

Arid Horticulture: An Overview

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Abstract: The arid region is spread over 38.7 million hectares mainly in the states of Rajasthan, Gujarat, Haryana, Punjab, Karnataka, Andhra Pradesh besides cold arid region situated in Leh, Laddakh and Himachal Pradesh. The region is marked by extreme environmental constraints due to which the cultivation of traditional crops is not economical. In a situation such as this, arid horticulture has ample scope to develop the hot arid and semi-arid regions. At present, the climatic scenario of arid region is also changing and the problems like frost, low temperature is becoming a challenge for cultivation of many crops. The available genetic resources of many fruit and vegetable crops have been conserved and utilized for crop improvement and increased production. For crop improvement, biotechnological methods have been tried. For large scale multiplication of quality planting material, technology has been standardized in arid zone fruits. In the present paper, an overview of the technologies developed in the field of arid horticulture, which can be used to make arid ecosystem a horticultural bowl and provide food, nutrition and livelihood security to the inhabitants has been discussed.

Key words: Arid horticulture, nutrition, food, biotechnology, climate change, arid region.

Indian arid zone is characterized by high temperature and low and variable precipitation, which limit the scope for high crop productivity. However, these conditions greatly favor the development of high quality produce in a number of fruit crops such as date palm (*Phoenix dactylifera*), ber (*Ziziphus mauritiana*), aonla (*Emblica officinalis*), bael (*Aegle marmelos*), pomegranate (*Punica granatum*), kinnow, lasoda (*Cordia myxa*) and in vegetables such as cucurbits, legumes and solanaceous crops, spices, medicinal and aromatic plants. The existing low productivity could be increased by following improved new technologies and inputs. It is now realized that there is a limited scope for quantum jump in fruit and vegetable production in the traditional production areas. The amelioration of the extreme conditions is also considered vital for life support to the inhabitants of this area. The recent awareness regarding the potential of these ecologically fragile lands for production of quality produce has not only opened up scope for providing nutritional sustainability for the people of this region, but also for bringing in new areas to increase horticultural production (More *et al.*, 2012). The area and yield potential of arid horticultural crops has increased many-fold because of the development of new varieties and agro-techniques in arid region.

Constraints in Arid Region

The soils of arid region are very poor in availability of nutrients, water holding capacity, etc. The soils of the north-western arid region described as 'desert soils', and 'grey brown soils' of the Order Aridisols, are light textured. Most of arid areas (about 64.6%) are duny, where the soils often contain only about 3.2-4.0% clay and 1.4-1.8% silt. Besides this, about 5.9% area is covered by soils having hard pan, 5.6% is under hills and pediments, 6.8% area is alluvial dunes and 1.6% is sierozems extending from the soils of Haryana and the Punjab. In the peninsular India, a considerable part of arid region has red sandy soil and some parts have mixed black soils. The soils are poor in organic matter having 0.03% OC in bare sand dunes to 0.1% in the stabilized dunes. Soils are generally rich in total potassium and boron, but are low in nitrogen, phosphorus and micronutrients such as copper, zinc and iron. The soils often have high salinity. The ground water is not only limited owing to poor surface and sub-surface drainage, but is also saline in quality. The irrigation water resources in the region are seasonal rivers and rivulets, surface wells and some runoff water storage devices (e.g., *nadi*, *tanka*, *khadins*) and canal irrigation in arid region. Thus, the water resources in arid region are limited and can irrigate hardly 4% of the area.

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The average annual rainfall in the arid regions is very low, erratic and varies from 100 mm in north-western sector of Jaisalmer to 450 mm in the eastern boundary or arid zone of Rajasthan. Most of the precipitation in north-western arid region occurs during July-September in about 19-21 rain spells. Due to low and erratic rainfall pattern in arid region, appropriate technology is needed to increase productivity. Water is precious input in hot arid region of the country therefore, adoption of micro-irrigation system is desirable to save water and enhance productivity. For arid climatic conditions, the variety is needed which is resistant to biotic and abiotic stresses for sustainable production. In some parts of arid region, occurrence of frost is also a common feature during winter season, which affects vegetative growth of plants as well as productivity, quality of fruits especially in ber, lasoda and aonla. There is no heat tolerant variety among arid horticultural crops, which should be developed to achieve higher production.

One of the major problems in development of horticulture scenario in arid parts of the country is lack of sufficient quality seed and planting material. Seed is a precious input to increase quality production of vegetable, spices and flowers as well as some fruit crops. Thus, production of quality seed material and their supply to farmers will boost up the production of arid horticultural crops. The post harvest management is essential to overcome the losses at different stages of grading, packing, storage, transport and finally marketing of both fresh and processed products. The weak processing infrastructure, as it exists today, has been one of the contributing factors for ineffective utilization of the raw materials resulting in huge post harvest losses. Lack of sufficient processing units for production of quality output is a major bottleneck for the arid fruit crops. Marketing of horticultural produce is a major constraint in the production and disposal system and has a major role to play in making the industry viable. The high capital cost involved in establishing orchards, or rejuvenation of existing old unproductive plantation poses serious constraint in area expansion. The situation becomes all the more difficult in view of the large number of small holdings devoted to these crops, which are essentially owned by weaker section, who have

no means to invest, nor can afford to stand the burden of credit even if available. The long gestation period of the perennial horticultural crops like mango, sapota, citrus and date palm coming to the economic bearing age is also a constraint for early returns. High cost of inputs and lack of enough incentives for production of quality varieties/species, product diversification, value addition, etc. also hinder crop development. Lack of proper storage facility and knowledge and equipment for grading and packaging of fruits and vegetables is also constraint for the growers of hot arid region. Another problem faced by the farmers is lack of proper marketing of produce to get better returns. The development of storage facilities and agro-based processing units in the region is also needed for development of horticulture (More *et al.*, 2012).

Prospects of Arid Horticulture

There is a much scope in expansion of horticultural crops in arid region and it has vast potential for changing scenario of horticulture of the country. Vast land resource, surplus family labors, increasing canal irrigated area, developing infrastructural facilities, plenty of solar and wind energy, etc. are the strength in the region for research and development of arid horticulture. Further, low incidence of diseases/insects in the region provides good scope for production of quality seed and planting material of horticultural crops. Ber is commercially grown in more than 80,000 ha area with production of 0.9 Mt under semi-arid and arid regions of the country. More efforts are needed for value addition. Pomegranate area and production (1.14 Mt) is increasing very fast in dry parts of the country as there is vast scope for export of this crop from semi-arid and arid regions of the country. In Maharashtra alone the area under pomegranate cultivation is about 93,500 ha with production of 6,01,500 Mt. Pomegranate worth Rs. 92 million is being exported to Middle East, UK, Germany, UAE, The Netherlands, Bahrain, Kuwait and Egypt. The crops like fig, custard apple, tamarind are also coming very well under dryland conditions. At present, fig is cultivated in more than 3,000 ha area in Maharashtra, Karnataka. Likewise, custard apple is grown in the states of Maharashtra, AP, Karnataka, Rajasthan and Tamil Nadu. In foot hills of Arawali, custard apple is grown naturally and its potential

should be exploited. Aonla is a medicinal fruit plant and cultivated in over 55,000 ha area with production of 150 Mt fruits per year.

Date palm is most suitable fruit tree of dry hot arid region and it is grown in Rajasthan, Gujarat, Punjab and Haryana. The area under date palm in Gujarat has increased from 12,493 (2004-05) to 16,688 ha in 2009-10 with production of 1,23,490 t fresh fruit. However, date is imported from Gulf countries due to its meager production in the country. In Kachchh region of Gujarat plants of cultivar Barhee raised through tissue culture have been planted in about 1000 acre (Muralidharan *et al.*, 2008). There is considerable increase in area and production of date palm in Kachchh region and estimated income from dates is around 17 crores. In recent years, imported plants of cvs. Barhee, Khalas, Khunezi, Medjool, Khadrawy, Zamli and Saggai have been planted in districts of western Rajasthan. The planting of male palms are also essential for pollination and male cvs. Ghanami and Al-in-city have been planted for this purpose. Looking to potential of date palm in hot arid region, area is being increased. In Bikaner district alone, date palm cultivars raised through tissue culture have been planted on about 250 ha area. Out of these, maximum plantation is under vegetative growth stage. In Tamil Nadu state also, date palm have been planted by the farmers on about 100 ha area. Bael is also an important fruit crop of semi-arid and arid regions. Earlier there were no systematic orchards of bael. Now, looking to its nutritional and medicinal value, attention is being given on its commercial production. India is the second largest producer of vegetables (125.88 Mt from 5.77 Mha area). In case of vegetables in the same period the area and production increased by 92.12 and 147.60%, respectively. A survey report of revenue department for the year 2009-10, revealed 32,000 ha area to be under plantation of fruit plants in the State of Rajasthan. In the reported period, the increase in area and production of major spices was 6.98 and 83.73%. The per capita consumption of vegetable in the country has increased from 47 kg in 1984 to 76 kg in 2000, with annual growth rate to 2.9%. By the adoption of improved production technology in arid region, many seed spices likes coriander, cumin, fenugreek, ajwain, fennel, dill and nigella, are being cultivated on large scale

and also exported to earn foreign exchange. There is a vast potential of floriculture in some parts of Rajasthan because of low infestation of diseases and pests, and good market demand for decorating and other uses. The prospects of floriculture under hot arid conditions are also important from seed and plant material production point of view. At present, roses, marigold, chrysanthemum and other flowers are being grown near by cities of Udaipur, Ajmer, Jaipur, Kota and Sri Ganganagar districts of Rajasthan. There is a better scope for tourism development with development in gardening, landscaping and floriculture in the state besides associated industries.

Plant Genetic Resources

The genetic resource conservation of major arid horticultural crops is being maintained in field repository at CIAH, Bikaner (Table 1 and 2). Among 318 ber genotypes, the varieties Gola, Seb, Umran, Kaithali and Banarasi Kadaka are performing well under hot arid climate. Tikadi is found tolerant to frost/low temperature during winter season in arid region. Out of 154 genotypes of pomegranate, Jalor Seedless, Ganesh, G-137, Mridula, Phule Arakta and Bhagawa are the better genotypes for fruit yield and quality. Besides this, anardana types pomegranate were also evaluated and Amlidana and Collection-12 from HP were found promising (Singh *et al.*, 2011). The varietal evaluation of aonla revealed that the NA-7 (Neelam) is a prolific bearer followed by Chakaiya and NA-6 (Amrit). Among 17 bael genotypes, NB-5 and NB-9 have performed well under irrigated hot arid conditions (Anon., 2011). New bael genotypes NB-16 and NB-17 have been recommended for cultivation from NDUAT, Faizabad. A five-year-old budded plant of NB-5 yields about 40 fruits tree⁻¹, while NB-9 yields about 29 fruits/tree. The fruit size of NB-5 is smaller (1.0 kg fruit⁻¹) than NB-9 (1.4 kg fruit⁻¹). The fruit quality of both the varieties is excellent. Goma Yashi bael variety developed by CHES, CIAH, is becoming popular among farmers due to high yield potential and better fruit quality (Singh *et al.*, 2011) under semi-arid conditions. In National repository of date palm, 61 indigenous and exotic cultivars/genotypes are maintained and evaluated for different horticultural traits. The cultivars Halawy, Khalas, Khuneizi, Barhee, Zahidi and Medjool are found suitable for cultivation in hot arid region. In addition to

this, a number of minor underutilized crops are also being conserved and evaluated for different traits (More and Singh, 2008). Some exotic fruits like marula nut, argan, carob and cactus pear have been introduced and evaluated for their utilization. Marula nut can be easily multiplied through stem cuttings treated with 1000 ppm IBA (Singh and Bhargava, 2008).

Looking to the importance of vegetable crops, particularly underexploited and less known crops, and having commercial potentials in arid and semi-arid regions, systematic research work on germplasm collection, conservation and utilization was initiated since 1993-94 at CIAH, Bikaner. In this context, intensive crop specific surveys in target variability pockets and explorations were undertaken in arid and semi-arid regions and a large number of land races, semi-cultivated and popular types of *mateera*, *kachri*, snap melon, beans and some perennial horticultural species of vegetable potential were made over the years for systematic evaluation, characterization and conservation of indigenous germplasm. A number of improved varieties of arid vegetables like *mateera*, *kachri*, snap melon,

Indian bean and clusterbean have been released for cultivation. *Kachri* (AHK-200; AHK-119) and *mateera* (Thar Manak) varieties are becoming popular in arid region.

Selection of Fruit Crops and Varieties

The environmental conditions of arid region are very harsh for sustainability of plants hence; selection of a plant species for such region is important for growth and production. While selecting the fruit species for dry land horticulture, one of the basic requirements is that those crops, which complete their vegetative growth and reproductive phase during the period of maximum moisture availability, should be selected. The fruits such as ber, guava, pomegranate, custard apple, aonla and sour lime, conform to this prerequisite. The crops must have xeric characters such as deep root system (e.g. aonla, ber), summer dormancy (e.g. ber), high 'bound water' in the tissues (e.g. cactus pear, fig), reduced leaf area (e.g. Indian gooseberry, tamarind), leaf surface having sunken stomata, thick cuticle, wax coating and pubescence (fig,

Table 1. Germplasm conservation at National Field Repository of CIAH, Bikaner

Crops	Scientific name	No.	Crops	Scientific name	No.
Fruit crops					
Ber	<i>Ziziphus mauritiana</i>	318	Marula nut	<i>Sclerocarya birrea</i>	01
Bordi	<i>Ziziphus rotundifolia</i>	22	Sweet orange	<i>Citrus sinensis</i>	03
Pomegranate	<i>Punica granatum</i>	154	Karonda	<i>Carissa congesta</i>	08
Aonla	<i>Emblia officinalis</i>	50	Lasora	<i>Cordia myxa</i>	65
Date palm	<i>Phoenix dactylifera</i>	61	Wood apple	<i>Feronia limonia</i>	01
Bael	<i>Aegle marmelos</i>	17	Ker	<i>Capparis decidua</i>	06
Cactus pear	<i>Opuntia ficus indica</i>	20	Manila Tamarind	<i>Pithecelobium dulce</i>	02
Phalsa	<i>Grewia subinaequalis</i>	06	Jamun	<i>S. cuminii</i>	02
Fig	<i>Ficus carica</i>	03	Mango	<i>Mangifera indica</i>	05
Mulberry	<i>Morus alba</i>	15	Guava	<i>Psidium guajava</i>	05
Vegetable crops					
<i>Kachri</i>	<i>Cucumis melo</i>	591	Bottle gourd	<i>Lagenaria siceraria</i>	65
<i>Mateera</i>	<i>Citrullus lanatus</i>	217	Bitter gourd	<i>Momordica charantia</i>	13
Snap melon	<i>Cucumis melo</i> var. <i>momordica</i>	114	Ridge gourd	<i>Luffa acutangula</i>	20
Chilli	<i>Capsicum annum</i>	217	Sponge gourd	<i>Luffa cylindrica</i>	18
Muskmelon	<i>Cucumis melo</i>	74	Indian bean	<i>Lablab purpureas</i>	32
Kakdi	<i>Cucumis melo</i> var. <i>utilissimus</i>	32	Cluster bean	<i>C. tetragonoloba</i>	15
Ivy guord	<i>Coccinia indica</i>	01	Sword bean	<i>Canavalia gladiata</i>	02
Pumpkin	<i>Cucurbita moschata</i>	04	Khejri	<i>Prosopis cineraria</i>	15
Round melon	<i>Praecitrullus fistulosus</i>	26	Indian Aloe	<i>Aloe barbedensis</i>	02
Brinjal	<i>Solanum melongena</i>	78	Other vegetables (Leafy, Cole crops, Tomato, etc.)		135

Table 2. Germplasm conservation at CHES, Godhra, Gujarat

Crops	Scientific name	No.	Crops	Scientific name	No.
Fruit crops					
Ber	<i>Ziziphus mauritiana</i>	55	Phalsa	<i>Grewia subinequalis</i>	02
Custard apple	<i>Annona squamosa</i>	09	Fig	<i>Ficus indica</i>	05
Pomegranate	<i>Punica granatum</i>	45	Mango	<i>Mangifera indica</i>	52
Aonla	<i>Emblica officinalis</i>	14	Wood apple	<i>Feronia limonia</i>	10
Sapota	<i>Achras zapota</i>	07	Karonda	<i>Carissa congesta</i>	40
Bael	<i>Aegle marmelos</i>	15	Mahua	<i>Madhuca latifolia</i>	50
Jamun	<i>Syzygium cuminii</i>	50	Chironji	<i>Buchanania lanzan</i>	30
Tamarind	<i>Tamarindus indica</i>	25	Khirni	<i>Manilkara hexandra</i>	30
Vegetable crops					
Drumstick (perennial)	<i>Moringa oleifera</i>	11	Pumpkin	<i>Cucurbita moschata</i>	17
Drum stick (annual)	<i>Moringa oleifera</i>	30	Cluster bean	<i>Cyamopsis tetragonoloba</i>	02
Bitter gourd	<i>Momordica charantia</i>	37	Okra	<i>Abelmoschus esculentus</i>	02
Ridge gourd	<i>Luffa acutangula</i>	37	Tomato	<i>L. esculantum</i>	23

ber, phalsa, tamarind), and ability to adapt to shallow soils, rocky, gravelly, and undulating wastelands (pomegranate, aonla, bael) (Pareek and Sharma, 1991).

Crop Improvement

The Institute has released 25 varieties of arid fruits and vegetable crops which include, Thar Bhubharaj, Thar Sevika, Goma Kirti of ber, Thar Shobha of khejri, Goma Aishwarya of aonla, Thar Samridhi of bottle guard; AHW-19, AHW-65, Thar Manak of mateera; AHK-119, AHK-200 of kachri, AHS-10, AHS-82 of snap melon, AHC-2, AHC-13 of kakri and Goma Manjri of clusterbean. There are a number of varieties of arid horticultural crops at prerelease stage, which include AHRM-1 of round melon, sponge gourd, chilli, brinjal, besides some promising lines in ber, mulberry, lasora and bael, have been identified for evaluation and release (More *et al.*, 2008). At Institute level, Goma khatta, a pomegranate genotype for anardana purpose has been released. Goma Pratik of tamarind and Goma Yashi of bael and Goma Priyanka of jamun have been released by the Institute for cultivation in semi-arid and arid parts of the country. Thar Mahi of sword bean; Thar Kartiki and Thar Maghi of Indian bean have also been released by the Institute. A promising line of Chirongi CHES C-7 has been identified by the Institute for cultivation in tribal belt of MP and Gujarat under name Thar Priya. Promising lines in mahua, karonda and khirni have also been

identified having better yield and quality under semi-arid conditions. A number of improved varieties have been developed and released through AICRP on arid zone fruits. Pomegranate cvs. Phule Arakta, Bhagava, Super Bhagava (Selection-4) from MPKV, Rahuri; Narendra Ber Selection-1 and Ber-2 from NDUAT, Faizabad, have been released for cultivation. CISH Bael-1 and CISH Bael-2 were released from CISH, Lucknow for cultivation. The custard apple cvs. Arka Sahan from IIHR, Bangaluru, and APK(Ca)-1 from RRS, TNAU, Aruppukkottai, have been released for cultivation in rainfed areas. Further, a number of varieties of arid fruit and vegetable crops have been recommended for cultivation in different parts of the country after evaluation of germplasm for high yield and quality (Table 3).

Varietal variation in endurance to drought has also been observed in horticultural crops. Early ripening cultivars seem to escape stress conditions resulting from receding soil moisture stored in the soil profile during the monsoon. Ber cultivars Gola, Seb and Mundia for extremely dry areas, Banarasi Kadaka, Kaithli, Umran and Maharwali for dry regions, and Sanaur-2, Umran and Mehrun for comparatively humid regions have been recommended. Apart from morphological parameters, plants should also have physiological parameters for endurance to drought for commercial cultivation in this region. Some physiological parameters

Table 3. Promising varieties of fruit and vegetable crops for cultivation in semi-arid and arid regions

Crops	Varieties
Fruit crops	
Ber	Gola, Seb, Umran, Mundia, Kaithali, Banarasi Kadaka, Thar Bhubharaj, Thar Sevika, Goma Kirti
Bael	NB-5, NB 9, Pant Aparna, Pant Sujata, Pant Shivani, CISH Bael-1, CISH Bael-2, Goma Yashi, NB-16, NB-17
Pomegranate	Ganesh, Jalor seedless, G-137, Mridula, Bhagawa, Phule Arakta, Super Bhagava (Sel-4)
Aonla	NA 7, NA-6, NA-10, Kanchan, Krishna, Balwant, Laxmi-52
Sweet orange	Blood Red Malta, Mosambi, Pineapple, Valencia
Custard apple	Arka Sahan, Balanagar, Mammoth, Island, Gem, Red Sitaphal, APK (Ca)-1
Guava	Allahabad Safeda, L-49, Kohir Safed, Safed Jam, Chittidar, Lalit, Hisar Surkha
Date palm	Halawy, Barhee, Medjool, Shamran, Khuneizi, Khadrawy, Zahidi, Chip chap,
Sapota	Kalipatti, Cricket Ball
Fig	Poona Fig, Dianna, Dinkar, Conadria, Excel, Chalisgaon
Mango	Banglora, Kesar, Rajapuri, Bombay Green, Dashehari, Vanraj
Tamarind	PKM 1, Pratisthan, Yogeshwari, Goma Prateek
Vegetables	
Chilli	Pusa Jwala, Mathania, Pant C-1, Arka Mohani, Arka Gaurav, Arka Basant, Bharat, Indira, Hripur-Raipur
Cowpea	Pusa Dofasali, Pusa Phalguni, Pusa Barsati, Pusa Rituraj, Pusa komal, Kashi Nidhi,
Cluster bean	Pusa Sadabahar, Pusa Mausami, Pusa Navbahar, Durga Bahar, AHG-13
Onion	Patna Red, Nasik Red, N-53, Pusa Red, Pusa Ratnar, Pusa White Round, Pusa White Flat, Punjab Selection, Agrifound Dark Red, Arka Pragati
Tomato	Pusa Ruby, Pusa Early Dwarf, Pusa-120, HS-102, Sweet-72, S-12, Mangla, Punjab Chhuhara
Brinjal	Pusa Purple Long, Pusa Purple Round, Pusa Kranti, Pusa Anmol, Arka Sheet, Arka Shirish, Arka Kusumakar, Arka Navneet
Amaranth	Chhoti Chauali, Badi Chaulai, CO-1, CO-2, CO-3
Okra	Pusa Makhmali, Punjab No. 13, Punjab Padmini, P-7, Parbhani Kranti
Pumpkin	Arka Chandan, CO-1, CO-2
Muskmelon	Pusa Sharbati, Pusa Madhuras, Hara Madhu, Punjab Sunehri, Durgapura Madhu
Watermelon	Sugar Baby, Arka Manik, Arka Jyoti, Durgapura Meetha, Kesar, Mateera (AHW-19 and AHW 65), Thar Manak
Bottle gourd	Pusa Summer Prolific Round, Pusa Summer Prolific Long, Pusa Meghdoot, Pusa Manjari, Pusa Naveen, Thar Samridhi
Bitter gourd	Pusa Do Mausmi, Arka Harit, Pride of Gujarat
Kachri	AHK-119, AHK-200

identified in ber are no mid-day depression in photosynthetic rate, low rate of transpiration, maintenance of leaf water balance, growth, canopy development, dry matter allocation, high water-use efficiency, etc. It has been demonstrated that plants having capacity for drought endurance are able to maintain turgour, dry matter allocation, leaf and fruit growth even under low soil moisture level.

Biotechnological Approaches for Improvement

Micropropagation has been commercialized in many ornamental crops and herbaceous fruit

crop species worldwide. However, its wide spread commercial use is still limited in fruit crops because of several inherent problems of *in-vitro* culture system such as hyperhydricity of cultures, frequent subculturing for shoot proliferation, poor morphogenic responses of explants from mature tree, contamination in culture, either systemic infection or infection, during long term culturing process, problem of somaclonal variation due to repeated subculturing process, poor root formation and low rate of survival during acclimatization of the plantlets *ex-vitro*. Keeping in view these inherent limitations of micropropagation of fruit

tree species, a new concept of micropropagation of fruit crops has developed using single or double node explants from the mature trees. Direct morphogenesis of shoot and root formation was achieved in lasoda (*Cordia myxa* Roxb.) (Singh *et al.*, 2006) mulberry (*Morus alba*) and lime (*Citrus aurantifolia*) using single or double node explant having physiologically active axillary buds. Under this *in-vitro* system two type of media were used, one for shoot induction in preexisting axillary buds and another for formation of roots at the basal of the original explant.

In another important study with citrus, direct shoot and root formation was achieved in double node explant within 35 days of culture period. These results conform the production of plantlets within a short period completely eliminating subculturing process. Thus, using this technique of micropropagation, the fruit tree species can be multiplied *in-vitro* with minimizing inherent problems of tissue culture in greater way to obtain a large number of genetically identical, physiologically uniform and developmentally normal plantlets preferably with high photosynthetic or phototrophic potential to survive the harsh *ex-vitro* condition.

Attempts have been made for mass multiplication of ker through tissue culture technique since it is a hardy plant and suitable for hot arid environment. Ker can also be multiplied through stem cuttings treated with growth regulators viz. IBA 7500 ppm + 1000 ppm thymine (Bhargava *et al.*, 2000). Work on date palm tissue culture is being done at various places in the country. However; some good results have been achieved through organogenesis and embryogenesis in date palm tissue culture at CIAH, Bikaner. At AAU, Anand, tissue culture plants of date palm cv. Barhee have been raised (Sharma and Singh, 2013).

Orchard Establishment

The fruit plants raised in the nursery are generally used to establish orchards. Such plants invariably lose their tap roots as a result of repeated transplanting. Plants raised in containers develop coiled roots. For success in dry lands, plants must have a root architecture with a strong tendency to penetrate deep into the soil. *In-situ* technique of orchard

establishment is found suitable under arid conditions (Vishalnath *et al.*, 2000). Rootstock seedlings of ber are raised in the nursery in 300 gauge polythene tubes (25 cm length and 10 cm diameter, open at both ends), filled with a mixture of farm yard manure (FYM), sand, and clay in 1:1:1 ratio. The seedlings can be budded at about 90 to 100-day-old stage. These plants become ready for transplanting 1 to 2 months after budding. This technique helps to retain the straight growth of the tap root as the tubes are open at the bottom. Thus, the tubes neither restrict root growth nor induce coiling. Budded plants raised by this technique are also suitable for transportation to distant place (Pareek, 1978).

Propagation techniques

The variability has been observed in plants raised through seeds. Except few plant species, in general, vegetative methods of propagation are used for multiplication of plants. Propagation of plant through vegetative methods viz. stem cutting, layering, stooling and grafting have been described for many arid fruit plants. Cactus pear can be easily multiplied through cladodes or stem cuttings (Singh and Bhargava, 2014). Manila tamarind is under-exploited fruit species and suitable for cultivation in dry parts of the country. Treatment of seeds with growth regulators (GA₃) enhanced per cent seed germination and growth of seedlings in *Pithecellobium dulce*

Table 4. Propagation methods of different fruit crops

Fruit crops	Period	Propagation methods
Aonla	July-August	Patch budding
Bael	June-July	Soft wood grafting and patch budding
Ber	June-July	T-Budding/I-budding
Chironji	July-August	Soft wood grafting
Jamun	March July-August	Soft wood grafting Patch budding
Ker	August -Sept.	Cutting and micro-propagation
Khejri	June-Sept.	Patch budding
Lasora	June-July	Patch budding and micro-propagation
Pomegranate	Feb.-March	Cuttings (soft and semi-hard wood)
Tamarind	July-August	Soft wood grafting and patch budding
Mahua	March-April	Soft wood grafting

under hot arid conditions (Singh *et al.*, 2011). In order to optimize the production of arid horticultural crops, propagation techniques of aonla, ker, lasoda, ber, khejri, pomegranate, mahua, bael, jamun, chironji, etc. have been standardized for large scale multiplication of plants as given (Table 4).

Planting of stem cuttings of pomegranate, phasla, marula nut, fig and mulberry in such polythene tubes would also induce straight roots. The pit size 2 x 2 x 2 ft and filling mixtures (FYM + pond silt + soil in 1:1:1 ratio) has been standardized for planting of ber and pomegranate in arid region. Seed soaking enhanced germination and seedling growth by pre-treatment of seeds with cow dung for 24 hrs in *Phoenix* species under nursery conditions (Singh and Bhargava, 2009).

The plant density mainly depend upon the plant type, soil fertility status and management practices while planting system to be adopted in dry lands depends largely upon the topography of the land, fruit species and soil type. In the plains, planting, is generally done in square or rectangular system. On slopy lands, fruit trees are planted on contour terraces, half moon terraces, trenches and bunds, and micro-catchments. On marshy and wet areas mounding and ridge-ditch method of planting have been suggested. The trenches and bunds made across the slope are staggered (Saroj *et al.*, 1994). In a micro-catchment, which may be triangular or rectangular, trees are planted at the lowest point where runoff accumulates. The planting distance 6 x 6 m or 8 x 8 m for ber cultivation is optimum for arid region. Date palm, bael and aonla is recommended for planting at 8 x 8 m or 10 x 10 m distance under arid conditions. High density plantation study revealed that maximum plant height was recorded at 2 x 2 m spacing, whereas plant height, stem girth, average number of fruits, average weight of fruit and yield was obtained under 4.5 x 3.0 m spacing in pomegranate under Rahuri conditions (Anon., 2013). High density planting is also beneficial in aonla fruit trees to achieve high yield under semi-arid conditions. Among the different planting systems viz, square, hedgerow, double hedgerow, cluster and paired, maximum gross return (Rs. 88,400 ha⁻¹) and net return were recorded with double hedgerow planting system followed by

hedgerow, cluster and paired planting systems in aonla (Singh *et al.*, 2010).

Plant Architecture and Canopy Management

The plant canopy plays a vital role to increase quality production of fruit trees. Canopy management work has been done for high yield and quality of fruits in guava at Central Institute for Subtropical Horticulture, Lucknow, and in citrus at National Research Centre on Citrus, Nagpur. Training at initial stages of growth gives proper shape and strong frame to the trees. The bushy pomegranate should be trained keeping 3-5 stems from the ground level while in other fruits, single stem training keeping 3-4 main branches is adopted. However, pruning is essential to regulate reproductive phase of plants. Ber is pruned during January in Tamil Nadu, by the end of April in Maharashtra, and by the end of May in North India. The main shoots of the previous season are cut back retaining 15 to 25 nodes, depending upon location, cultivar, and age and vigor of tree. All the secondary shoots are completely removed. As a result of light pruning for several years, long non-flowering shoots develop. To eliminate this, half the number of shoots on the tree should be pruned keeping normal length and remaining half should be pruned keeping one to two nodes to induce new growth for fruiting in the following year. In phalsa, the time of pruning should be regulated according to the flowering period and should result in maximum number of new shoots on which bearing takes place. Established phalsa bushes should be pruned at 150 cm height once a year during January in north India and twice a year (December and June) in south India. Pruning from ground level is done either to rejuvenate old bushes or to train young plants into bush form. Defoliation of leaves in lasoda trees in the month of December-January produces early flowering and fruiting in arid region. Defoliation of leaves in pomegranate by using chemicals has been useful for bahar treatment.

Water Management

In arid region, the major constraint in commercial cultivation of fruit crops is inadequate water resources. Hence, the need of the hour is to develop technologies, which

not only require low water input, but also have high water-use efficiency. Water being a rare commodity in arid eco-system, the first and foremost requirement is to conserve the available soil or rain water. For conservation of rain water both *in-situ* and *ex-situ* technologies have been developed. It has been reported that micro-catchment slopes greater than 5% did not significantly affect run off at Jodhpur, and that the highest ber yields were obtained when 0.5% and 5% slopes had 8.5 m and 7.0 m length of run, and 72 m² and 54 m² catchment area per tree, respectively (Sharma *et al.*, 1986). Work done at Aruppukottai (Tamil Nadu) and Anantapur (Andhra Pradesh) has indicated usefulness of *in-situ* water harvesting technique for fruit production.

Arora and Mohan (1988) found V-shaped micro-catchments with run-on surface mulched with grass to enhance the productivity of lemon, sweet orange and plum in Doon valley. At Hyderabad, micro-relief of 3 m width and 25 cm height, spaced 9 m from ridge to ridge, have been used to store extra rain water for fruit trees such as kagzi lime, coorg mandarin, and sweet orange with tomato and okra as intercrops.

Mulching with organic materials (e.g., hay, straw, dry leaves, and local weeds) has been found to be highly beneficial in reducing evaporation losses. The practice also suppresses weed growth, prevents erosion, and adds organic matter to the soil (Gupta, 1995). Black polythene mulch is very effective in ber orchards in western India. Although, local organic mulch materials are cheaper than polythene mulches, but these require proper care to maintain effective cover thickness. Leaf mulch has been used to conserve soil moisture in sapota orchards in Karnataka, Tamil Nadu, and Andhra Pradesh. Sugarcane trash mulch in pomegranate, fig, and custard apple was found effective in Maharashtra. Paddy straw mulch was found suitable for aonla crop to improve production under semi-arid conditions of Gujarat (Singh *et al.*, 2010).

At CIAH, Bikaner, the work on *in-situ* water harvesting has been undertaken in pomegranate, aonla and vegetable crops. It has been demonstrated that application of black polythene mulch and local weeds help in conserving soil moisture status in above crops.

It has been demonstrated that plant growth and development remains optimum with use of above mulching materials. Mulching studies with respect to soil hydro thermal regimes in brinjal revealed that organic mulches curtailed soil temperature during warm months, while an increase was recorded during the winter months. Significant increase in fruit yield by 66 and 58% could be obtained through lasoda and kheep (*Leptodenia pyrotechnica*) mulching (Awasthi *et al.*, 2006).

Among the *ex-situ* water conservation methods, in arid ecosystem, emphasis has been given mostly on pressurized irrigation system. It has been demonstrated that fruits and vegetables can be grown economically by use of drip or sprinkler irrigation system. At CIAH, Bikaner, and its regional station it has been demonstrated that crops such as pomegranate and ber can be grown successfully under drip irrigation system. It has been proved that upto 25% water can be saved if pressurized irrigation system is used as compared to conventional flooding or bubbler system.

The use of drip alone or in combination with mulching has been demonstrated as a successful technology for cultivation of pomegranate at Anantapur. The studies have shown that highest number of 'B' grade pomegranate can be harvested under drip + mulch. FYM mulching is found beneficial for production of brinjal crops than other mulches in arid region.

Application of pitcher irrigation was attempted in cactus pear at CIAH, Bikaner, and the growth of cactus pear was better as compared to control. The use of double ring system to conserve the moisture applied for production of fruit crops was attempted in aonla. It was observed that by this method the water is applied in zone having functional roots, which enhanced the water-use efficiency. In Maharashtra, double dripper line is used in pomegranate for proper and equal distribution of water to the plants. Same case of irrigation is used in date palm crop in Gujarat state.

Water loss due to transpiration can be reduced by use of radiation reflectants, stomata closing chemicals, and plastic films. Spraying of 4 to 6% kaolin, 0.5-1.0% liquid paraffin, and 1.5% power oil, after occasional rains in low rainfall areas, considerably reduce plant water losses (Pareek and Sharma, 1991). Chemicals

such as phenyl mercuric acetate (PMA), decynyl succinic acid (DSA), abscisic acid (ABA), and cetylalcohol cause stomatal closure thereby reducing transpiration (Jones and Mansfield, 1991). Shelterbelt and windbreaks can reduce evapo-transpiration by reducing the wind speed and stabilizing microclimate (Muthana *et al.*, 1984).

Weed control has special significance in rainfed orchards in reducing soil moisture losses and improving fruiting in trees. Timely weeding is essential to improve fruit quality even in high rainfall areas. Application of pre-emergence weedicides such as Diuron, Bromacil, and Atrazine @ 2-3 kg ha⁻¹ and post emergence weedicides such as Grammaxone (Paraquat) and Glyphosate @ 1.0 L ha⁻¹ have proved effective in checking weed growth in the orchards.

Integrated Nutrient Management

The balanced nutrition in fruit plants are required at appropriate time according to the age of plants. The application methods also play important role for availability of nutrients to the plants. In ber orchards, besides 10-15 kg organic manure, annual application of 100 g N, 50 g P₂O₅ and 50 g K₂O per tree is recommended. Fertilizer doses should be raised according to the age of plants and soil fertility of the region. Application of 15-20 kg FYM per tree has been found beneficial in aonla, custard apple, and tamarind. At MPKV, Rahuri, in addition to 50 kg FYM, 625 g N, 225 g P₂O₅ and 225 g K₂O has been recommended for application to 5-year-old pomegranate trees. In 6 to 7-year-old fig trees planted at 5 m x 5 m spacing, fertilization with 900 g N + 250 g K improved fruit production.

The nutritional trials have been carried out in arid fruits at CIAH, Bikaner, and centres of AICRP on Arid Zone Fruits. The studies conducted on date palm at Abohar showed that annually application of 300-400 g N tree⁻¹ gave maximum number and weight of bunch. Similarly in pomegranate, it has been demonstrated that application of 50% recommended dose of nitrogen at monthly interval gave best performance.

In order to conserve fertilizer, attempts were made to supply nutrients along with water under pressurized irrigation system.

The studies conducted in pomegranate and ber have demonstrated that upto 25% fertilizer can be saved if plants are fertigated through drip system.

Keeping in view the export potential of pomegranate, attempts have been made to produce it organically. In this pursuit, inorganic fertilizers were substituted with organic fertilizers. The results have demonstrated that a good crop of pomegranate can be harvested by giving 50% RD (Recommended dose) of NPK through Vermicompost and 50% through inorganic fertilizer. Thus, the use of inorganic fertilizers can be reduced to half through this technology.

Micronutrients are often found deficient in semi-arid and arid soils. Foliar feeding of nutrients such as nitrogen (0.5-2.0% urea), zinc (0.05-1.0% zinc sulphate), and boron (0.05-1.0% borex) has given beneficial results in these areas (Pareek and Sharma, 1991). In the medium rainfall region of eastern Uttar Pradesh, application of FYM, pond soil, gypsum, and pyrite in sodic soils resulted in better establishment and growth of aonla and bael plants. Foliar spray of micronutrients (Fe 0.50% + Zn 0.50% + Cu 0.25%) improved the yield and fruit quality in kinnow mandarin in arid region. For fast recoupment of nutritional requirement to the plants, foliar spray is easy method to use micronutrients. Foliar spray of 0.5-1.0% zinc sulphate improved fruit quality in ber cv. Seb in semi-arid conditions (Singh and Vashishtha, 1997).

Fruit Based Farming Systems

Monoculture in arid zone is highly risk prone due to crop failures, hence a suitable tree crop combination is essential for risk alleviation, income generation, improved productivity as a result of efficient use of natural resources and inputs, and ameliorate and improve adverse agro-climate. Agri-horticultural combinations with legume intercrops such as mung bean, moth bean, clusterbean, and cowpea are beneficial. In the rainfed orchards of guava and ber, clusterbean okra, and cowpea in kharif (rainy season) proved good in the medium rainfall region of Gujarat (Raturi and Hiwale, 1988). Under South Indian conditions of Hyderabad; cowpea, green gram, clusterbean and horse gram in ber orchards and bitter

gourd, tomato and okra in acid lime orchards have been grown as intercrops.

In areas with large livestock population, horti-pastoral system would be beneficial. In the arid areas, the system could have combinations such as khejri (*Prosopis cineraria*) + ber + dhaman (*Cenchrus ciliaris*, *C. setigerus*) or sewan (*Laisurus indicus*). In semi-arid areas, perennial trees (mango, tamarind, sapota, jackfruit and palmyrah palm) could be grown with fodder crops.

Fruit trees can also be planted in association with forest trees, and they yield wood for packaging and fuel. Multistorey combinations incorporating large trees, small trees, and ground crops can be used. In low rainfall (300-500 mm) zone, combinations such as khejri or ber + ber or drumstick + vegetables (legumes and cucurbits); in 500-700 mm rainfall zone, combination of mango or ber or aonla or guava + pomegranate or sour lime or lemon or drumstick + solanaceous or leguminous or cucurbitaceous vegetables; and in 700-1000 mm rainfall zone, combination of mango or jackfruit or mahua or palmyrah palm or tamarind or guava + sour lime or lemon or pomegranate or aonla + vegetables can be adopted.

In arid ecosystem, attempts have been made to develop models for crop diversification. Keeping in view the traditional over storey crops as ber and new introduction aonla, the cropping models have been developed. It has been demonstrated that in ber-based farming system cultivation of Indian aloe can be taken up as a remunerative model (Dhandar *et al.*, 2004). Similarly, in aonla-based cropping system, it has been demonstrated that model consisting of aonla + ber along with moth bean or fenugreek can be adopted as a sustainable model for nutritional and income security of the inhabitants (Awasthi *et al.*, 2007).

Mono cropping of either fruit or seasonal crops is highly risk prone in arid areas, hence to mitigate the effect of total crop failures, fruit-based multistorey cropping system, such as aonla-ber-brinjal-moth bean, aonla-drumstick-senna-moth, bean-cumin can be profitably adopted by the farmers of arid region for better cash flow, nutritional and environmental security and sustainable livelihood. In areas where frost is severe aonla-khejri-suaeda-moth

bean and mustard can be another lucrative option (Awasthi *et al.*, 2007).

Crop diversification studies in ber and aonla based cropping led to the recommendations that in pre-establishment phase of ber orchard, Indian aloe (*Aloe barbedensis*) and clusterbean (*Cyamopsis tetragonoloba*) are the low input and high-return crops in arid region. In aonla-based multi storey cropping system, the model with crop combination of aonla-drumstick-senna-moth bean-cumin recorded highest net return followed by cropping model aonla-ber-brinjal-mothbean-fenugreek has been recommended for sustainable and remunerative under arid ecosystem. Under semi-arid conditions of Godhra, Gujarat, fruit-based farming system like aonla/ber + okra/brinjal/cowpea have been recommended to the farming community for sustainable production. In date palm plantations at Abohar, Punjab, growing of turmeric and ginger was found suitable as inter crops. However, under hot arid conditions, Taramira, an oil seed crop, can be grown as dryland inter crop in interspaces of date palm plantations.

Integrated Pests/Disease Management

Besides wild animals, rodents and birds there are many insects and diseases causing loss of horticultural crops. Major diseases of arid fruit crops and their control measures are presented in Table 5.

Termites cause considerable damage particularly in low rainfall areas. Methyl parathion dust (5%) should be applied in the pits (50 g pit⁻¹) dug for planting fruit trees. Subsequently, water soluble insecticides (Chloropyrifos) should be applied with irrigation water. Fruit fly (*Carpomyia vesuviana*) causes serious damage in ber fruits. To keep the infestation under check, the chemical spray schedule should consist of spray at pea stage with 0.03% monocrotophos, second spray after 15 days with 0.1% carbaryl. During maturity of the fruits, if necessary, sprays should be done with 0.5% Malathion mixed with 0.5% gur or sugar solution. This schedule has also been found effective against fruit borer (*Meridarchis scyroides*), which causes serious damage in southern and western India. Pomegranate butterfly (*Virachola isocrates*) causes considerable damage to pomegranate fruits. Bagging of fruits with butter paper gives good protection. For

Table 5. Major pests and diseases of arid horticultural crops and their control measures

Crops	Pests/diseases	Control measures
Pests		
Ber	Fruit fly	Comprising digging of soil in basin, mixing of 50 g insecticidal dust, spray of 0.05% Monocrotophos during monsoon, 2-spray of Monocrotophos (0.03%) at pea stage
	Weevil	Management practices and spray of Monocrotophos @ 0.03% to control the weevil
Pomegranate	Fruit borer	Two spray of Deltamethrin (0.02%) and Carbaryl 50 WP (0.2%) at 21 days interval
	Barkeating caterpillar	Plugging of holes with mud followed by spray Dimethoate/Monocrotophos (0.08%)
Aonla	Leaf gall midge	Spray of Endosulphon (0.05%) minimizes the problem
Bael	Leaf eating cater pillar	Spray of Dimethoate/Monocrotophos (0.08%)
Diseases		
Pomegranate	Leaf and fruit spot	One spray of Ziram (1.0%) or Bordeaux (1.0%) at flowering or fruit setting and subsequent 4 sprays at 20 days interval
Date palm	<i>Graphiola</i> leaf spot	Spray of Bavistin (0.1%) or Blitox-50 WP (0.4%) to minimize the disease
	Fruit rot	Sprays of Carbendazim (0.1%) minimize the rotting
Aonla	Rust	Three spray of Moncozeb (0.3%) at 15 days interval from diseases initiation under Faizabad conditions. Four spray of Chlorothalonil (0.2%) at 10 days interval
Fig	Rust	Two spray of Mancozeb (0.3%) is effective

control, 0.02% Deltamethrin and 0.2% Carbaryl 50 WP sprayed in rotation at 21 days interval starting from fruit set is the most cost effective.

For the control of ber powdery mildew, fungicides such as 0.1% Dinocap or Carbendazim or Triademorph or Thiophenate methyl and 0.2% wettable sulphur have been found most effective when sprayed 2-4 times at 15 to 20 day interval starting from initiation of the disease. One spray of the fungicide at initiation of new growth after pruning is an effective prophylactic measure. Black leaf spot (*Isariopsis indica*), found under more humid conditions, can be controlled by 2-3 sprays of 0.2% Captafol or Copper oxychloride or Mancozeb and 0.1% Carbendazim at 15-day-interval. For the control of leaf and fruit spot in pomegranate, four sprays with 0.25% Ziram and 1% Bordeaux mixture at 15-day-interval are most effective. Since, the intensity of the disease is more under humid conditions during mrig bahar as many as 10 sprays at 10-day-interval may be necessary. Fungicides such as Captafol, Mancozeb, Carbendazim, Copper oxychloride, and Thiophenate methyl could also be used. For the control of rust in aonla, 4 sprays of 0.2% Chlorothalonil at 15-day-interval soon after initiation of symptoms give the best control.

Apart from chemical control, attempts have also been made to use bio-pesticides for control of pests in arid fruit crops. It has been demonstrated that application of Neem Seed Kernal Extract (NSKE @ 2.5-5.0%) on various crops was effective in controlling pests in pomegranate, aonla, chilli and brinjal.

Similarly use of bio-control measures to control ber powdery mildew was also attempted. It has been demonstrated that isolates CIAH-196 of *Trichoderma* has potential to be used as bio-control of ber powdery mildew. The isolates thus obtained are resistant even to fungicides and hence can be used in combination with pesticides.

Post Harvest Management

The post harvest handling accounts for 20 to 40% of the losses at different stages of grading, packaging, storage, transport and finally marketing of both fresh and processed products. Value addition to perishable commodities is needed to achieve better price of produce in the market. In arid region the quality production is obtained because of minimum pressure of disease and insects. The

horticulture produce suffers heavy post-harvest losses in the absence of adequate post-harvest and marketing infrastructure *viz*; pre-cooling units, packaging and grading sheds, short and long term cold storage facilities, refrigerated containers, storage and phyto-sanitary facilities at airports.

The value addition signifies the steps and series of operations like delineation of criteria for maturity, pre-harvest treatments to reduce post harvest losses, techniques of harvesting to minimize on farm losses, standards for grading and packing for distance transportation, post harvest treatments and conditions of storage to improve shelf life, processing techniques to develop more useful product and utilization of waste to develop byproducts. In real terms, value addition deals with the process of conversion of useless commodity into useful product however, converting a less useful produce or waste material into more useful product is also considered in value addition. In arid region, due to plenty of solar radiation value addition through dehydration technique is more common for vegetables and spices. Many dehydrated products such as sangri, methi leaves, coriander leaves, kachri are available in the market. Brining, pickling, beverage making, preserve making, etc. are the other methods of value addition being adapted to various arid commodities. For arid horticultural crops, value addition is essential for their proper utilization. However, post harvest techniques should be commercialized to fetch high price of produce in the market. Some of the value added products prepared

Table 6. Value added products

Crop	Products
Ber	Squash, RTS, Dehydrated ber, Jam,
Aonla	Chyawanpras, Shreds, Candy, Preserve, Squash, Pickle,
Date palm	Squash, Dry dates (<i>Chuhara</i>), Pind khajoor, Biscuits,
Khejri	Sangri (dehydrated pods), Biscuits
Bael	Squash, Powder, Candy
Kinnow	Squash
Ker	Vegetable, Pickle
Indian Aloe	Vegetable, Pickle, Laddu
Lasoda	Mixed pickle
Kachari	Dehydrated kachri, Powder (ingredient of channa masala)

from arid horticultural crops at CIAH, Bikaner, are presented in Table 6.

It can be concluded that much efforts have been made to develop technology compatible for commercial production of arid horticultural crops. A number of varieties and agro-techniques suitable for arid region have been developed to increase production. However, there is a need to address various issues for further refinement of technology, improvement in socio-economic status of peoples of arid region and development of sustainable agro-horti-system. The major issues are utilization of plant genetic resources, exploitation of biotechnology in arid horticultural crops, protected cultivation and off season production, hi-tech crop production, efficient utilization of water resources, rehabilitation of degraded lands, diversified cropping systems and organic farming, use of solar and wind energy, post harvest management, marketing and export, transfer of technology and human resource development.

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