculture with a reduced carbon footprint. The Economic Survey (2019) highlighted ZBNF as a viable alternative for improving farmers' incomes amidst declining fertilizer efficiency and stagnating farm earnings.

Biological sciences, including microbiology, ecology, and soil science, provide further inspiration for the ecological renewal of agriculture. With increasingly symbiotic (Gilbert et al., 2012) and "probiotic" (Lorimer, 2017) understandings of soil and plant life, these disciplines emphasize the importance of feeding soil microbes to restore soil health. Wallenstein (2017) suggests this can be achieved by adding organic material back to the soil, minimizing tillage, and eliminating synthetic fertilizers and chemicals.

Natural farming, initially proposed by Japanese farmer Masanobu Fukuoka, is based on the philosophy of working in harmony with natural cycles and processes (Fukuoka, 1987). It is considered a holistic solution to reduce dependence on purchased inputs, enhance family health and nutrition, ensure stable crop yields, and alleviate farmer indebtedness and suicides in India.

Subhash Palekar's Approach to zero budget natural farming (ZBNF)

In this study, the terms **Natural Farming** and **Zero Budget Natural Farming (ZBNF)** are used interchangeably, with the practices advocated by Sh. Subhash Palekar serving as the reference point. ZBNF focuses on improving soil health by enhancing biological activity through the application of microbial inoculants and organic matter.

The core practices of Natural Farming include:

1. **Addition of Microbial Cultures**: These are used to accelerate decomposition and promote nutrient recycling within the soil.
2. **Utilization of Local Seeds**: Indigenous seeds are prioritized for their adaptability and resilience.
3. **Integration of Crops, Trees, and Livestock**: This holistic approach primarily involves native breeds of cows, which play a central role in nutrient management and ecosystem sustainability.
4. **Water Conservation Techniques**: Practices such as proper crop spacing, contour farming, and the creation of bunds help retain moisture and prevent erosion.
5. **Intensive Mulching**: Mulching is extensively practiced to protect the soil, conserve water, and return organic biomass.
6. **Diverse Planting Strategies**: Methods like intercropping and crop rotation are employed to improve biodiversity, optimize land use, and maintain soil fertility.

Mulching, in particular, has a significant positive impact on soil organic carbon (SOC) content. It contributes to enhanced soil and water conservation, reduces average and maximum soil temperatures, and supports nutrient cycling mechanisms. Mulched soils benefit from improved biodiversity and biomass incorporation, which collectively strengthen the soil ecosystem (Lal and Kimble, 2000).

This integrated approach aligns with the principles of sustainable agriculture, offering a cost-effective, chemical-free, and ecologically balanced farming method that benefits both smallholder farmers and the environment.

## Key Practices in Zero Budget Natural Farming (ZBNF)

### 1. Jeevamritha (Microbial Culture for Soil Health)

**Jeevamritha** is a fermented microbial culture that provides essential nutrients and, more importantly, acts as a catalytic agent. It enhances the activity of soil microorganisms and increases the population of native earthworms, thus improving soil fertility.

**Preparation of Jeevamritha:**

- Fill a 200-litre barrel with water.
- Add the following ingredients:
    - 10 kg fresh local cow dung (rich in microorganisms).
    - 5–10 litres of aged cow urine (acts as a natural anti-bacterial agent).
    - 2 kg jaggery (unrefined sugar, a carbon source for microbes).
    - 2 kg pulses flour (provides nutrients for microbial growth).
    - A handful of soil from the farm bund (serves as a microbial inoculant).
- Stir the mixture thoroughly and allow it to ferment in the shade for 48 hours.

After fermentation, the solution is ready to use. A 200-litre preparation is sufficient for one acre of land. During fermentation, aerobic and anaerobic bacteria multiply, utilizing organic components like jaggery and pulse flour. The soil inoculant introduces native microbial species, further enriching the solution. Jeevamritha also helps prevent fungal and bacterial diseases in plants.

**Application of Jeevamritha:**

- Apply it twice a month either as a 10% foliar spray or by mixing it with irrigation water.
- It can be stored for up to 15 days and is particularly effective for horticultural crops when applied to individual plants.

**2. Beejamritha (Seed Treatment)**

**Beejamritha** is used to treat seeds, seedlings, or planting material, protecting young roots from fungal infections and soil-borne or seed-borne diseases, especially during the monsoon season.

**Preparation of Beejamritha:**

- Mix the following ingredients:
    - Local cow dung (natural fungicide).
    - Cow urine (anti-bacterial agent).
    - Lime (50 grams per preparation).
    - Soil.

- Tie the cow dung in a cloth and submerge it in cow urine for about 12 hours.
- Remove the cloth, squeeze out the dung, and mix the liquid with lime.

**Application:**

- Coat the seeds of any crop with the prepared Beejamritha, ensuring even coverage. Let them dry completely before sowing.
- For leguminous seeds, dip them quickly in the solution, then allow them to dry before planting.

**3. Acchadana (Mulching)**

Mulching is an essential practice in ZBNF for conserving soil moisture, enhancing fertility, and improving soil structure. Three types of mulching are recommended:

a. **Soil Mulch:**

- Protects the topsoil during cultivation and prevents its destruction by tilling.
- Promotes aeration and water retention, reducing the need for deep ploughing.

b. **Straw Mulch:**

- Involves spreading dried biomass, such as crop residues, over the soil.
- These materials decompose, forming humus through the activity of soil biota activated by microbial cultures.

c. **Live Mulch:**

- Promotes multiple cropping patterns of monocotyledons (e.g., rice, wheat) and dicotyledons (e.g., pulses) in the same field.
- Dicot plants fix nitrogen, while monocots contribute essential elements like potassium, phosphorus, and sulfur.

**4. Whapasa (Soil Moisture Optimization)**

**Whapasa** refers to the condition where soil contains both air and water molecules, ensuring an optimal moisture balance. Unlike conventional practices that rely heavily on irrigation, ZBNF emphasizes minimal irrigation by:

- Irrigating only at noon.

- Alternating water application between furrows.

This method reduces water usage while meeting the moisture needs of crops. Although promising, the adoption of Whapasa practices remains limited among farmers.

# Natural Panchkutta herbal Garden in the arid region

The panchkutta herbal Garden was established as demonstration block with 30 plants each of Lasora (Cardia mixa) cv. Thar Bold, Khejri (Prosopis cineraria) cv. Thar Shobha, Ker (Caparis decidua) seedlings and 20 plants each of kumatta (Senegaliasenegal) and phog (Calligonumpolygonoides) during September 2018 at 5 x 5 m spacing under complete organic cultivation practices with drip irrigation. During IRC 2023, the same block was included under natural farming project. At present, in panchkutta herbal garden, there are 30 plants of lasoda, 18 plants of khejri, 20 plants of kumatta, 14 plants of ker and 15 plants of Phog are live and under fruiting except ker plants.

During the reported period, 315 kg of lasora fruits were harvested at tender stage from 20 fruited plants. The highest fruit yield was reported to be 44 kg (Plant No 10) and lowest to 6 kg per plant in its first fruiting season under natural farming (Figure 1). Out of which, 177 kg of fruits were sold among institute staff and a revenue of Rs. 1770/- was generated from the block and remaining was used under post-harvest laboratory for value addition and other research activities.

In block some biotic stress incidences were recorded during the period. A sever infestation of tingid buf was reported in lasora plants during flowering time (Figure 2) and completely managed with two sprays of biopesticide "Thar Jaivik 41EC" @ 4ml/litre of water at 7 days interval. Another incidence was reported in during January 2024 a new threat to phog plant as a gall-forming insect attack on its foliage at the in panchkutta (Figure 3). It draws attention due to its infection severity, potential impact on the plant's health and its ecological and economic implications. At the initial stage it was reported on 2-3 plants and the infection severity was as high that more than 90% of its foliage's were converted in to galls as shown in the accompanying figure. The insect attacks the tender foliage at internodes, causing the internodes to swell and form gall. The microscopic examination of dissected galls revealed that the nymph stage of the insect was damages the internal part at internode junction, creating a cavity inside while the outer part swells into a gall-like structure. Upon maturation, the adult fly emerges, breaking through the gall.

**Effect of organic manures on growth, yield and fruit quality in ber**

The effect of organic nutrition in improving yield and quality of ber cv. Gola was studied at ICAR-CIAH, Bikaner. The treatments were control, FYM (40 kg plant), Vermi-compost (20 kg plant), FYM (40 kg plant) +Bio fertilizers, Vermi-compost (20 kg plant) + Bio fertilizers and

crop residue (20 kg plant) +Decomposer. All organic manures was found to be effective in improving quality of fruits as well the yield, soil microbial population and enzymes activity in soilas compared to control treatments. FYM or vermicompost and their combination with Bio fertilizers resulted higher fruits as well the yield, soil microbial population and enzymes activity in soil. The physico-chemical characters of ber were found to be superior with Vermi-compost + Bio fertilizers followed by FYM +Bio fertilizers as compared to others. Application of Vermi-compost + Bio fertilizers gave higher diameter, volume, average pulp fress weight, average stone fresh weight, T.S.S, vit.C and acidity which were 3.42cm, 23.50ml, 22.25gm, 1.19gm, 26.55%, 212.50mg/100g and 0.38%, respectively. Higher yield (14.90 kg/plant), enzymes activity i.e. Dehydrogenase (8.15µg TPF $g^{-1}$ dry soil $h^{-1}$), alkaline phosphatase (8.25µg p-NP $g^{-1}$ dry soil h-1) and Urease (395µg $NH_3^{-1}$g dry $soil^{-1}$h) and microbial population (Bacterial, Fungal and Actinmycetes population) were recorded in similar treatment

**Table: 1 Organic cultivation of ber**

| Treatments | Diameter (cm) | Volume (ml) | Av. Pulp fress wt (gm) | Av. Stone fresswt (gm) | T.S.S (%) | Vit.C (mg/100g) | Acidity (%) |
|---|---|---|---|---|---|---|---|
| Control | 2.78 | 19.16 | 18.32 | 1.08 | 19.16 | 102.51 | 0.19 |
| FYM | 2.99 | 21.53 | 20.21 | 1.18 | 21.22 | 107.89 | 0.24 |
| Vermi-compost | 3.41 | 23.36 | 22.73 | 1.20 | 22.25 | 108.81 | 0.28 |
| FYM +Biofertilizers | 3.20 | 22.05 | 21.79 | 1.21 | 21.74 | 110.54 | 0.30 |
| Vermi-compost + Biofertilizers | 3.59 | 24.68 | 23.36 | 1.25 | 22.86 | 111.57 | 0.33 |
| Crop residue +Decomposer | 2.92 | 20.74 | 19.58 | 1.13 | 19.67 | 106.34 | 0.21 |
| CD at 5% | 0.49 | 20.25 | 19.40 | 1.09 | 19.54 | 99.74 | 0.24 |

**Organic cultivation of Karonda**

An experiment was conducted on Eight-year-old plants of Karonda to know the effect of different organic manures on plant and soil, at ICAR-CIAH, Bikaner. There were six manurial treatments which consisted of different organic manures applied individually following R.B.D. Highest fruit yield (3.9 kg/plant) was recorded in plants where vermi-compost (20 kg plant) + biofertilizers was applied followed (3.6 kg/plant)by FYM +Biofertilizers, vermi-compost (3.7 kg/plant) and FYM (3.4 kg/plant) and minimum was observed on control (2.5 kg/plant) followed by crop residue +decomposer (2.8 kg/plant).

**Natural farming Vs INM on phalsa performance**

Natural Farming (or ZBNF) involves the application of Jeevamritha, Beejamritha, mixed cropping system, home-made preparations for plant protection and seed/planting materials, and mulching. Thus, it envisages complete freedom from chemicals from farming. Phalsa is a sub-tropical fruit and is commercially grown in Punjab, Haryana, Rajasthan, Uttar Pradesh, Madhya Pradesh and Bihar. Phalsa is also suitable for arid and semi-arid regions. Because of its hardy nature and capacity to tolerate high temperature it can be grown on a wide range of soil including moderately alkaline soils. Keeping in view, an experiment was conducted for comparison natural farming of phalsa Vs INM. Result revealed that phasla performance under natural farming is low comparison to INM in the first year of experiment which was conducted on five plantation. Application of FYM+100% NPK have higher fruit yield (3.57 kg/plant), Shoot length (1.65 cm), Internodal length (6.41 cm), fruit length (0.96 cm), fruit breadth (1.12 cm), pulp/stone ration (1.2), non -reducing sugar 1.84 (%), acidity (2.32 %), no.of fruit/node (12.25), no. of fruiting node/shoot (12.21), no. of shoot/plant (99), no. of leaves/plant (59.83), Juice (42.21%), weight of fifty fruit (30.57g), TSS (23.17%), total sugar (19.93%), ascorbic acid (27.83 mg/100 ml juice) and reducing sugar (17.99%), whereas, under natural farming, higher fruit yield , Shoot length, Internodal length , fruit length , fruit breadth, pulp/stone ration non -reducing sugar cidity, no.of fruit/node, no. of fruiting node/shoot, no. of shoot/plant, no. of leaves/plant, Juice, weight of fifty fruit, TSS, total sugar, ascorbic acid and reducing sugar were 3.2 kg/plant, 1.5 cm, 5.78cm, 0.92cm, 0.98cm, 1.1, 1.9(%, 2.5% , 11.5, 12.25, 95.78, 60.55, 40.41%, 29.58 g, 24.55%, 21.25%, 26.7mg/100 ml juic and17.5%, respectively.

**Table: 5 Natural farming Vs INM on phalsa at ICAR-CIAH, Bikaner**

| Treatments | No.of fruit/node | No. of fruiting node/shoot | Fruit yield kg/plant |
|---|---|---|---|
| Natural farming | 8.63 | 9.19 | 2.40 |
| FYM+100% NPK | 9.65 | 9.16 | 2.68 |

| | | | |
|---|---|---|---|
| FYM+100% NPK+ZnSO4 (0.4%) | 11.12 | 13.71 | 3.21 |
| FYM+75% NPK+ Bio-fertilizer consortium | 11.14 | 10.57 | 2.96 |
| FYM+50% NPK+ Bio-fertilizer consortium | 11.09 | 13.04 | 2.79 |
| CD at 5% | 1.57 | 1.70 | 0.43 |

**Table: 6 Natural farming Vs INM on phalsa at ICAR-CIAH, Bikaner**

| Treatments | Shoot length (cm) | No. of shoot/plant | No. of leaves/plant | Internodal length (cm) |
|---|---|---|---|---|
| Natural farming | 1.13 | 71.81 | 45.41 | 6.24 |
| FYM+100% NPK | 1.24 | 74.25 | 44.87 | 6.92 |
| FYM+100% NPK+ZnSO4 (0.4%) | 1.50 | 76.00 | 49.13 | 7.31 |
| FYM+75% NPK+ Bio-fertilizer consortium | 1.71 | 79.00 | 53.38 | 7.63 |
| FYM+50% NPK+ Bio-fertilizer consortium | 1.72 | 82.75 | 65.75 | 7.68 |
| CD at 5% | 0.22 | 11.71 | 7.89 | 1.09 |

**Table: 7 Natural farming Vs INM on phalsa at ICAR-CIAH, Bikaner**

| Treatments | Fruit length (cm) | Fruit Breadth (cm) | Weight of fifty fruit (g) | Juice % | Pulp/stone ratio |
|---|---|---|---|---|---|
| Natural farming | 0.73 | 0.77 | 23.34 | 31.67 | 0.87 |
| FYM+100% NPK | 0.76 | 0.88 | 24.12 | 33.35 | 0.95 |
| FYM+100% NPK+ZnSO4 (0.4%) | 0.81 | 0.90 | 26.96 | 35.51 | 1.01 |
| FYM+75% NPK+ Bio-fertilizer consortium | 0.83 | 0.95 | 28.96 | 34.97 | 1.04 |
| FYM+50% NPK+ Bio-fertilizer consortium | 0.80 | 0.95 | 27.75 | 36.35 | 1.06 |
| CD at 5% | 0.12 | 0.14 | 4.00 | 5.24 | 0.15 |

**Table: 8Natural farming Vs INM on phalsa at ICAR-CIAH, Bikaner**

| Treatments | TSS (%) | Reducing sugar (%) | Non - reducing sugar (%) | Total sugar (%) | Acidity (%) | Ascorbic acid (mg/100 ml juice) |
|---|---|---|---|---|---|---|
| Natural farming | 20.97 | 9.80 | 1.62 | 14.95 | 2.14 | 22.87 |
| FYM+100% NPK | 19.79 | 10.21 | 1.66 | 15.36 | 2.49 | 23.77 |
| FYM+100% NPK+ZnSO4 (0.4%) | 21.12 | 10.45 | 1.83 | 15.59 | 2.39 | 29.29 |

| | | | | | | |
|---|---|---|---|---|---|---|
| FYM+75% NPK+ Bio-fertilizer consortium | 21.55 | 10.46 | 1.83 | 15.58 | 2.13 | 29.21 |
| FYM+50% NPK+ Bio-fertilizer consortium | 22.37 | 10.49 | 1.84 | 15.64 | 2.27 | 30.74 |
| CD at 5% | 3.23 | 1.60 | 0.27 | 2.35 | 0.35 | 4.14 |

## Natural Farming of Ber

Organic farming, ecological farming and biodynamic farming are the components of natural way of farming. Natural farming is self-sustaining but it is difficult to meet our requirement to feed the increasing population. On the other hand, chemical farming yields much but possess the serious problems for soil, environment and human health. There is a path in between aforementioned two type of systems of farming, that is organic farming and its aim is to create integrated, humane, environmentally and economically sustainable agricultural production systems, which maximize reliance on farm-derived renewable resources and the management of ecological and biological processes and interactions, so as to provide acceptable level of crop, livestock and human nutrition, protection from pests and diseases and an appropriate return to the human and other resources employed (Lampkin, 1990; Neuerburg and Padel, 1992).

**Table: 9Natural Farming of Ber in the arid region**

| Treatments | Diemeter (cm) | Volume (ml) | Av. Pulp fress wt (gm) | Av. Stone fresswt (gm) | T.S.S (%) | Vit.C(mg/100g) | Acidity (%) |
|---|---|---|---|---|---|---|---|
| Control | 2.97 | 19.85 | 18.26 | 1.21 | 19.13 | 101.53 | 0.21 |
| Panchgavya | 3.40 | 21.20 | 21.34 | 1.58 | 16.80 | 95.39 | 0.25 |
| Agniastra | 2.82 | 17.00 | 15.54 | 1.34 | 22.65 | 81.54 | 0.30 |
| Jiwamrita | 3.20 | 20.00 | 20.10 | 1.68 | 18.71 | 100.77 | 0.28 |
| Tumbastra | 2.90 | 17.20 | 15.80 | 1.22 | 21.68 | 95.38 | 0.30 |
| Panchgavya + Jiwamrita | 2.92 | 19.60 | 18.92 | 1.54 | 20.21 | 39.23 | 0.29 |
| Tumbastra + Agniastra | 2.98 | 19.20 | 18.02 | 1.34 | 21.94 | 101.54 | 0.30 |
| Ghan-jiwamrita | 3.23 | 20.98 | 20.65 | 1.54 | 19.12 | 94.87 | 0.20 |
| Tharastra | 2.64 | 16.73 | 15.76 | 1.36 | 20.10 | 101.02 | 0.32 |
| Biochar | 3.23 | 18.62 | 17.43 | 1.39 | 20.02 | 95.89 | 0.22 |
| Straw mulching | 2.72 | 18.52 | 18.48 | 1.34 | 18.90 | 101.23 | 0.21 |
| CD at 5% | 0.36 | 2.26 | 2.16 | 0.17 | 2.39 | 11.09 | 0.03 |

The table compares various treatments and their effects on different parameters of a fruit produce. These parameters include diameter, volume, average pulp fresh weight, average stone fresh weight, total soluble solids (T.S.S), Vitamin C content (Vit. C), and acidity. The largest

average diameter was observed in "Ghan-jiwamrita" (3.23 cm) and "Biochar" (3.23 cm), indicating these treatments might promote better growth.The smallest diameter was recorded in "Tharastra" (2.64 cm)."Panchgavya" resulted in the highest volume (21.20 ml), closely followed by "Ghan-jiwamrita" (20.98 ml).The lowest volume was recorded for "Tharastra" (16.73 ml)."Panchgavya" showed the highest average pulp fresh weight (21.34 gm), suggesting it enhances fruit mass.The lowest weight was noted for "Agniastra" (15.54 gm)."Jiwamrita" led to the heaviest stones (1.68 gm), while the lightest stones were observed in the "Control" treatment (1.21 gm).Agniastra" resulted in the highest T.S.S (22.65%), indicating better sugar content and sweetness.The lowest T.S.S was observed in "Panchgavya" (16.80%).Control" treatment produced the highest Vitamin C content (101.53 mg/100g), closely followed by "Tumbastra + Agniastra" (101.54 mg/100g).The lowest Vitamin C content was in the "Panchgavya + Jiwamrita" treatment (39.23 mg/100g)."Tharastra" exhibited the highest acidity (0.32%), while "Ghan-jiwamrita" and "Straw mulching" showed the lowest acidity (0.20% and 0.21%, respectively).

"Ghan-jiwamrita" stands out as a balanced treatment with high diameter, volume, and pulp weight, coupled with moderate T.S.S and Vitamin C.

"Agniastra" and "Tumbastra" treatments enhanced the T.S.S values, indicating potential for sweeter produce.Traditional or control treatments seem to retain Vitamin C levels better compared to others, possibly due to fewer external additives.Treatments like "Tharastra" and combinations (e.g., "Tumbastra + Agniastra") tend to increase acidity, which could influence flavor profiles.The table highlights how different treatments impact fruit or crop quality. For growers targeting higher yield and sweetness, "Panchgavya" or "Ghan-jiwamrita" could be ideal. However, if Vitamin C content is a priority, traditional methods may still hold significance. The choice of treatment ultimately depends on the desired outcome, balancing yield, flavor, and nutritional content.

**Natural Farming of Aonla**

Aonla (Emblica officinalis Gaertn), also known as Indian gooseberry, is an important indigenous fruit crop and grown in all parts of the country under the diverse agro-climatic conditions. It has been regarded as sacred tree and known as 'Amritphal 'in ancient literature. It is used in Ayurvedic medicine for making Triphala and Chyavanprash. Owing to its hardy nature, high productivity, nutritive and therapeutic values, and its suitability for various kinds of value added products, aonla has now become an important fruit of 21st century (Pathak, 2003). The fruit is useful against several ailments, and can be made into various value-added products Fruit is also used to prepare aonla powder, which is superior to synthetic vitamin C in treating deficiencies. It is grown at an estimated area of 1,05,000 ha with an annual production of 12,78,000 tonnes (Anonymous, 2023). It is commercially cultivated in Uttar Pradesh, Uttarakhand,

Gujarat, Maharashtra, Rajasthan Tamil Nadu, Andhra Pradesh, Karnataka, Bihar, Haryana, Madhya Pradesh and West Bengal (Pathak 2003). Besides India, aonla Organic Culture of Tropical and Subtropical Fruit Plants trees are also found in the natural forests of Cuba, USA, Pakistan, Sri Lanka, Malayasia, China, Java and West Indies. In last two decades, there has been tremendous increase in the area under aonla cultivation across the country, utilizing the wasteland. This has resulted in efficient utilization of resources leading to better income to farmers, nutritional security coupled with enhanced employment and rehabilitation of wastelands (Singh et al., 2014c).

**Table: 10 Natural Farming of Aonla in the arid region**

| Treatments | Pulp fresh (g) | Stone (gm) | T.S.S (%) | Vit.C(mg/100g) | Acidity (%) | Moisture content (%) |
|---|---|---|---|---|---|---|
| Control | 24.31 | 1.78 | 10.78 | 210.00 | 1.74 | 85.25 |
| Panchgavya 3% spray (two spray) | 31.46 | 2.26 | 11.20 | 253.00 | 2.02 | 83.30 |
| Jiwamrita (10 ltr/plant) | 26.58 | 2.02 | 12.30 | 216.36 | 2.16 | 82.08 |
| Panchgavya + Jiwamrita Treatment | 32.13 | 2.31 | 11.30 | 262.81 | 2.07 | 84.60 |
| GhanJiwamrita(10 kg/plant)+Agniastra | 28.81 | 1.82 | 12.50 | 217.95 | 2.21 | 83.47 |
| GhanJiwamrita (10 kg/plant)+Tumbastra | 26.58 | 1.59 | 12.12 | 283.65 | 1.48 | 83.49 |
| GhanJiwamrita(10 kg/plant)+Agniastra + Tumbastra | 26.12 | 1.51 | 13.10 | 221.15 | 1.51 | 82.56 |
| CD at 5% | 4.20 | 0.28 | 1.79 | 35.68 | 0.28 | NS |

The table presents the effects of various treatments on fruit quality parameters, including pulp fresh weight, stone weight, total soluble solids (T.S.S), Vitamin C content (Vit. C), acidity, and moisture content. Here's a detailed analysis of the observations:The highest pulp fresh weight was recorded in the "Panchgavya + Jiwamrita Treatment" (32.13 g), suggesting this combination significantly enhances fruit mass.The lowest pulp weight was observed in "GhanJiwamrita + Agniastra + Tumbastra" (26.12 g).The heaviest stones were found in the "Panchgavya + Jiwamrita Treatment" (2.31 g) and "Panchgavya 3% spray" (2.26 g).The lightest stones were recorded in "GhanJiwamrita + Agniastra + Tumbastra" (1.51 g).The highest T.S.S was observed in "GhanJiwamrita + Agniastra + Tumbastra" (13.10%), indicating a higher sugar content and sweetness. The lowest T.S.S was noted in the "Control" (10.78%)."GhanJiwamrita + Tumbastra" produced the highest Vitamin C content (283.65 mg/100g), suggesting this treatment enhances nutritional value.The lowest Vitamin C content was seen in the "Control" (210.00 mg/100g).The highest acidity was recorded in "GhanJiwamrita + Agniastra" (2.21%), while the lowest acidity was found in "GhanJiwamrita + Tumbastra" and "GhanJiwamrita + Agniastra + Tumbastra"

(both at 1.48%).The highest moisture content was recorded in the "Control" treatment (85.25%), while the lowest was observed in "Jiwamrita (10 ltr/plant)" (82.08%).The "Panchgavya + Jiwamrita Treatment" exhibited a balance of high pulp weight (32.13 g) and significant Vitamin C content (262.81 mg/100g)."GhanJiwamrita + Agniastra + Tumbastra" resulted in the highest T.S.S (13.10%), making it ideal for growers targeting sweeter produce."GhanJiwamrita + Tumbastra" excelled in Vitamin C content (283.65 mg/100g), indicating its potential for boosting nutritional benefits.Treatments with "GhanJiwamrita + Tumbastra" and its combinations reduced acidity, which may improve palatability.Higher moisture content in the "Control" treatment may indicate less efficient nutrient utilization compared to other treatments.For **higher yield**and**balanced growth,** the "Panchgavya + Jiwamrita Treatment" appears most effective.For **enhanced Vitamin Ccontent**, "GhanJiwamrita + Tumbastra" is the preferred treatment.

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# Climate smart production technology of leguminous vegetable in arid and semi arid regions of the country

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## Introduction

India is endowed with varied agro-climatic condition, which can excel the vegetable production in next decades and fulfill the challenges of economical and nutritional security for a large group of vegetarian population. In India, almost all vegetable crops have been exploited at considerable level through intensive research and tremendous achievement has been attained both in crop improvement and production system. However, our per capita consumption and average productivity is still low as compared to developed countries.

The Indian arid and semi-arid regions are characterized by extreme temperature, erratic rainfall, poor soil and water quality, which ultimately limit the productivity. However, these conditions can favourably be utilized to enhance the productivity through advanced fruit technological interventions, resulting in more income by utilizing solar and wind energy, human work force, and developing infrastructural facilities which greatly favour in doubling the framer's income. In semi-arid region, a number of farming communities have small land holdings and poor resources, and cannot afford the burden of credit with available resources, but they can generate income by using scientific rainfed horticultural technologies. Due to erratic rainfall pattern in this region, appropriate technology is needed to increase productivity. With increasing biotic and abiotic pressure, most of the semi-arid regions are confronted with challenges of low productivity due to uncertain supply of water.

Millions of people are suffering from the disorder like malnutrition and under nutrition in the country especially, the poor people in the villages and tribal areas who cannot afford the vegetables from a market. The leguminous crops like Indian bean, cluster bean and cow pea has a potential in frighting the problems of protein and minerals in the malnutrition affected tribal areas. Therefore, documentation of traditional crop knowledge and dissemination of information relating the indigenous plant food utilization is very essential for solving nutritional problems. Apart from this, these beans (Indian bean, cluster bean and cowpea) forms excellent forage and they gives a heavy vegetative growth and covers the ground so well that it checks the soil erosion. As a leguminous crop, it fixes the atmospheric nitrogen and boosts the crop health. By introducing the above mentioned advanced agronomic practices would bring the tremendous increase in the crop yields and ultimately it increases socio economical conditions of the tribal people. The systemic research work on leguminous vegetable crops and their improvement for

yield, quality and pest and disease resistance has been taken at Central Horticultural Experiment Station (ICAR-CIAH), Godhra, Gujarat. Large number of germplasm of arid and semi-arid leguminous getable crops were maintained especially, the crops like dolichos bean, vegetable cowpea (both pole and bush types) and cluster bean has been maintained both at the CIAH, Bikaner as well its regional station. The wide variability was observed among the genotypes under study with respect to growth, yield and quality attributes including biochemical composition under rainfed semi-arid condition.

Leguminosae is one of the major family of the dicotyledons flowering plants, which comprises approximately more than 18000 species and which is further divided into 650 different genera. This Leguminosae family has great potential for use of its members in various forms on the basis types of plant but yet, this family is not much utilized (Young and Bharti, 2012; Varshney and Kudapa, 2013). Many members of this family are annuals and cultivated for their fresh pods foliage, tender shoots and roots as a vegetables and even they can be dried or processed for round the year availability (Rubatzky et al., 1997; Ntatsi et al., 2018).The today's agriculture is facing the problems of climate change conditions, leguminous vegetable crops could reduces its harmful effects and provide global food security (Abelson, 1992; Smit et al., 1996). Most of the underutilized and commercial cultivated leguminous vegetables are well adapted to extreme climatic conditions and have a high tolerance of different stresses like drought and mineral deficiency; they have a broad genetic base due to the absence of human interference (Nagarajan and Nagarajan, 2010). Also, legumes are well known for their nodules, which can support nitrogen fixation and protect the soil from the harmful effect of erosion (Ampomah et al., 2012).

Some of the leguminous vegetables like Pea (*Pisum sativum* L.), French bean (*Phaseolus vulgaris L.*), Indian bean (*Lablab purpureus* L.), Cowpea (*Vigna unguiculata*), Cluster bean (*Cyamopsis tetragonaloba* L.), Lima bean (*Phaseolus lunatus* L.), Broad bean (*Vicia faba* L.), Winged bean (*Psophocarpus tetragonolobus L*), Sword bean (*Canavalia gladiata* ), Soya bean(*Glycine max* L.) etc., are an important source of plant proteins in the human diet and are considered as **"meat of the poor"** (Heiser 1990). These crops can be grown in adverse climatic conditions even with use of minimum inputs to get maximum yields. Legumes are rich in protein because of a symbiotic relationship between the roots of legumes and nitrogen fixing bacteria belonging to the genus *Rhizobium*. The immature pods of legume vegetables are also high in vitamins A and C (M.S. Dhaliwal, 2017). They contain essential micronutrients, especially iron and folic acid, which are particularly important for women of child-bearing age and other vulnerable groups. Leguminous crops fix atmospheric nitrogen in the soil, thus improving soil fertility. It can be used as high quality livestock fodder and are planted to control soil erosion. The crops like Indian bean, cowpea, cluster bean and sword bean are performing well under ranifed arid and semi arid climatic conditions of our institute.

**Germplasm maintenance and status:** A total of 123 genotypes of dolichos bean (both pole and bush types),181genotypes of vegetable cowpea (both pole and bush types) and 62 genotypes of cluster bean were maintained and multiplied at ICAR-CHES (CIAH), Vejalpur, Gujarat.

**Indian bean or Dolichosbean**(L.) Sweet (Syn. *Dolichos lablab* L., 2n=22, Family- Fabaceae) is one of the most ancient crops among cultivated plants and an important legume as well as vegetable crop cultivated in the tropical region of Asia, Africa and America. It is commonly called as Indian bean, hyacinth bean, lablab bean, country bean, Egyptian bean, Tonga bean, field bean or sem. This multiplicity of names is indicative of the range of forms available globally and the fact that it has long been cultivated for human food and as a green manure.Two types of *Dolichos* bean are recognized, i.e., *purpureus*var. *typicus*, which is a garden type with soft edible pods having less fibre in their pod walls. The second type is*purpureus*var. *lignosus*, which is a field bean grown for dry seeds generally used as a pulse. Its pods have a characteristic aroma and the pod walls have high fibre content.

**Nutritive value**

Dolichos bean is an important source of proteins, minerals and dietary fibre. The pods have a strong flavour. Some varieties have purple colour of the pods, which disappears after cooking. Per 100 g of edible green pod contain moisture 86.1 g, carbohydrates 6.7 g, protein 3.8 g, fibre 1.8 g, minerals 0.9 g (calcium 210 mg, phosphorus 68 mg, sodium 55.4 mg, potassium 74 mg, sulphur 40 mg, magnesium 34 mg, iron 1.7 mg)and fat 0.7 g. The vitamin composition is: vitamin C 9 mg, vitamin A 312 IU, riboflavin 0.06 mg, thiamin 0.1 mg and nicotinic acid 0.7 mg. The mature seeds, however, contain anti-nutritional factors such as tannins, phylate and trypson inhibitors. Removing seed coat, soaking and proper cooking minimize activity of these compounds.

**Some of the Dolichos bean varieties developed at CHES, Vejalpur (ICAR-CIAH) and their features are as follows.**

**Thar Kiran:** It is an unique variety of dolichos bean developed by ICAR-CIAH, RS-Central Horticultural Experimental Station (CHES), Vejalpur, Godhra, Gujarat. It is having attractive shining purple pod colour with high yielding and rich in anthocyanins. It is in vigorous in growth having dark green leaves with purple veins. The whole plant has purple pigmentation in their stem, petiole, flower, leaf veins and pod. The plants have climbing (pole type) growth habit and grow up to 3.5-4.0 m and they require stacking or support for higher yield and better quality pod production. The pods are medium having an average pod length, pod girth and pod weight of 10.8cm, 5.33cm and 8.4g respectively. The fresh purple pods are harvested between 100 to 110 days after sowing. A total of 1100-1600 pods per plant with on an average yield of 7-9 kg/plant of fresh purple pods can be harvested under dry land semi arid conditions with yield potential of

60-63 t/ha. It has higher nutritional value in terms of antioxidants, proteins, vitamins, micro nutrients and minerals. It is rich source of anthocyanins (190 mg/100g), proteins (5.4g/100g) and other antioxidants like total phenols (376.5 mg GAE/100g), flavonoids (42.6 mg cat.equi/100g), total antioxidants (662.5 mg AAE/100g), β-carotene (5.4 mg/100g), vitamin C (89.34mg/100g) and lycopene (1.5mg/100g). The variety 'Thar Kiran' is performing well under rainfed semi arid conditions and showed resistance to dolichos bean yellow mosaic virus disease under field conditions.

**Thar Ganga:** This variety was developed by ICAR-CIAH, RS-Central Horticultural Experimental Station (CHES), Vejalpur, Godhra, Gujarat. It is having attractive long green pod appearance and heavy bearer. The plants have climbing (pole type) growth habit and grow up to 4.5-4.7 m. The plant requires stacking or support for higher yield and better quality pod production. The pods are longwith an average pod length of 17.5cm and pod girth 5.21cm with pod weight 15.2g is recorded. The first harvest of fresh pods starts at 98 to 110 days after sowing. A total of 800-1200 pods per plant with on an average yield of 8-10 kg/plant of fresh pods can be obtained under the rainfed semi arid conditions. It has higher nutritional value in terms of proteins (4.8g/100g), vitamin-C (7.2 g/100g), β-carotene (12.8 mg/100g) and other antioxidants like total phenols (264.6 mg GAE/100g), flavonoids (40.2 mg cat.equi/100g) and total antioxidants (345.5 mg AAE/100g).The variety 'Thar Ganga' is performing well under rainfed semi-arid conditions and found moderately resistance to dolichos bean yellow mosaic virus disease under field conditions.

**Thar Vinaya:** This variety was developed through pure line selection from local material collected from tribal forest areas of Ghoghamba taluk, Panchmahal district, Gujarat. It has attractive long, light green colour pods. It is pole type Indian bean variety with cluster pod bearing in nature. The plants have climbing growth habit and grow up to 4.0 - 4.6m.The plant requires stacking or support for higher yield and better quality pod production. Pods are long (14 cm), girth (4.20 cm) with pod weight (8.5g). It takes 90-91 days for first flowering & 102-105 days after sowing for first harvest. Yield total of 1000-1265 fresh pods/ plant with yield 6.5-7.5 kg/plant and 50t/ha of fresh tender pods. Nutritional value- proteins(4.2g/100g), Vitamin C (7.7 g/100g), beta carotene (7.2 mg/100g), total phenols (138.2 mg GAE/100g), & total antioxidant (158.65 mg AAE/100g). It is moderately resistant to dolichos bean yellow mosaic virus disease under field conditions.

**Thar Lakshmi:** This variety was developed through pure line selection from local material collected from tribal forest areas of Ghoghamba taluk, Panchmahal district, Gujarat. It is a Pole type variety having long flat and medium sized green colour pods. Length of pod 14 cm, girth 5.5 cm and weight 10 g. First harvest of fresh pods was start at 90-95 days after sowing. Total of 800-1240 pods/plant with on an average yield of 6.5-6.7 kg/plant and 45-50t/ha of fresh pods can be obtained under rainfed conditions. This genotype rich in proteins (4.2g/100g), vitamin C (8.8

mg/100g), beta carotene (11.8 mg/100g), flavonoids (36.2 mg cat.equi/100g) and total antioxidants (227.86 mgcat.equi/100g). This variety found moderately resistant to dolichos bean yellow mosaic virus disease under field conditions

**Thar Kartiki:** This variety was developed by ICAR-CIAH, Bikaner. It takes 70-75 Days for first flowering and 90-95 DAS for first harvest. Pod yield is 1.75 kg/plant and yield 110 q/ha.

**Thar Maghi:** This variety was developed by ICAR-CIAH, Bikaner. It is high yielding, stable and found to be the most potential for commercial cultivation. For first marketable harvesting, it took 90-95 days in comparison to AHDB-3 (95-100 days). Average pod yield 1.77 kg/plant and tender post yield is 113.25 q/ha.

**Production technology of Dolichos bean**

**Soil and climate**

*Dolichos*bean is a cool season crop. It grows well under warm, humid conditions at temperatures ranging from 18-35°C and is fairly tolerant to high temperatures. The bean is drought hardy and is grown in wide areas under diverse climatic conditions such as arid, semiarid, Subtropical and humid regions, low lands and uplands**.**pH varying from 5.3 to 6.0 is suitable. The varieties suitable for cultivation under long day and short day conditions are different.However, some photo-insensitive varieties can be grown throughout the year.

**Sowing, Seed rate and Spacing**

The seeds are dibbled or drilled behind the plough. The climbing types are sown near houses and allowed to climb on the roof tops. The seed rate for this crop is 50-60kg/ha for bush types with spacing of 30 x 60 cm and 5-6 kg/ha for pole type with a spacing of 75 cm X 1-1.5 m is followed.

**Manure and fertilizer**

About 25t/ha of well decomposed FYM should be applied to the soil at the time of land preparation. Application of NPK 20:60:60 kg/ha is recommended. Half of N along with entire dose of P and K fertilizer should be applied at sowing time. The remaining half dose of N should be top dressed 30 days after sowing.

**Intercultural operations**

Weeds may be controlled mechanically or by using weedicides. Pre sowing application of fluchloralin @ 2litre/ha check the weed growth for 20-25 days. Pole type dolichos bean needs support, since the plants have climbing growth habit. The plants should be trained on thin bamboo stakes or small iron poles for better growth and fruit set. Over-crowding of plant vines due to non-staking affects formation of pods and yield adversely. Staking improves plant spread and photosynthetic activity. As a result, there is higher yield due to higher number of pods per

plant. Light irrigation is given when required. For higher yield the crop should be irrigated regularly at 7-10 days interval. Flowering and pod development period are the critical stages.

**Harvestingand Yield:**

In bush type, the crop is ready for harvest two months after sowing and only 3-4 picking are obtained. In pole type, it takes 3 months for first harvest with 9-10 pickingat 8-15 days interval. Fully grown immature pods are harvested. Improved varieties of dolichos bean (Pole type) give an average yield of 30-40 tonnes/ha of fresh pods.

**Cowpea** (*Vigna unguiculata* L. 2n=2x=22) is a warm season, annual and herbaceous legume known by various names such as black-eye bean, China pea, southern pea and *lobia*. It is one of the most ancient human foods and has probably been cultivated since Neolithic times. *Vigna unguiculata* ssp.*unguiculata* (dual purpose type) is widely distributed. Other cultivated species of cowpea is *Vigna unguiculata* var. *sesquipedalis,* known as yard long bean or vegetable cowpea or asparagus bean is used as vegetable.

**Nutritive value:**

Cowpea is low in saturated fat and very low in cholesterol and sodium. 100g of green tender pods contain 4.3g protein, 2.0g of fibre, 8.0g carbohydrates, 74mg phosphorus, 2.5mg iron, 13.0mg vitamin-C, 0.9mg minerals etc. Cowpea is called as vegetable meat due to high amount of protein in grain with better biological value on dry weight basis. On dry weight basis, cowpea grain contains 23.4 per cent protein, 1.8 per cent fat and 60.3 per cent carbohydrates and it is rich source of calcium and iron (Gupta, 1988).

**Vegetable cowpea & Yardlong bean varieties developed at CHES, Vejalpur and their features are given below.**

**Thar Jyothi (Bush cowpea):** This variety was developed by ICAR-CIAH, RS-Central Horticultural Experimental Station (CHES), Vejalpur, Godhra, Gujarat. It is a **photo insensitive** type and **high yielding** variety of vegetable cowpea**.** It grows up to of 50-56 cm height, having dark green leaves with dark green pods which can be cultivated round the year. It is having short stature (bushy growth habit) grows up to of 50-56 cm height. It is an **early flowering** and **early maturing** variety. It takes 40-42 days for first flowering and 48-50 days after sowing for first harvesting of fresh tender dark green colour pods. This variety has an average pod length of 25 to 26.50cm with pod girth of 2.5cm and pod weight of 9.65g. The total number of pods per plant varies between 120-150 and an average yield of 1.5 to 2.0 kg/plant of fresh pods was obtained with yield potential of 20-25 t/ha. The 'Thar Jyothi' is rich in nutritional value in terms of proteins (4.82g/100),vitamin-C (55.8mg/100g), calcium (460.5 mg/100g), magnesium (252.12 mg/100g), phosphorus (105.64 mg/100g), sodium (20.3 mg/100g), potassium (206.5 mg/100g), iron (5.2 mg/100g). It contains antioxidants like phenols (2.435 mg/g) and total antioxidant activity (14.0µ.moltrolox.equi./g).The variety 'Thar Jyothi' performing well under rainfed semi-

arid conditions and has exhibited tolerance to cowpea mosaic virus and rust diseases under rainfed semi-arid conditions.

**The striking features of yardlong bean varieties viz., Thar Prateeksha, Thar Deeksha and Thar Surya as follows below.**

**Thar Prateeksha:** It has attractive long light green colour pods. It is an early flowering (38-40 days) and early maturing (45-48 days) variety with 66.00 cm pod length, 3.4 cm pod girth and 32.0g pod weight. It bears 120-150 pods/plant with an average yield of 3.0kg/plant of fresh pods. Nutritionally, it is rich in terms of proteins (6.0mg/100g), vitamin-C (14.5g/100g), Calcium (420.30 mg/100g), Magnesium (248.6 mg/100g), Phosphorus (258.84 mg/100g), Sodium (22.0 mg/100g), Potassium (294.5 mg/100g) and Iron (5.3 mg/100g). Antioxidants like total phenols (2.8 mg/g) and total antioxidant activity (8.7µ.moltrolox.equi./g). This variety is moderately resistant to cowpea mosaic virus disease under field conditions.

**Thar Deeksha:** It is an early flowering and early maturing variety (Pole type) which has attractive long & light green colour pods. It takes 29-30days for first flowering and 36-38 days after sowing for first harvesting of fresh tender pods. The pods have 52.0-54.0cm length, 3.30cm girth and 28.0-30.0g pod weight. It bears 150-180 pods/plant with an average yield of 3.0kg/plant of fresh pods. Nutritional value in terms of proteins (5.8mg/100g), vitamin-C (18.5 mg/100g), Calcium (268.30 mg/100g), Magnesium (262.6 mg/100g), Phosphorus (155.96 mg/100g), Sodium (8.0 mg/100g), Potassium (316.5 mg/100g) and Iron (4.3 mg/100g). Antioxidants like total phenols (2.8 mg/g) and total antioxidant activity (18.7µ.moltrolox.equi./g).

**Thar Surya:** It is an anthocyanin rich (190-200mg/100g) variety (pole type) having attractive long & dark purple red colour pods. It is an early flowering and early maturing genotype. It takes 35-36 days for first flowering and 44-46 days after sowing for first harvesting of fresh tender pods. The pods have 52.50cm length, 2.5cm girth and 23.0g pod weight. The total number of pods per plant varies 180-200 pods/plant with an average yield of 2.5 to 3.0kg/plant of fresh pods. Nutritional value in terms of proteins (5.2mg/100g), vitamin-C (17.2mg/100g), Calcium (258.50 mg/100g), Magnesium (226.6 mg/100g), Phosphorus (212.84 mg/100g), Sodium (12.0 mg/100g), Potassium (394.5 mg/100g) and Iron (3.96 mg/100g). Antioxidants like Anthocyanins (190-200mg/100g), total phenols (3.17mg/g) and total antioxidant activity (19.24µ.moltrolox.equi./g).

**Production technology of Vegetable cowpea**

**Soil and climate:**

Cowpea is a warm season crop and comes up well under rainfed conditions where temperature ranging from 21 to 35°C. It can tolerate hardy conditions including high temperature, drought and poor soil with 6 - 7 pH range.

**Sowing time, spacing and seed rate:**

In India the crop is grown almost all the season mainly kharif with onset of monsoon ranging from early June to end of July, Rabi- October to November (Southern India), summer – February- March (grain) in north Indian plains and April-May in Hills. The seeds of busy varieties are sown at a spacing of 30 x15cm, and or semi trailing varieties 45x30cm. The seed rate of cowpea is 20-30 kg/ha for bush and semi trailing varieties.

**Manures and Fertilizers**

Although cowpea is a legume crop, it responds well to the application of fertilizers. About 25 t/ha of FYM is applied at least fifteen days before sowing. A fertilizer dose of 25:75:60: kg NPK/ha is recommended. Half of the N, full P and K are applied as basal dose and remaining half N is applied 25 -30 days after sowing.

**Intercultural operations**

Shallow cultivation during the early stages of crop is necessary to check the weeds and to facilitate earthing up. Two hand weeding are required before the earthing up. Cowpea is a hardy crop comes up well in rainfed conditions. Flowering and pod development periods are the critical stages. It is sensitive to water logging and requires less moisture compared to other vegetables. Depending on the atmospheric conditions two or three protective irrigations may have to be given. Yardlong bean is climbing in nature and it needs support/stacking with bamboo or iron poles with gunny threads or coir or plastic wire for its commercial cultivation.

**Harvesting and Yield**

Tender pods are harvested after attaining full size but before they become fibrous. Harvesting starts 45 days after sowing. In bush type varieties 2-5 harvests are possible. Trailing/pole type varieties usually harvested at alternate days. The green pod yield of 4-5t/h in bush varieties and 7-8t/ha in semi trailing varieties are obtained. Yardlong bean varieties usually harvested at alternate days. The improved varieties of yard long bean give yield of 20-25t/ha of fresh pods.

**Cluster bean** (*Cyamopsis tetragonolobus* L.Taub.), commonly known as *guar*, has come to be recognized as one of the most important commercial crop of arid and semi-arid region. it is grown for its tender fruits as vegetable. India is the world leader with 80% production of guar with its cultivation in semi-arid, North-Western parts of country encompassing States of Rajasthan, Gujarat, Haryana, Punjab and parts of southern India.

**Nutritive Value and Uses:** each 100g of fruit contains 10.8g carbohydrate, 3.2g of protein, 1.4g minerals, 316IU vitamin-A and 47mg of vitamin-C. The seed of clusterbean contains about 30-33% gum in the endosperm. Moreover, its gum also used in many other industries like pharmaceuticals, cosmetics, mining, textile, paper, oil drilling, explosive industry and food

industry.etc. Its plant, seed and straw are good source of nutritive fodder and feed for livestock. It is also raised as a green manure and cover crop. Being a leguminous crop, it enriches the soil fertility by fixing the atmospheric nitrogen (Girish *et al*., 2012).

**The evaluation and performance of promising genotypes in Cluster bean**

The Cluster bean genotypes were evaluated for their morphological, yield and quality attributes under rainfed semi-arid conditions at Central Horticultural Experimental Station (ICAR-CIAH) Vejalpur, Godhra, Gujarat. The data were recorded for growth, yield and quality parameters, incidence of pest and diseases. Among them, the genotypes like CHESCB-60, CHESCB-59, CHESCB-25 and CHESCB-24 are superior with respect to fresh number pods and pod yield. The promising genotypes (CHESCB-25 & CHESCB-24) and variety Goma manjari their different horticultural traits are given below.

**Goma Manjari:** This variety was developed by ICAR-CIAH, RS-Central Horticultural Experimental Station (CHES), Vejalpur, Godhra, Gujarat. The plants are erect, single stemmed, bearing in clusters of 30 to 305 with 9-10pods per cluster at short internodes. Pods are medium-long, thin, smooth, green, non fibrous and stringless. The variety is photo insensitive, drought hardy with a crop period of 75 to 85 days. It is best suited for inter and mixed cropping and nutrition garden at closer spacing of 45×15 cm. It has moderate field resistance to major diseases like bacterial blight, powdery mildew and alternaria leaf spot.

**Thar Bhadavi:** This variety was developed by ICAR-CIAH, Bikaner. It is high yielding variety which has 9.0 cluster/plant. Plant height is 65-70 cm. First harvest is 55-60 days after sowing. Pod yield potential is 65-125 q/ha.

**CHESCB-25:** It is single stem growth behavior with green colour pods, having an average pod length of 11.00cm and an average pod girth of 2.5cm with pod weight of 3.93g.The total number of pods per plant varies 280-320 with an average yield of 1.2kg/plant of fresh pods.

**CHESCB-24:** It is single stem growth behavior with green colour pods, having an average pod length of 11.02 cm and an average pod girth of 2.8cm with pod weight of 3. 12g.The total number of pods per plant varies 300-320 with an average yield of 1kg/plant of fresh pods.

**Production technology of Cluster bean**

**Soil and Climate**

It is a drought tolerant, multi-purpose legume crop cultivated mainly in the *kharif* season in arid environment. A crop that can be raised in poor soil with 7-8.5 pH and require lower agronomic inputs is currently cultivated predominantly in arid regions of northern-western parts of India. It thrives well on light texture, sandy to sandy loam soils receiving 300-500 mm annual rainfall. The crop requires 30 to 35ºC temperatures at the sowing time for proper germination and 32 to 38ºC temperature encourages good vegetative growth, but high temperature at

flowering stage can result in pre-mature flower drop. It can tolerate temperature as high as 45-46ºC.

**Sowing, Seed rate and Spacing**

In India, farmers sow guar mainly by traditional method of broadcasting. But in order to ensure uniform germination, to maintain optimum plant population and easy intercultural operations, sowing should be done in rows. Seed rate also depends on variety, purpose and time of sowing. Generally 10-12 kg seed per hectares is recommended for spreading type varieties whereas 15-16 kg /ha for un-branched varieties. spacing should be done 10-15 cm plant to plant distance in a row and 35-60 cm row to row distance on the basis of rainfall, soil type and inputs availability. For low rainfall (200-350 mm) spacing of 60 x 10 cm, semi-arid, having moderate rains (450-500 mm), and the spacing should be 45 x 10 cm and those regions having still higher rainfalls (550-600 mm) spacing of 30x 10 cm would be fallowed.

**Manures and Fertilizers**

Though a hardy legume, clusterbean responds to fertilizer application. About 25 t/ha of FYM is applied at least fifteen days before sowing. A fertilizer dose of 50:60:60: kg NPK/ha is recommended. Half N, full P and K are applied as basal dose and remaining N, 25 -30 days after.

**Intercultural operations**

The fields of clusterbean are kept free of weeds during initial stages. Generally manual weeding is very effective for controlling all type of weeds. Two manual weeding is given at 25 and 45 days after sowing are sufficient to keep the crop weed free. Cluster bean is grown as rainfed crop in arid and semi-arid condition but for better yield irrigation should, however, be provided whenever, crop suffers moisture stress. Irrigation at flowering and fruiting stages is the most critical. Irrigation may be done at 7-10 days interval. Staking is necessary to avoid the lodging in tall varieties.

**Verities:** PusaMausami, PusaSadabahar, PusaNavabahar, Sharad Bahar, Thar Bhadavi, Goma Manjari and Durga jay, Durgapurasafed, Durga Bahar, Agaita Guara-111 and Agaita Guara-112 etc.

**Harvesting and yield**

Green pods will be ready for harvest 40- 45 days after sowing and pods are harvested at tender stage. Dry seeds are harvested when a maximum percentage of pods are full n dost of the remaining will turn yellow. Average yield of green pods is 5-8 t/ha and seed yield of 0.6 to 1.0 t/ha are expected within a crop duration of 120 days.

## Summary

Thus, the leguminous crops like Indian bean, cluster bean and cow pea has a potential in role to overcome the problems of protein and minerals in the malnutrition affected tribal areas. Therefore, documentation of traditional crop knowledge and dissemination of information relating the indigenous plant food utilization is very essential for solving nutritional problems. Apart from this, these beans (Indian bean, cluster bean and cowpea) forms excellent forage and they gives a heavy vegetative growth and covers the ground so well that it checks the soil erosion. As a leguminous crop, it fixes the atmospheric nitrogen and boosts the crop health. By introducing the above mentioned advanced agronomic practices would bring the tremendous increase in the crop yields and ultimately it increases socio economical conditions of the tribal people. Climate change is inflicting serious threat to global food security, biodiversity and sustainable development. One of the strategies to adapt and mitigate climate change effects involves adaption of climate resilient crops. Dolichos bean, cowpea and cluster bean other legume vegetables have a huge potential to play a crucial role in sustainable agriculture, nutritional and income security of small and marginal farmers in dry and semi-arid regions of the country

The varieties of dolichos bean (Thar Ganga, Thar Kiran, Thar Vinaya, Thar Lakshmi, Thar Maghi and Thar Kartiki) and cowpea (Thar Jyothi), yardlong bean types (Thar Prateeksha, Thar Deeksha and Thar Surya), Cluster bean (Goma Manjari and Thar Badhavi) have greater adoptability, high nutritional value and with minimum agronomical inputs will fetches higher yield under rainfed semi-arid conditions.

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# Establishment of nursery and propagation of arid fruit crops for rural entrepreneurship and income generation

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## Introduction

The growing commercialization and consumer-driven tendencies in a globalized economy have significantly impacted traditional areas of nursery and plant propagation. The profitability of such technologies must be clearly demonstrated. In the case of nursery enterprises, high input costs can be easily offset through bulk production, high productivity, and low mortality rates. An economic evaluation of a plastic house for year-round grafting revealed a net return of Rs 39,295 from a 75 $m^2$ low-cost polyhouse within just six months. Nursery operations not only involve the production and supply of grafts and seedlings but also require strategic marketing efforts to reach the maximum number of clients. This is especially important for perennial horticultural crops, which have long gestation periods, with results only visible in later stages. Timely availability of plantlets also helps mitigate issues caused by erratic weather conditions, as witnessed in recent years. Losses during plant multiplication in nurseries can be minimized by implementing high-tech facilities and addressing common errors. Therefore, the nursery sector is poised to play a key role in employment generation and as a lucrative enterprise in the evolving national landscape.

A nursery serves as the foundation for successful planting. In a typical nursery, several activities can be carried out, including raising plant seedlings, growing rootstocks, propagating improved crop varieties, vegetative propagation, conserving delicate seedlings, multiplying rare plant types, and generating income. High-tech facilities in nurseries play a crucial role in increasing the success rate of grafting and rooting cuttings, enhancing seedling vigor, reducing transplant shock, and generally minimizing manual labor. Nursery management has evolved into a commercial venture, with retail nurseries selling planting materials to the general public and supplying the needs of institutions and private estates. Entrepreneurship is the ability and willingness to develop, organize, and manage a business venture, taking on associated risks to generate profit. In economics, entrepreneurship, when combined with land, labor, natural resources, and capital, can lead to profitable outcomes. With this in mind, anyone aspiring to start a nursery business must understand the different types of nurseries, their components, profit management strategies, and the common errors encountered in nursery operations, along with precautionary measures to overcome them.

**Types of nursery enterprises**

Different types of nursery plant production can provide avenues of employment and availability of plants through sale. Based on business type and size classified in following ways:

1. **Based on business type-**

**A. Production nurseries (wholesale nurseries)-** Propagate plants and grow seedlings and either sell them direct to retail outlets, landscapers and horticulture or forest departments, or wholesale them to growing –on nurseries. Important features of successful production nurseries.

Innovation- supplies new varieties to the market or developing new ways of growing and allow the grower to develop new markets for existing varieties.

Specialization- growing fewer lines in larger quantities allows the grower to improve efficiency.

Meeting market demands- knowing market demand and customer's choice or are likely to want, and growing them in sufficient quantities allows the grower to meet consumer's requirements and maintain customer loyalty.

**B. Growing-on nurseries-** Growing-on nurseries buy bulk quantities of seedlings or small plants from propagators. At the time of purchase, the plants are grown in plugs, trays or tubes and then the plants are potted into larger containers and grown for a period of time, adding value to the nursery's purchase. In addition to increasing plant size, specialized growing techniques, such as topiary, may be used to add value to the plant during the growing –on phase. The most critical aspect of production in growing-on nurseries is developing a quality product for the retail market. At the time of resale, every plant must be at its peak, displaying healthy, vigorous and sturdy growth.

**C.Mail order nursery-** It is a specialized type of whole sale nursery. It depends primarily on the catalogue display of the plants, which it offers for sale. Customers see the catalogue and order or receive the plants through mail or parcel service. This nursery is located in the locality, where land is comparatively cheaper and labour, water and transport facilities are easily available.

**D. Retail nurseries-** Retail nurseries buy plants from production/propagation nurseries and resell them in small quantities as per consumer's need. In addition, the retailer also sells seedlings, bulbs, containerized and bare-rooted plants, pots, packaged potting mixes, fertilizers, sprays and bulk landscaping materials.

2. **Based on business size-**

**A. Small size nurseries (Home nursery/ Company nursery)-**It is small in size (500 sq. meter area) in which the plant materials are grown to meet the demand for own use and closely

related persons. This type of nursery is only for personal use for beautification of own home, specific colony and company garden. The main objective of such nursery is to provide the quality materials. Usually costly method of nursery practices is followed in this type of nursery for raising high quality planting materials. Annual plant production of small nursery is less than 5000 plants; here the economy does not play a major role.

B. **Medium size nurseries-** It is medium in size (500-2500 sq. meter area) in which the plant materials are produced to meet out the demand of local specified area for particular crops. Medium size nurseries should be located in the specific crop producing area like papaya production, mango production, and citrus production area. Utilization of available farm machinery, human power and other resources are main objectives for producing quality planting material. Average annual plantlet production of medium nursery is 5000 to 50000. It is a supplementary business of farmers.

C. **Large nursery (Commercial nursery) -** This type of nursery is large in size (2500-10000 sq.meter area) and the main objective of such nursery is to earn money on investment. Costly nursery practices are usually avoided and there is optimum utilization of available resources. Moreover, the control on quality of planting material is also reduced but quantity and types of plants are increased. Commercial nurseries should be located in the well connected cities, towns and in the villages. Average annual plantlet production of large nursery is more then 50000.

Nursery unit at ICAR-CIAH, Bikaner

**Components of nursery**

For starting up nursery as an enterprise general idea about nursery components is needed these are as under:

**i. Fence: -** Prior to the establishment of a nursery, a good fence with barbed wire must be erected all around the nursery to prevent tress pass of animals and theft. The fence could be further strengthened by planting a live hedge, with thorny fruit plants. This also adds beauty in bearing and also provides additional income through sale of fruits and seedling obtained from the seed eg. Karonda, Opuntia, ker, jharber etc suited to this arid region.

**ii. Roads and paths:-** A proper planning of roads and paths inside the nursery will not add only beauty, but also make the nursery operation easy and economical. This could be achieved by dividing the nursery into different blocks and various sections. But at the same time, the land should not be wasted by unnecessarily lying out of paths and roads.

**iii. Progeny block / mother plant block:-** The nursery should have a well-maintained progeny block or mother plant block/scion bank planted with those varieties in good demand. A well managed progeny block or mother plants block will not only create confidence among the customers but also reduces the cost of production and increases the success rate of grafting/budding/layering because of availability of fresh scion material throughout the season within the nursery and there will not be any lag period between separation of scions and graftage. There are so many cultivars for fruit crops, grow only important cultivar in mother blocks as per demand and germplasm conservation.

**iv. Irrigation systems:-** Horticultural nursery plants require ensured supply of water for irrigation, since they are grown in portrays, poly bags or pots with limited quantity of potting mixture. Generally, it is assumed that the daily requirement of water @ 200 litre per 1000 seedlings for irrigation (depending on kind of soil and weather conditions).

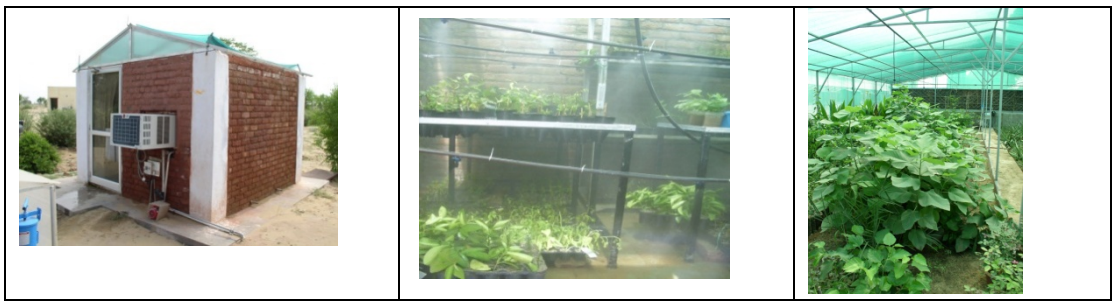
**v. Office cum stores:-** An office-cum-stores is needed for effective management of the nursery. The office buildings may be constructed in a place, which offers better supervision and also to receive customers. The office buildings of suitable sizes are needed for storing materials use in plant raising.

**vi. Seed beds: -** In a nursery, this components is essential to raise the seedlings and rootstocks. These are to be laid out near the water source, since they require frequent watering. Beds of 1-1.5 meter width of any convent length 10-15 meter are to be made. A working area of 60 cm between the beds is necessary. To avoid flow of water outside the beds in dry areas usually 15 cm deeper than the normal ground level beds (sunken beds) are made.

**vii. Nursery beds:-** Rising of seedling / rootstock in poly bags requires more spaces compared to seed beds. Nursery beds area should also have a provision to keep the grafted plants either in trenches of 30 cm deep and 1m wide so as to accommodate 500 grafts in each bed. Such beds can be irrigated either with a rose fitted to a flexible hose pipe or by overhead micro-sprinklers.

**viii. Potting mixture:-** For better success of nursery plants a good potting mixture is necessary. The potting mixture may be prepared well in advance by adding sufficient quantity of sand: clay: FYM and fill in Polybags. For portray media mixture containing vermiculite, perlite and cocopeat gave better result.

**ix. Propagation Structures:** Propagation structures useful for multiplication of grafts and seedlings. Generally 200 $m^2$ poly house units with shade house of 400 $m^2$ and 15 $m^2$ mist chamber facilities are sufficient for propagation of fifty thousand saplings per annum.

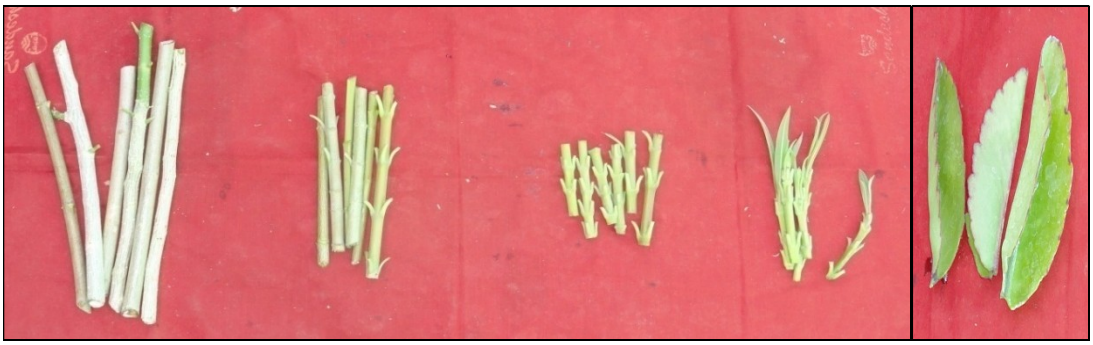


Mist chamber and hardening unit in nursery

## Techniques used in vegetative propagation of fruit crops :

Vegetative method of propagation includes cuttings, layering, grafting, budding and propagation by other special organs like bulb, corm, rhizome, tuber, tuberous root, sucker, runner, offset, crown etc. Each plant is propagated by specific method at specific time period. One method of propagation and time may not be suitable for other plants.

- ***Cutting-*** Plant parts that are normally used for this purpose are stems, roots, leaves and modified stems such as tubers, corms and rhizomes, runners and bulbs. This method is very popular, particularly because it is the cheapest and most convenient one. In arid fruit crops mostly use in pomegranate, mulberry, fig, lemon, ker etc.



**Hard Wood** **Semi-hard wood** **Soft wood** **Herbaceous** **Leaf**

- **Accelerated growth techniques (AGT) in soft wood cuttings: -** 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 (Sarolia *et al*., 2018).

- ***Layering-*** The method of inducing roots in a stem which is still attached to the plant and then detaching it after the root is formed for transplanting is called a layering or layerage. Mostly creepers and trees are raised by this method. Lime, guava, muscadania grape, pomegranate etc. propagated by this means.

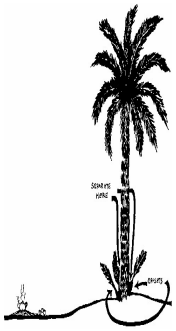
**Plant (lime) propagation by air layering**

- ***Division and separation-*** The plants which produce masses of stems at ground level, each having its own root system are lifted from ground and divided into individuals. This is called division. In separation, the rooted or unrooted parts usually detach themselves on maturity and start or develop as a new individual next season. Plants like chrysanthemum, tube rose, *Russelia juncea* and most of the herbaceous perennials are easily propagated by division. Bulb hyacinth and crocus are examples of plants that can

be propagated by separation. Suckers, rhizomes, tubers, runners, stolons, bulbs, corms, bulbils, etc., are some other plant parts which are used for vegetative propagation.

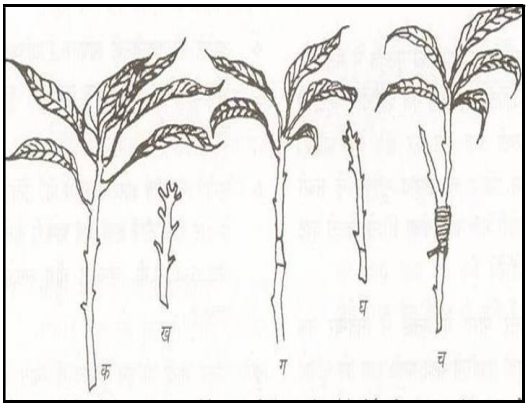
Strawberry -Runner

Banana -Suckers



Date palm-off shoot

- ***Grafting-*** Grafting, except budding (which is also a form of grafting) is not widely used in ornamental horticulture except in a few cases. The types of grafting which are used in ornamental plants are limited to inarching, side grafting, splice grafting, saddle grafting, flat grafting and cleft grafting. Inarching is followed in the propagation of mango, guava in some parts of the country. The method of side grafting is followed in jamun, bael, mango, tamarind, custard apple etc.



Soft wood grafting-Jamun, mahua, custard apple *etc*

- ***Budding-*** mostly 'T'-budding or 'Shield' budding is employed for propagation of khejri, sweet orange, mandarin, lasoda, bael, ber *etc*.


Budding-in situ in bael

**Methods of propagation in fruit crops.**

| S.N. | Name of fruit | Methods of propagation | |
|---|---|---|---|
| | | **Standardized method of propagation** | **Commercial method** |
| 1 | Acid lime | Seed, budding | Seed |
| 2 | Almond | Tongue grafting and T-budding | T-budding |
| 3 | Aonla | Budding | T-budding/ Patch budding |
| 4 | Apple | Tongue grafting, stooling for rootstocks, cutting under mist | Tongue or whip grafting |
| 5 | Apricot | Budding and grafting | Grafting & T-budding |
| 6 | Avocado | Grafting (cleft, side, whip), chip budding, and cutting | Layering, T-budding |
| 7 | Bael | Root cutting, budding, layering | Patch budding |
| 8 | Banana | Suckers (sword) and micro propagation | Micropropagated plantlets |
| 9 | Ber | Budding (T, I, ring and forkert) | *In-situ* budding (T-budding) / Polytube budding method |
| 10 | Cape gooseberry | Seed | Seed |
| 11 | Cashew nut | Seed, grafting (soft wood, epicotyls) | Soft wood grafting |
| 12 | Cherry | Whip/tongue grafting | Layering, whip or tongue grafting |
| 13 | Coconut | Seed, division of growing shoots, air layering | Seed |
| 14 | Custard apple | Soft wood grafting | T-budding/ inarching |
| 15 | Date palm | Seed, offshoots | Off shoot (suckers) |
| 16 | Fig | Cutting, budding and air layering | Hard wood cutting |

| | | | |
|---|---|---|---|
| 17 | Grape | Hard wood stem cutting, leaf cutting, bud cutting, layering, chip budding and micro propagation | Hard wood cutting |
| 18 | Grape fruit | Seed and budding | T-budding |
| 19 | Guava | Cutting, air layering and budding | Stooling, Inarching |
| 20 | Jackfruit | Inarching, air layering, cutting, epicotyls grafting, budding (forkert, chip and patch) | Inarching |
| 21 | Jamun | Seed and budding | Shield & patch budding |
| 22 | Ker | Seed and suckers | Suckers/ seed |
| 23 | Karonda | Seeds | Seeds/ hard wood cutting |
| 24 | Lemon | Seed and layering | Air layering |
| 25 | Litchi | Air layering, splice grafting, inarching, budding (chip), cutting (soft wood) | Air layering |
| 26 | Loquat | Budding, grafting and seed | Inarching |
| 27 | Mandarin | Seed and budding | T/shield budding |
| 28 | Mango | Inarching, side and veneer grafting, budding, stool layering, and cutting | Inarching, softwood grafting |
| 29 | Mangosteem | Inarching and seed | Seed and Inarching |
| 30 | Mulberry | Cutting and budding | Stem cutting/ shield budding and cutting |
| 31 | Olive | Budding | T-budding |
| 32 | Papaya | Seed and cutting with heel | Seed |
| 33 | Passion fruit | Stem cutting | Seed |
| 34 | Peach | Seed, budding, and grafting | T-budding & tongue grafting |
| 35 | Pear | Tongue grafting and double grafting | Tongue or whip grafting & T-budding |
| 36 | Pecan | Grafting and budding | Patch budding |
| 37 | Persimon | Grafting (cleft and whip) and budding (chip and T) | Crown grafting |
| 38 | Phalsa | Seed and cutting | Seed |
| 39 | Pilu | Suckers | Root suckers/layers |
| 40 | Pineapple | Suckers (crown, root and | Sucker, slip |

| | | | |
|---|---|---|---|
| | | shoot), slips | |
| 41 | Plum | Budding and grafting | T-budding, tongue grafting |
| 42 | Pomegranate | Budding (chip, patch and forkert), layering (air, ground and pot), | Hard wood cutting and air layering |
| 43 | Pummelo | Seed and budding | Seed, T-budding |
| 44 | Sapota | Air layering, inarching and soft wood grafting | Inarching |
| 45 | Straw berry | Runners | Runner |
| 46 | Sweet orange | Seed and budding | T- budding |
| 47 | Tamarind | Seed and soft wood grafting | *In-situ* soft wood grafting |
| 48 | Walnut | Epicotyl grafting and patch budding | Patch budding |
| 49 | Wood apple | Root cutting, budding and seed | Seed/*In-situ* budding |

**SOURCE-** ***BHIMRAJ BHUJBAL (2012)***

- **Micro propagation or tissue or *in vitro* culture** - *in vitro* techniques in which true-to-type propagation of selected genotypes using axillary shoot (shoot tip, meristem tip, nodal culture, stool shoot, pseudo corms, mini tubers), adventitious shoot (internodal section, leaf pieces, fragmented shoot apices, immature inflorescence, bulb scale), micro root, leaf, cell, nucellus tissue, callus etc. of suitable ex-plant in aseptic condition with media till develop a successful independent plant.

Plantlets propagation by vegetative means mainly depends on season in open conditions but for round the year require propagation structures like:

1. Greenhouses: structures are designed for temperature and light control and that arused for the production of pot plants, foliage plants, bedding plants, and cut flowers.
   - Gable-roof construction (it has more expensive, reinforced support for hanging mist systems, supplementary lightings, or additional tiers of potted plants.).
   - Retractable roof (it has a roof that can be opened during the day and closed at night.
   - Quonset-type (it is inexpensive propagation house made of bend tubing or PVC frame that is covered with polyethylene.)

2. Cold frames and shade houses (lath houses) : structures are constructed to acclimatize young, tender liner plants. Some other structures for shade and protects container stock from high summer temperatures and high light intensity lath house is required

3. Hot frames and tunnels - They are similar in function as a greenhouse and may consist of a wooden box or frame with a sloping, tight-fitting lip made of window sash. A tunnel is made from hoped metal tubing or bent PVC pipe, which is covered with polyethylene plastic sheets.
4. Agroshed net houses: these structures widely used by the nurserymen. These net houses are available in different intensities and colours with aim to provide congenial atmosphere to the growing saplings.
5. Net houses: Structures specially designed for nursery raising of virus free stock. Cladding material nylon net of different sizes, mostly 40 mesh not allow any insect inside. Other net houses like anti hail, bird protecting can be used according to need.
6. Mist chamber: This facilities specially 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.
7. Hardening chamber: a unit that consists of separate preparation, transfer, and growing areas designed to develop and harden delicate tissue cultured or other vegetative propagated plants.

**Management of vegetative propagated fruit crops:**

Nursery area should be neat and clean, free from weeds, proper drainage facility and comparatively at higher elevation with leveled site to be chosen for nursery bed preparation. Different kind of nursery beds can be built on the basis of area viz., high rainfall area raised bed and arid region sunken bed (Hartman *et al*., 1993 & 2000). Some partial modification and refined techniques helping in plants raising.

- **Mother bed**: a convenient size nursery bed have good mixture of media where generally seeds are sowing in enclosed area and all viable and vigours seedlings at early stage may be shifted in polybags for further growth. Advantage of this bed due to easy to manage and better survivability of seedlings/rootstocks for further use.
- **Polybag nursery**: most common material use for planting preparation of germinated seeds and bud-grafted when five to six months old. The bags may be of black or transparent polyethylene. Depending on the size of the plant to be produced, bags of different dimensions may be used. The filled bags can be kept in the nursery either in trenches or on the ground supported with wooden poles. For small bags, depth of trench may be about 20 cm and the distance between rows in a pair of trenches 15 cm. The corresponding depth and distance for large bags are 30 cm and 20 cm. The gap between bags of same trench is 10 cm. Footpath of 75 cm width may be left between two pairs of trenches. After placing the bag in the trench, the excavated soil is filled in the gap between them. The remaining soil is mounted around the bags. Planting of budded

stumps or sprouted seeds is undertaken thereafter. When budded stumps are used, the bud patch should face the footpaths to facilitate growth of sprouts. Regular cultural operations like manuring, watering, weeding, shading and plant protection are adopted. Application of NPK Mg 10-10-4-1.5 mixture is done at monthly intervals. During the first month 10 g of the mixture is given per bag which is gradually increased to 30 g in four months time.

- **Mother plant**: Mother block of fruit plants is the most important components of plant nursery. It provides bud sticks and scions for grafting and budding operations in nursery. It should be true to type, vigorous, healthy, free from insect-pests, diseases and viruses.

**Management of plants after propagation**-

The propagated plants need to be hardened. It is always better to harden them in the shade net houses or climate controlled houses. If these are not available then they need to be kept in semi-shade conditions, so that there is no mortality of plants when they are taken to the main field. Timely sprays for insects and diseases need to be given after ascertaining the cause. To maintain the plants in healthy condition, it is better to be given micro-nutrient sprays. However, it is also of paramount importance that the plants need to be labeled properly so that the variety is not mixed up. General management of growing saplings require time to time with regards to -

- Watering, weeding and nutrient management in field & nursery
- Nursery disease and their management
- Nursery pests and their management

Timely sprays for insects and diseases need to be given after ascertaining the cause. Integrated approach (chemical, cultural and biological control techniques) always better for management of nursery stock.

| **Disease Management** | ***Insect-Pest Management*** |
|---|---|
| • Selection of apparently healthy seeds/propagules for seedling production.<br>• Seed dressing with 0.2% Carbendazim /Methyl thiophanate / Benomyl/Thiram<br>• Sowing in sterilized/fumigated, clean beds and adequate watering<br>• Using sterilized budding knife, secateurs, and scissors during budding and grafting<br>• Transplanting seedling after root dip for | • Mapping the nursery by identifying plants which are most susceptible to insects problems. Note which species and cultivars are affected first.<br>• Identifying pests and beneficial insects, noting life cycle stages and population levels.<br>• Making a decision on appropriate control from collected information. |

| | |
|---|---|
| 3-5 min in 0.02% Carbendazim solution<br>• Healthy planting material maintenance by keeping them under proper sunlight,<br>• Watering and clean environment<br>• Frequent examination of seedling health and removal of diseased stocks<br>• Foliar spray of 0.2% Carbendazim / Dithane M-45 at regular interval<br>• Biocontrol agent *Aspergillus, trichoderma, Psuedomonas*etc use against soil born fungus against wilt and decline problems | • Chemical like Systemic insecticides Dimethoate, Metasystox, Rogar, Acephate, Profenofos50EC, Chloropyriphos -25 EC, Fipronil 5%SC @ 1-1.5ml litre-1 or Imidacloprid 17.8SL @ 1 ml per 3 litre water.<br>• Neem based bio-agents like neem cake, NSKP &NSKE @ 5% .<br>• Biological controls are available for use in the nursery like *Bacillus thuringiensis* var. *kurstaki* against moths, *Trichogramma* against Lepidoptera insects. |

**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.

**Marketing management & nursery accreditation**

Nurserymen do not get good price from their products because the price in the market depends on demand and supply of the products. Nursery accreditation provide proper platform about recognition of enterprises and quality branding in form of star rating. 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 materials.
- Plants to be sold should be uniform in size and vigour.
- Graded saplings require proper packing and nicely labelled.
- Timely accreditation require and based on star rating online possible to search and order can place or easy to market.
- The nursery should supply the catalogue or pamphlets containing the detailed information of plants, NHB accreditation with rating *etc*, handling and management of the plants offered for sale.

**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. Specific quality standards of fruit plant in nursery given in table-

| 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 |
| 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 |

**Source: Singh *et al.* (2003)**

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

| | | | | | |
|---|---|---|---|---|---|
| scion | | | | | |

**Profitability in a Nursery Enterprise**

Nursery enterprise mostly based on assumptions of demand of plants and availability of various production inputs like raw material and labour. It would therefore be wise to carry out market survey to anticipate demand of various plants in the coming season before production of plants in a nursery enterprise begins. The fixed and variable costs associated with establishment of nursery and expected return by saplings production activity will be helpful to assess the net returns of this activity. It is estimated that less than 10 per cent of nursery established face losses during the initial three years period only. One successful example was taken for explanation of returns from proper running nursery of Central institute for arid horticulture, Bikaner.

**Variable cost for 80,000 sapling preparation of *Khejri***

| Particulars | Required quantity | Rate (Rs.)/unit | Cost (Rs.) |
|---|---|---|---|
| Cost of poly bag | 80 thousands | 1.0/- | 80,000 |
| Seed | 25 | 1100/- | 27500 |
| FYM/ Compost | 10 trolley | 1500/- | 15,000 |
| Soil/ pond silt | 20 trolley | 600/- | 12000 |
| Growth regulators | 5 g | 800/ g | 5000 |
| Trench preparation/Bag filling/ arrangement labour | 80000 bags | 1/- bag | 80,000 |
| Insecticide-fungicide & other agrochemicals | 12 months | - | 15,000 |
| Watering, seedling maintenance cost | 12 months | 5000/month | 60,000 |
| Budding/grafting labour on successful budding | 40,000 | 20/- | 800,000 |
| Sprout removal/Shifting/ hardening labour | 80,000 | 1/- | 80,000 |
| Miscellaneous | - | - | 10,000 |
| **Total** | | | **11,84,500** |

**Expected returns per year from *Khejri* nursery**

| Particulars | Quantity and rate | Gross returns (Rs.) | Net returns (Rs.) |
|---|---|---|---|
| Sale of budded khejri | (40,000 thousands) Rs.80 each | 3200000 | 20,15,500 |

* Diminish of saplings in nursery before sale 10-20 % (depends on kind of fruit crops)

| | | |
|---|---|---|
|  |  |  |
| ***Khejri* Rootstocks** | **Budding in *Khejri*** | **Khejri budded saplings for sale** |

Above figure of sale out of saplings from the nursery in common condition and return may be enhanced many fold by involvement of hi-tech infrastructure facilities that will reduce the loss.

| | | |
|---|---|---|
|  |  |  |
| Sweet orange | *Ber* | Pomegranate |

Some important points to be taken into consideration for bringing nursery enterprise into a profitable venture are as follows:

1. Production of saplings in a nursery is a commercial business activity and is to be seen from the point of view of economics of expenditure and returns.
2. There is need to balance the technical aspects and practical feasibility of production and sale of plants in a nursery unit.
3. The nursery enterprise may not start yielding profits right from the first year onwards but may require minimum four to five years for planning and execution of operations and bringing the nursery business into profit.
4. Records of expenditure and income need to be maintained regularly to ascertain the profitability or loss in the business. A critical analysis of such records may provide solution for overcoming the problem of poor profit.
5. Monitoring of daily activities in nursery premises can provide immediate answers to the problems faced during the production and sale in nursery produce.

6. There is needs to be coordination among three important aspects of nursery enterprise i.e., production of plants, rearing of plants and sales of plants.
7. Increasing the sales through marketing, publicity and advertisement.

**Summary**

Nursery enterprise to be a profitable venture, meticulous planning is required in the way of improving the availability of healthy planting material of improved/recommended varieties. The infusion of latest technologies has become essential for increased productivity. Presently only 30- 40% demand of planting material is being met by the existing infrastructure facilities. The demand for horticultural produce is accelerating with passing time. Unless uniform planting material of desired type is available, increased productivity levels cannot be achieved. Hence, adoption of frontier technologies like hi-tech nursery for raising plantlets has to be encouraged. The responsibility of providing food and nutritional security to aspiring populace, coupled with projected growth rate of 7 per cent can be met by various hi-tech inventions of which hi-tech nursery is the stepping stone. Educational and training programmes need to be strengthened for the development of human resource and sustainable progress in this direction.

# Disease Management Strategies for Enhancing the Production and Productivity of Arid Horticultural Crops in Hot Arid and Semi-Arid Regions

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## Introduction

Horticultural crops play an important role in food and nutritional security of India. At present, there is huge scope for expansion of area under horticultural crops in arid region as this region is blessed with vast land resources, developing infrastructural facilities, plenty of solar and wind energy. Horticultural crops (aonla,ber, bael, date palm, pomegranate, mulberry,bottle gourd, longmelon, muskmelon, watermelon and chillies) are important which are grown in arid region. These crops can be infected by several diseases (*Alternaria* leaf blight, *Cercospora* leaf spot, powdery mildew, wilt, mosaic disease, leaf curl disease,*etc*. These diseases pose serious damage in their cultivation, which inflict significant losses to the crops every year. However, plant diseases caused by fungi, bacteria, viruses and phytoplasmas often reduce crop yields (Khoury and Makkouk, 2010).

Integrated disease management strategies, which includes cultural, biological, host resistance and chemical control strategies in a holistic way rather than using a single component strategy proved to be more effective. Success of management strategies needs appropriate policies in place that cover a wide range of themes such as plant protection, private sector investment, awareness and agriculture extension. Wide adoption of disease management practices in horticultural crops is a pre-requisite for achieving impact at the country level. Adoption and support for using participatory approaches help to farmers in fruit disease management, reducing costs and improving production efficiency. Production and productivity of the fruit crops in arid and semi-arid regions are enhanced through adoption of following disease management strategies against major diseases:

## Integrated disease management strategies of arid horticultural crops

### 1) Diseases of a*onla*((*Emblicaofficinalis*Gaertn.)

### i) Anthracnose disease

This disease is the second serious disease in aonla growing areas under arid and semi-arid regions particularly, in Rajasthan and Uttar Pradesh. This disease appears on leaflets and fruits in August-September (Mishra and Shivpuri, 1983).

### Symptoms

At the beginning, symptoms are minute, circular, brown to grey spots with yellowish margin in leaflets. Leaves dried up at advance stages. In fruits, pin lead like spots appear with

dark brown to pink having yellow halo, while on fruits, depressed lesions develop which later turn dark. In severe cases, many spots coalesce with each other to form bigger lesions. The central areas of spots remain grayish raised with dot like fruiting bodies- the acervuli arranged in rings. Under severe condition, plenty spots result the fruits become shrivel and rot.

**Causal organism-** *Colletotrichumgloeosporioides*

**Integrated disease management strategies**

**Cultural strategies**

(a) Discard affected fruits and leavesat initial stage from the orchard.

(b) Proper pruning should be done in orchard to improve air circulation within the crown.

c) Plant trees on a wide spacing and keep the surrounding area clear of vegetation.

**Chemical strategies**

Spraying of carbendazim (0.1%) or difolatan (0.2%) can reduce the disease (Bhardwaj and Sharma, 1999).

**2) Ber (*Ziziphusmauritiana*Lamk.)**

Ber is one of the most important fruit crops grown in arid and semi-arid regions of India (Pareek, 2001) and worldwide. Many fungal diseases such as powdery mildew, black leaf spot, fruit rot and *Alternaria* leaf spot in ber have been identified in arid and semi- arid regions.

**i) Powdery mildew**

It was first reported from Allahabad. Kumar *et al.* (1978) noted the occurrence of this disease of ber in Indian arid zone.This disease is one of the most serious diseases of ber and causes fruityield losses in semi-arid and sub-tropical region. Maximum severity (35.2%) was observed in orchard of Hathnoda,Chomu, Dist. Jaipur(Anon., 2019).

**Symptoms**

Initial symptoms appear on young fruits at pea stage of development. White specks may appear on immature fruit and later may cover the entire fruit. Mildew produces symptoms as whitish powdery masson all the aerial plant parts causing pre-mature drop offlower buds.The infected fruits become misshapen and corky. Fruits finally drop. In severe conditions, floral parts, whole fruits, tender branches and leaves would appear with powdery mass of fungal conidia. Whole tree would appear unhealthy with less fruit setting and malformed fruits. Such *ber* orchards are devastated completely. Infected fruits fail to develop, show discolouration and become mummified.

**Causal organism**:*Oidiumerysiphoides f.* sp. *ziziphi*

Integrated disease management strategies

Cultural strategies

a) Removal and destruction of infected leaves, twigs and collateral hosts from orchard.
b) Ber orchards should be free from wild species of ber (*Ziziphusnummularia*).
c) Summer ploughing in the orchard.
Chemical strategies
Maximum disease control has been found by combined application of*Psendomonasfluorescens* (1%) and Karathane@ 0.05% (Nallathambi*et al.*, 2003).
Biological strategies
Spraying of *Trichoderma* spp. (CIAH- 240) @ 5% also reduced the disease.

**ii) Black leaf spot**

Gupta and Madan (1977) reported this disease from Haryana for the first time. Verma*et al*. (1992) also reported this disease from Punjab. Disease incidence was noted during survey programme of Rajasthan and Uttar Pradesh from 01- 8.0 and 4.75 to 38.75 per cent, respectively (Anon., 2010).

**Symptoms**

Sooty tuft like circular to irregular black spots develop on lower surface of leaves. At advance stage, the larger part of lower surface of leaves is also covered with spots while the upper leaf surface shows brownish discolouration. Leaves and twigs are dried rapidly under severe infection.

**Causal organism-** *Isariopsisindica*var. *ziziphi*

**Integrated disease management strategies**
Cultural strategies
a) Removal and destruction of infected leaves and twigs from orchard.
b) To keep the ber orchard free from all weeds.
c) Pruning should be done properly in the orchard.
Chemical strategies
a) Fungicidalsprays at 15 days interval (mancozeb or copper oxychloride @ 0.2%) (Verma and Cheema, 1988).
b) Minimum diseaseintensity (10.60%) of this disease was recorded with 02 sprays ofpropiconazole 0.1% followed by difenconazole 0.1%(11.70%) and carbendazim 0.1% (12.81%)at an interval of 15 days, startingfrom the initiation of the disease i.e. first week of September
and also increased fruit yield (Kumar *et al*. 2017).
Use of Host resistance
Use of resistant varieties such as ZG-3, Seo, Bahadurgarhi and SafedaRohtak.

**3) Date palm(*Phoenix dactylifera*L.) diseases**

**i) *Alternaria* leaf spot**

It has been observed in severe form at Date Palm Research Centre, SKRAU, Bikaner and disease incidence was recorded from 14.16 to 72.50% depending upon cultivars as well as climatic conditions.

**Symptoms**

The spots are most common on the lower leaves (pinnae) of the plants, whereas, on upper leaves the spots are few and small size. The disease cause heavy losses to the date industries in both quality and quantity of production (Pal *et al*., 2006).

**Causal organism**- *Alternariaalternata*

**Integrated disease management strategies**

**Cultural strategies**

a) Removal and destruction of infected leaves, twigs and weeds from orchard.
b) Pruning should done.
c) To disinfect all tools in pruning, etc. and cut surfaces.

**Chemical strategies**

a) Fungicidal sprays at 15 days interval (mancozeb @ 0.2%) was given to minimize the disease.
b) Copper oxychloride (0.2%) are also useful for retarding the fungal growth.

**ii) Graphiola leaf spot**

It is the most widely spread disease and occurs wherever the date palm is cultivated under humid conditions.

**Symptoms**

Symptoms of the disease appear as sub-epidermal spots on both sides of the pinnae (leaf flat) and on the rachis with small black sori (fruiting bodies) developing in abundance on old fronds. Fruiting structures emerge as small-yellow/brown to black sori. These sori are abundant on three year-old leaves. The sori are 1-3 mm in diameter.

**Causal organism-** *Graphiolaphoenicis*

**Integrated disease management strategies**

**Cultural strategies**

a) Removal and destruction of infected leaves, twigs and weeds from orchard.
b) Pruning should be done in orchard.

c) To disinfect all tools in pruning, etc. and cut surfaces.
d) Use of disease free and quality planting material of date palm.

**Approaches host resistant**

a) Grow genetically tolerant date palm varieties (Barhee, Adbad, Rahman, Gizaz, Iteema, Khastawy and Tadala).
b) Use of variety Hatemi was found to be resistant (Pundir, *et al*. 2006).
c) Variety Khadrawi was found resistant under field conditions of Haryana.

**Chemical strategies**

a) Carbendazim (0.2%) is most effective followed by thio-phanatemethyl (Mehta *et al*. 1989).
b) Two sprays and soil drenching of copper oxychloride (0.2%) at fortnight interval in checking the infection and further disease spread.

**4) Pomegranate (*Punicagranatum*)**

It was cultivated mostly in Asia, Northern Africa, Southern Europe, Egypt, and Afganistan.

**i) Bacterial leaf and fruit spot**

It is a major constraint for productivity, healthy and quality of fruits in Southern states particularly in Tamil Nadu, Maharashtra and Karnataka as well as in some parts of Gujarat and Rajasthan. It appeared as an epidemic form in Bangalore, Karnataka, causing 60-80% fruit yield losses. Dhandar*et al*(2004) have made in extensive survey in Solapur and Sangola districts ofMaharashtra against this disease and other aspects.

**Symptoms**

Small, transluscent watersoaked spots appeared on the leaves and became necrotic and finally may turn dark brown. Many spots may coalesce and cover big area which are surrounded by chlorotic halo. Leaves are distorted and defoliated. Watersoaked spots on fruits may turn dark brown. The spots are oily in appearance.

**Causal organism:** *Xanthomonasaxonopodis*pv. *punicae*

**Integrated disease management strategies**

**Cultural strategies**

a) Removal of weed hosts and other infected plant parts.
b) Pruning should be done in pomegranate orchard.

**Chemical strategies**

Spraying of 200 ppm streptocycline can be controlled followed by Pausamycin (0.05%) + Copper oxychloride (0.2%) with 3 sprays at fortnightly intervals (Suriachandraselvan*et al*. 1993).
**Use of Host resistant:** Variety Jalore seedless was resistant to this disease (Nallathambi *et al.* 2006).

6) **Diseases and their management of citrus:**

**i) Citrus canker**

**Symptoms**

Cankerous lesions appear on leaves, twigs and fruits as small, round, watery and translucent spots. They first develop on the lower surface of the leaf and then on both the surface. As the disease advances, the surface of the spots becomes white or greyish and finally ruptures in the centre giving a rough, corky and crater-like appearance. The rough lesions are surrounded by a yellowish-brown to green raised margin and watery yellow halo. Cankers on fruits are similar to those on leaves except that the yellow halo is absent and a crater like depression in the centre is more prominent.

**Causal organism- Xanthomonasaxonopodispy Citri**

**Disease management**

**a)** Two pruning of infected plant parts along with 4 sprays of copper oxychloride (0.5 %) or bordeaux mixture (1%) have been reported effective and economical.
**b)** Application of *neem* cake solution (3-5%) on the foliage has also been reported effective against this disease in nurseries.

**ii) Citrus greening**

Citrus greening disease, also called Huanglongbing (HLB), is one of the more serious diseases of citrus. The disease spreads through vegetative propagation and citrus psylla insect.

**Symptoms**

The most characteristic symptoms are a blotchy leaf mottle and vein yellowing that develop on leaves attached to shoots showing the overall yellow appearance. These foliar symptoms may superficially resemble a zinc deficiency and citrus variegated chlorosis. Infected leaves have a mottled appearance. Fruits are small, often misshapen, and typically some green

color remains on ripened fruit. On Mandarin orange, fruit may develop an uneven ripening such that they appear half orange and half yellow.

**Causal organism-***Candidatusliberibacter*

**Integrated disease managementstrategies**

**Cultural strategies**

a) Destruction of infected plant parts from the orchard.
b) Proper pruning

**Chemical strategies**

a) Sprayings of endrin (0.02-0.05%) reduce disease spread.
b) Sprayings of bavistin + ledermycin (500 ppm each) at 10 days interval are very effective.

**Biological strategies**

There are some predators that attack the Asian citrus psyllid. They include lady beetles (also known as ladybugs), spiders and predatory bugs.

**6) Bottle gourd (*Lagenariasiceraria)***

It is an important crop of Rajasthan and widely grown in open field conditions as well as in river beds to harvest early crop (Maheshwari and Haldhar, 2018).

**i) Alternarialeaf blight**

Highest disease incidence (35.33%) and disease severity (24.0%) of this disease were recorded in bottle gourd during survey programme of Rajasthan (Maheshwari*et al*., 2013).

**Symptoms**

Characteristic symptoms first appear on leaves as small, circular and light brown spots of different size which later enlarge in a concentric rings and margins appear. These spots mix together to form larger necrotic areas on leaves. Disease started from margin of the lower leaves which gradually increased and covered lamina.

**Causal organism:** It is caused by a fungal pathogen *Alternariacucumerina.*
Integrated disease management strategies

**Cultural strategies**

a) Removal of infected crop debris, collateral hosts and weeds.

b) Use of certified seed.
c) Deep ploughing of the soil
d) Follow a 3-year crop rotation with non-cucurbitaceous crop.

**Chemical strategies**

a)Combined treatment of carbendazim @ 0.1% (seed treatment) + mancozeb @ 0.25% (foliar spray) + *Pseudomonas fluorescens* @ 5% (foliar spray) + neem leaf extract @ 5% (foliar spray) was the most effective with minimum disease incidence of 9.25%, minimum disease severity of 7.07% and maximum disease control (78.23%) against Alternarialeaf blight in bottle gourd (Maheshwari *et al*., 2017).
b) Three sprays of indofil M-45 (0.2%) at regular interval of 10 days were very effective against this disease (Maheshwari *et al*., 2019).

**Approaches of host resistance**

a) Use of moderately resistant varieties such as Pusa Naveen, PusaSantushti, PusaSandesh, PusaSamridhi, PSPL and Arka Bahar against Alternaria blight of bottle gourd (Maheshwari and Choudhary, 2015).

**b) Symptoms**

Sooty tuft like circular to irregular black spots develop on lower surface of leaves. At advance stage, the larger part of lower surface of leaves is also covered with spots while the upper leaf surface shows brownish discolouration. Leaves and twigs are dried rapidly under severe infection.

**Causal organism-** *Isariopsisindica*var. *ziziphi*

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It has been observed in severe form at Date Palm Research Centre, SKRAU, Bikaner and disease incidence was recorded from 14.16 to 72.50% depending upon cultivars as well as climatic conditions.

**Symptoms**

The spots are most common on the lower leaves (pinnae) of the plants, whereas, on upper leaves the spots are few and small size. The disease cause heavy losses to the date industries in both quality and quantity of production (Pal *et al*., 2006).

**Causal organism**- *Alternariaalternata*

**Integrated disease management strategies**

**Cultural strategies**

a) Removal and destruction of infected leaves, twigs and weeds from orchard.
b) Pruning should done.
c) To disinfect all tools in pruning, etc. and cut surfaces.

**Chemical strategies**

a) Fungicidal sprays at 15 days interval (mancozeb @ 0.2%) was given to minimize the disease.
b) Copper oxychloride (0.2%) are also useful for retarding the fungal growth.

**ii)Graphiola leaf spot**

It is the most widely spread disease and occurs wherever the date palm is cultivated under humid conditions.

**Symptoms**

Symptoms of the disease appear as sub-epidermal spots on both sides of the pinnae (leaf flat) and on the rachis with small black sori (fruiting bodies) developing in abundance on old fronds. Fruiting structures emerge as small-yellow/brown to black sori. These sori are abundant on three year-old leaves. The sori are 1-3 mm in diameter.

**Causal organism-** *Graphiolaphoenicis*

**Integrated disease management strategies**

**Cultural strategies**

a) Removal and destruction of infected leaves, twigs and weeds from orchard.
b) Pruning should be done in orchard.
c) To disinfect all tools in pruning, etc. and cut surfaces.
d) Use of disease free and quality planting material of date palm.

**Approaches host resistant**

a) Grow genetically tolerant date palm varieties (Barhee, Adbad, Rahman, Gizaz, Iteema, Khastawy and Tadala).
b) Use of variety Hatemi was found to be resistant (Pundir, *et al*. 2006).
c) Variety Khadrawi was found resistant under field conditions of Haryana.

**Chemical strategies**

a) Carbendazim (0.2%) is most effective followed by thio-phanatemethyl (Mehta *et al*. 1989).
b) Two sprays and soil drenching of copper oxychloride (0.2%) at fortnight interval in checking the infection and further disease spread.

**4) Pomegranate (*Punicagranatum*)**

It was cultivated mostly in Asia, Northern Africa, Southern Europe, Egypt, and Afganistan.

**i)Bacterial leaf and fruit spot**

It is a major constraints for productivity, healthy and quality of fruits in Southern states particularly in Tamil Nadu, Maharashtra and Karnataka as well as in some parts of Gujarat and Rajasthan. It appeared as an epidemic form in Bangalore, Karnataka, causing 60-80% fruit yield losses. Dhandar*et al*(2004) have made in extensive survey in Solapur and Sangola districts ofMaharashtra against this disease and other aspects.

**Symptoms**

Small, transluscent water soaked spots appeared on the leaves and became necrotic and finally may turn dark brown. Many spots may coalesce and cover big area which are surrounded by chlorotic halo. Leaves are distorted and defoliated. Water soaked spots on fruits may turn dark brown. The spots are oily in appearance.

**Causal organism:***Xanthomonasaxonopodis*pv. *punicae*

**Integrated disease management strategies**

**Cultural strategies**

a) Removal of weed hosts and other infected plant parts.

b) Pruning should be done in pomegranate orchard.

**Chemical strategies**

Spraying of 200 ppm streptocycline can be controlled followed by Pausamycin (0.05%) + Copper oxychloride (0.2%) with 3 sprays at fortnightly intervals (Suriachandraselvan*et al*. 1993).

**Use of Host resistant:** Variety Jalore seedless was resistant to this disease (Nallathambi*et al.* 2006).

**5)Diseases and their management of citrus:**

**i) Citrus canker**

**Symptoms**

Cankerous lesions appear on leaves, twigs and fruits as small, round, watery and translucent spots. They first develop on the lower surface of the leaf and then on both the surface. As the disease advances, the surface of the spots becomes white or greyish and finally ruptures in the centre giving a rough, corky and crater-like appearance. The rough lesions are surrounded by a yellowish-brown to green raised margin and watery yellow halo. Cankers on fruits are similar to those on leaves except that the yellow halo is absent and a crater like depression in the centre is more prominent.

**Causal organism-**Xanthomonasaxonopodis*pv.* citri

**Disease management**

**a)** Two pruning of infected plant parts along with 4 sprays of copper oxychloride (0.5 %) or bordeaux mixture (1%) have been reported effective and economical.

**b)** Application of *neem* cake solution (3-5%) on the foliage has also been reported effective against this disease in nurseries.

**ii) Citrus greening**

Citrus greening disease, also called Huanglongbing (HLB), is one of the more serious diseases of citrus. The disease spreads through vegetative propagation and citrus psylla insect.

**Symptoms**

The most characteristic symptoms are a blotchy leaf mottle and vein yellowing that develop on leaves attached to shoots showing the overall yellow appearance. These foliar symptoms may superficially resemble a zinc deficiency and citrus variegated chlorosis. Infected leaves have a mottled appearance. Fruits are small, often misshapen, and typically some green color remains on ripened fruit. On Mandarin orange, fruit may develop an uneven ripening such that they appear half orange and half yellow.

**Causal organism-***Candidatusliberibacter*

**Integrated disease managementstrategies**

**Cultural strategies**

c) Destruction of infected plant parts from the orchard.
d) Proper pruning

**Chemical strategies**

c) Sprayings of endrin (0.02-0.05%) reduce disease spread.
d) Sprayings of bavistin + ledermycin (500 ppm each) at 10 days interval are very effective.

**Biological strategies**

There are some predators that attack the Asian citrus psyllid. They include lady beetles (also known as ladybugs), spiders and predatory bugs.

**6) Bottle gourd (*Lagenariasiceraria)***

It is an important crop of Rajasthan and widely grown in open field conditions as well as in river beds to harvest early crop (Maheshwari and Haldhar, 2018).

**i) Alternarialeaf blight**

Highest disease incidence (35.33%) and disease severity (24.0%) of this disease were recorded in bottle gourd during survey programme of Rajasthan (Maheshwari*et al*., 2013).

**Symptoms**

Characteristic symptoms first appear on leaves as small, circular and light brown spots of different size which later enlarge in a concentric rings and margins appear. These spots mix together to form larger necrotic areas on leaves. Disease started from margin of the lower leaves which gradually increased and covered lamina.

**Causal organism:** It is caused by a fungal pathogen *Alternariacucumerina.*

**Integrated disease management strategies**

**Cultural strategies**

a) Removal of infected crop debris, collateral hosts and weeds.
b) Use of certified seed.
c) Deep ploughing of the soil
d) Follow a 3-year crop rotation with non-cucurbitaceous crop.

**Chemical strategies**

a) Combined treatment of carbendazim @ 0.1% (seed treatment) + mancozeb @ 0.25% (foliar spray) + *Pseudomonas fluorescens*@ 5% (foliar spray) + neem leaf extract @ 5% (foliar spray) was the most effective with minimum disease incidence of 9.25%, minimum disease severity of 7.07% and maximum disease control (78.23%)against Alternarialeaf blight in bottle gourd (Maheshwari *et al*., 2017).
b) Three sprays of indofil M-45 (0.2%) at regular interval of 10 days were very effective against this disease (Maheshwari *et al*., 2019).

**Approaches of host resistance**

a) Use of moderately resistant varieties such as Pusa Naveen, PusaSantushti, PusaSandesh, PusaSamridhi, PSPL and ArkaBahar against Alternaria blightof bottle gourd (Maheshwari and Choudhary, 2015).

**ii) Powdery mildew**

The disease is destructive among cucurbits in most areas of the world and can be a major production problem causing yield losses of 30%–50% (El-Naggar*et al*. 2012). Maximum disease incidence (up to 58%) was observed in different bottle gourd genotypes at ICAR-CIAH, Bikaner (Maheshwari and Choudhary, 2018).

**Symptoms:** The symptoms appear as small floury patches on leaves first on the lower surface followed by upper surface. Fungal growth on these spots results in production of powdery growth. Powdery mass on the leaves decreases the photosynthetic rate (Queiroga*et al*. 2008), causing reduction in plant growth, premature defoliation, and consequently reduction in yield.The infected plant parts remain stunted and distorted. Severely affected leaves lose their dark green colour and become pale yellow green to brown and are shriveled, drying and collapse.

**Causal organism:***Sphaerothecafuliginea*

**Integrated disease management strategies**

**Cultural strategies**

a) Removal of infected crop debris.

b) Deep ploughing may burry the pathogen where it may be killed by soil microflora of the pathogen present in below soil layers.

c) Crop sequence with appropriate crops may be the most effective management practices in eliminating soil borne pathogens.

(d) Introduction of non-host crops in rotation helps in disease reduction.

**Approaches of host resistance**

Use of moderately resistant varieties such as Pusa Naveen, PusaSantushti, ArkaBahra and PusaSandesh against powdery mildew (Maheshwari *et al*., 2012).

**Chemical strategies**

(a) Three sprays ofhexaconazole (0.05%) were found effective (Gupta and Gupta, 2001).

b) Three foliar sprays of non-target chemicals (mono-potassium phosphate, potassium nitrate) and neem kernel extract (1-5%)provide effective against powdery mildew.

**approaches of bio-pesticides/botanicals**

a) Three foliar sprays of neem seed kernel extract (5%) were effective against this disease (Maheshwari *et al.,* 2021).

b) Seed treatment with *Trichodermaharzianum/T. viride@* 5 gm/kg seed was also effective against this disease (Maheshwari *et al*., 2021).

**7) Muskmelon (*Cucumismelo* L.)**

**i) Wilt**

Yield losses up to 80% have been reported in the worst affected areas in cucurbits (Gupta *et al*. 2001). Its disease incidence in muskmelon was also observed from 5.0 to 60% at experimental field of ICAR-CIAH, Bikaner (Maheshwari and Choudhary, 2018).

**Symptoms**

The leaves are accompanied by yellowing and marginal necrosis. Older plants may first exhibit temporary wilting only during the heat of mid-day but will die within a few days. The infection results in lesion formation on the collar region and infected areas appear brown and water soaked. Wilting begins sudden after disease initiation. As a result of softening of the tissue, the plants shriveled and after that rapid plant mortality. The older plants wither and die during the growing season.

**Causal organism:***Fusariumacuminatum* which is identified from IARI, New Delhi.

**Integrated disease management strategies**

**Cultural strategies**

a) All infected plant should be collected and burnt.Crop rotation with garlic, radish, onion has been found to retard it (Sen, 1986).
b) Deep ploughing should be practiced during summer.
c) Growing the crop with non-host crop.
d) Certain soil amendments in soil which destroy the soil inoculums, can also be used to control the disease.

**Approachesof host resistance**

a) In muskmelon, The Indian cultivars (DurgapuraMadhu and Punjab Sunehri) are resistant to wilt(Radhakrishnan and Sen, 1985).
b) Muskmelon var. 'PusaMadhuras' was found moderately resistant against this disease.
c) Mark *et al*. (2005) found Hannahs Choice F1 as resistance source against Fusariumrace 2.

**Chemical strategies**

a) Drench the soil around roots with carbendazim @ 0.1% (Maheshwari*et al*., 2021).
b) Treat the seeds with bavistin/ captan @ 2 g/ kg seed before sowing.
c) Drench the soil with bavistin (0.1%).

**Use of botanicals and bio-agents**

a) Minimum wilt incidence (7.40%) in muskmelon was found in neem cake @ 5 q/ ha + biofertilizer followed by neem cake @ 5 q/ ha with incidence of 8.12% (Choudhary*et al*., 2019).
B )*Trichodermaharzianum/T. viride* when applied as seed treatment (5 gm/kg seed) followed by soil application along with FYM/ neem cake were effective against this disease (Maheshwari *et al*., 2021).
c) Wilt in cucurbits can be suppressed by *Pseudomonads* isolates.

**8) Watermelon (*Citrulluslanatus*)-**

**i) Mosaic disease**

Mosaic disease has become potential threat to the cultivation of watermelon/*mateera* in western Rajasthan and other watermelon growing states of India. It is recorded from 14.28-35.0 % disease incidence in Bikaner and nearby areas of Rajasthan (Maheshwari andHaldhar, 2018).

**Symptoms**

Infected plants showed characteristic symptoms of dry, yellow mosaic or mottling with chlorotic patches on foliage, development of vein clearing, reduction of leaf size and stunting of the plants. Systemic symptoms consist of downward leaf curling or rolling and mosaic. Disease incidence is found low in this crop due to unfavorable environmental conditions.

**Causal organism:** This disease is caused by WMV/CMV.

**Integrated disease management strategies**

**Cultural strategies**

a) Remove infected plants as early as virus symptoms are observed to prevent/minimize spread of the virus by aphids.
b) Destruction of weed hosts.
c) Use of virus free seeds.
d) Using reflective mulch that reduces the early season infection from aphids and gives an additional 2-4 weeks of a virus-free cucurbit field. Once the plants cover the plastic reflective mulch, it ceases to be an effective deterrent.

**Chemical approaches**

a) Spray at seedlingstage with acephate (0.15%) gives good results.
b) Among 11 treatments, imidacloprid (0.05%) was found the most efficient treatment against mosaic disease in ridge gourd with minimum per cent disease index (15.90%) and per cent disease reduction (61.69%) followed by neem leaf extract (Maheshwari*et al*., 2020).

**9) Longmelon**

Cooling effect of this crop, it is very popular in hot arid region in summer season (Choudhary*et al*., 2018).

**i) Gummy stem blight**

**Symptoms**

The first disease symptoms appear as grayish-green, circular spots between the veins on leaves. Lesions develop first on the vinesat the nodes and elongate into water-soaked streaks that become pale brown to gray with time. The fungus damages the tissues of the stem at all stages of development.The infection often begins at leaf margins (Koike 1997). Symptoms included stem necrosis with characteristic exudation of gummy material andstem tissue often cracks. Main stem lesions enlarge and slowly girdle the main stem.Infected vines die eventually, and entire plants die occasionally.

**Causal organism:** The fungus DIDYMELLABRYONIAE is the causal organism for this disease.

**Integrated disease managementstrategies**

**Cultural strategies**

a) Remove and destroy infected fruits, vines and weed hosts at the end of the season.
b) Deep ploughing
c) Crop rotation with non-host crops should be followed.
d) Procure disease-free seeds from reliable sources.

**Chemical strategies**

a) Apply fungicides likechlorothalonil and mancozeb (0.2%) in a preventative mannerare effective and there are many effective systemic fungicides for its management.
b)Treat the seeds with thiram(2 g/kg seed).
c)Spraying of bavistin (0.1%) as soon as the disease is noticed. In case, the disease is not controlled, spraying of propiconazole (0.1%).
d) Bio-fungicides (*B. subtilis*) alternated with chlorothalonil also minimized use of synthetic fungicides.

**10) Chilli diseases**

Chilli (CAPSICUM ANNUM L.) is the fourth major crop cultivated worldwide and is one of the most important constituent of the cuisines of tropical and subtropical countries.

**i) Anthracnose disease**

In India, a calculated loss of 10–54% has been reported in chilli yield due to this disease to both mature fruits in the field as well as during their storage (Lakshmesha *et al*., 2005).

**Symptoms**

The small lesion is the most economically important aspects of the disease as on the fruit is enough to lower its market value thereby affecting the profitable yield of the crop. The disease is reported to affect almost all aerial parts of the plant. Chiefly, it causes fruit rot at both green and red stages primarily attacking ripe fruits, hence is also known by the name ripe fruit rot of chilli (Agrios, 2005). The disease is seed borne, soil borne, water borne and airborne and hence may lead to damage at the seedling stage or on the aerial parts of the plants.

**Causal organism:**COLLETOTRICHUMCAPSICI

**Integrated disease management strategies**

Culturalapproaches

a) Crop rotation and removal of any infected plant parts of the field.

b) Proper distance between the plants should be maintained so as to reduce dense canopy.

c) Transplants raised from disease free seeds of the chilli variety. The transplants should be kept weed free and away from other solanaceous crops.

**Chemical strategies**

Carbendazim/Difenoconazole @ 0.1%. was found effective for the control of the disease

**Approaches of resistant varieties**

Use of resistant varieties (BS-35, BS-20, BS-28, Punjab Lal, BhutJolokia, Taiwan-2, IC-383072 and Pant C-1of CAPSICUM spp. are recommended against this disease (Garg *et al*. 2014).

**Application of bio-agents**

The bio-agents (Psuedomonasfluorescens, *Trichoderma harzianum* and *Bacillus subtilis*) were used against Colletotrichum spp.

**ii) Leaf curl disease**

It was prevalent in Bikaner, Jodhpur and Jaisalmer district and nearby areas. This disease causes heavy yield losses.

**Symptoms**

Leaves are yellowing, followed by slight curling. The interveinal areas puckered, shortening of the internodes and reduction in leaves size giving witch's broom appearance. Plants remain stunted and appear as bushy.

**Causal organism**

Chilli leaf curl symptoms are caused by begomovirus.

**Integrated disease management strategies**

**Cultural strategies**

a) Removal of infected plant and weeds.
b) Use seeds from healthy plants of previous season, growing nursery in protected structures (Kenyon *et al*., 2014)
c) Grow the maize crop as barrier crop and also trap cropfor reducing the disease.

**Chemical strategies**

a) Imidacloprid (0.05%) and acephate (0.05-0.1%) was found effective against this viral disease (Ahmed and Ram, 2016).

**Approaches of natural extracts/botanicals**

a) Neem seed kernel extract (5%) was also effective against this disease (Pandey *et al*., 2010).

b) Raw cow milk and *Trichoderma* spp. reduced this disease (Kumar, 2006).

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