Horticulture Based Production Systems in Indian Arid Regions

D. C. Bhandari, P. R. Meghwal and S. Lodha

1 Introduction

The Indian arid zone covers around 12 % of country's geographical area occupying 31.8 million ha of land (Fig. 1). It covers parts of Andhra Pradesh, Gujarat, Haryana, Karnataka, Maharashtra, Punjab and Rajasthan states of India (Fig. 2). These areas experience an annual rainfall between 100 and 500 mm with a coefficient of variation varying from 40 to 70 %. The region is characterized by low and erratic rainfall with extremes of temperature (1–48 °C), high wind velocity and sandy soils. Vegetation constitutes primary source of life support where animal husbandry being major vocation of people that depends entirely on natural vegetation, besides being of direct economic relevance, provides stability to wind prone sandy friable surface covering nearly two-third of the region. Further, inhospitable climate, too deep or too shallow soils with low moisture and poor fertility, deep underground water, which is often brackish or saline, coupled with intense biotic pressure permits specialized plants, which are well adapted to these climatic, edaphic and biotic adversities and fluctuations. With the increasing biotic pressure, most of the arid and semi-arid regions are confronted with the challenges of producing more per unit land with uncertain and dwindling supplies of water.

To sustain livelihood, desert dwellers have tested many crops for the last several centuries. During this exercise, they have identified crops, which can be cultivated under the harsh climate of the region with scarce water through rainfall or in the form of deep underground water. This traditional knowledge of hardy crops, cultivation practices and land races was inherited generation after generation to

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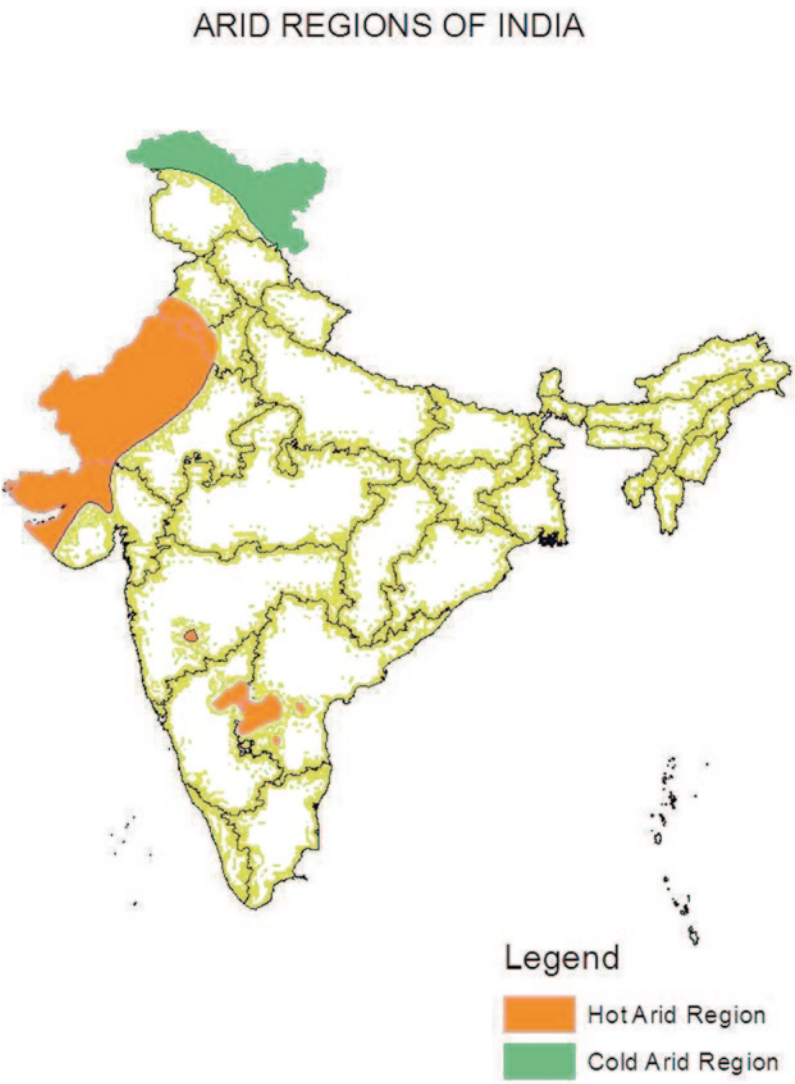

Fig. 1 Hot and cold arid regions in India

the extent that 'Thar desert' is considered as most thickly populated desert of the world because of time tested water harvesting structures providing livelihood security. The principle rainfed crops include pearl millet (*Pennisetum glaucum* (L.) R. Br.), guar or cluster bean (*Cyamopsis tetragonoloba* (L.) Taub.), moth bean (*Vigna aconitifolia* Jacq. Marechal), green gram (*V. radiata* (L.) Wilczek), cowpea (*V. unguiculata* (L.) Walp.), sesame (*Sesamum indicum* L.), sorghum (*Sorghum vulgare* Pers.), etc. These crops are cultivated during rainy season (July–October) at the

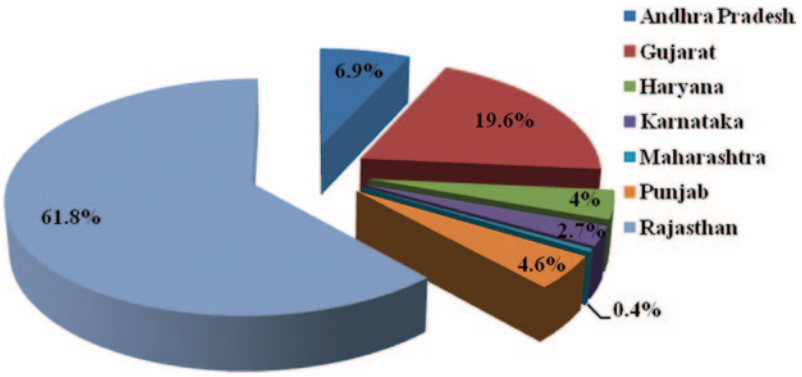

Fig. 2 Area under hot arid region in different states of India

onset of the monsoon. Depending on distribution of rainfall, fluctuations in temperature and other climatic features and selection of varieties, these crops mature in a period of 60–100 days. Produce of these crops are the main source of food for the people, which they consume for a year, keep as a security for next year (may be a drought year) and remainder is sold in the market. Certain time tested land races were evolved, which can produce seed as well as fodder for the livestock maintained by the farmers.

During winter season, wherever irrigation facilities are available, farmers grow wheat (*Triticum aestivum* L.), mustard (*Brassica juncea* (L.) Czern & Coss.), chickpea (*Cicer arietinum* L.) cumin (*Cuminum cyminum* L.), blond psyllium or isabgol (*Plantago ovata* Forsk.), onion (*Allium cepa* L.), garlic (*A. sativum* L.), etc. Among these, cumin and isabgol are also monopoly crops of this region in India owing to favorable soil and climatic conditions. These are considered as 'cash crops' because even under limited irrigation farmers can earn substantial amount of income from one hectare of land. In spite of being risk oriented, farmers are traditionally cultivating these crops in their fields by adopting a sound crop rotation.

In addition to above annual crops, some important tree species are also an integral part of arid agriculture, which provide alternative means of security to the farmers. One of the most important trees is the Indian mesquite locally called as khejri (*Prosopis cineraria* (L.) Druce), also known as 'Kalpavriksh' of the Indian desert. This tree is the most important component of the agro-forest in agricultural fields. Farmers are maintaining 30–60 trees of khejri in a hectare as it improves the growth of companion annual crops. Being a legume, it also fixes nitrogen in the soil. All parts of tree are used in one or other way as fodder or vegetable. Other trees of importance are marwar teak (*Tecomella undulata* D. Don), gum Arabic or kumat (*Senegalia senegal* Britton), Israeli babool (*Acacia tortilis* Hayne), etc. The region is also bestowed with drought hardy horticultural and medicinal plants. Some of these are Indian jujube (*Ziziphus mauritiana* Lamk.), kair (*Capparis decidua* (Forsk.) Edgew), Bengal quince or bael (*Aegle marmelos* (L.) Corr. Serr.), henna

(*Lawsonia inermis* L.) etc. Similarly, to sustain animal husbandry three major species of grasses are also abundantly growing in the region viz. *Cenchrus ciliaris* L. (buffel grass), *C. setigerus* Vahl. (birdwood or dhaman grass) and *Lasiurus sindicus* Boiss. (sewan grass). If one travels in the remote areas of Jaisalmer district of Rajasthan, he can witness thousands of hectares of natural grasslands with this species.

Arable cropping in the region is often risky due to its complex and multifarious problems i.e. environmental, biotic, technological and socio-economic. Crop yields are meagre and unstable and consequently the income from existing cropping alone is hardly sufficient to sustain the farmers' family. Therefore, to mitigate the risk and uncertainty of the income from conventional cropping, it is essential to integrate various agricultural enterprises in the production programme that yield regular and evenly distributed income, cater diverse needs of the farmer's family along with imparting sustainability through conservation and improvement of natural resources in fragile arid ecosystem. These regions are endowed with appreciable agro-ecological diversity and hence various components viz. crop, animal, tree, grass, fruit tree can be integrated in production system for livelihood security. Moreover, simple and high input packages designed for mono crop systems do not fit well either with the complexity and diversity of resource poor farming community or with their poor access to agricultural and risk prone environment.

2 Importance of Horticultural Crops

Over the past 40 years, the world's agricultural systems have been changing in response to population pressures (Waterlow et al. 1988). Population growth and local economics are driving both the intensification of agriculture and its extensification in to the marginal lands, where risks of crop failure and environmental degradation are high. As Lal (1987) points out, 'subsistence farmers, who face famine, would consider a successful technology to be one that produces some yield in the worst year rather than one that produces high yields in the best'. Horticulture based production systems are now considered to be the most ideal strategy to provide food, nutrition and income security to the people (Chundawat 1993; Chadha 2002). Integration of annual crops with fruit trees yields multiple outputs that ensure production and income generation (Osman 2003).

The importance of horticulture in improving the productivity of the land, generating employment, improving economic conditions of the farmers and entrepreneurs, enhancing exports and above all, providing nutritional security to the desert dwellers, can hardly be overemphasized. Horticulture has assumed significant importance in the crop diversification in recent years, which has become essential to arrest serious land degradation and enhancing the farm income. In fact, the horticulture has also gained commercial importance with a very significant share in the economy of the region. Diversification of agriculture from traditional land use with predominantly cereal/legume-based cropping systems to more productive and remunerative one has become a milestone to be achieved. Horticulture provides one

Table 1 Improved cultivars, propagation method, plant geometry and yield potential of different fruit crops

Fruit crops	Improved cultivars	Propagation method	Yield (kg plant^{-1})
6 × 6 m spacing			
Bengal quince	Dhara Road, Faizabadi local, NB5, NB9, Pant urvashi, Pant aparna, Pant shivani and Pant sujata	Patch budding (May–July)	30–60
Indian cherry	–	Seeds and budding	40–150
Indian gooseberry	Chakiya, Kanchan, NA7, Krishna, Anand 2	Patch budding (July–August)	40–150
Indian jujube	Gola, Mundia (early) Seb, Banarasi, Kaithli, Goma keerti (medium), Umran, Illaichi, Tikdi (late)	I-budding (July–August)	40–100
Orange	Kinnow	Budding (March–April)	30–50
Sweet orange	Mosambi and blood red	Budding (March–April)	30–50
5 × 5 m spacing			
Pomegranate	Jalore seedless, Ganesh, G137, G131, P26, P 23, Mridula, Araktha, Bhagwa, etc.	Hard wood cutting and air layering (July–August)	15–25
Sour lime	Kagzi lime, Vikram, Pramalini, etc.	Air layering and budding	20–30
4 × 4 m spacing			
Karonda	Pant manohar, Pant suvarna, Pant sudarshan	Seeds and cutting (August)	10–20

of the few viable and most attractive alternative land use system. Apart from their contribution to the total agricultural production, their potential for providing much higher income to the farmers has been another major factor for favoring these crops in this campaign. Awasthi and Pareek (2008) have reviewed the horticulture based cropping system for arid region. The improved cultivars of prevalent fruit crops with their propagation method, spacing and yield potential was worked out during past four decades (Table 1).

2.1 Horticultural Crops

2.1.1 Indian Jujube (*Ziziphus mauritiana* Lamk.)

The Indian jujube (ber) of family Rhamnaceae is one of the most ancient cultivated fruit trees in north Indian plains. It grows even on marginal lands or inferior soils where most other fruit trees either fail to grow or give very poor performance. It is regarded as the king of arid zone fruits and also as poor man's apple. There are three main species found in the country. The *Z. mauritiana* is the main species of commercial importance with its several varieties. Z. *nummularia* is prized for its

leaves (rich in protein) which provide fodder (Pala) for livestock. The third one, *Z. rotundifolia* also bears edible fruits but of smaller size. It is used as rootstock for commercial Indian jujube. The seeds contain saponins, jujubogenin (Kawai et al. 1974) and obelin lactone. Jujube fruits contain fairly high amount of vitamin C, besides vitamin A, B, protein, calcium and phosphorus (Jawanda and Bal 1978). It is a perennial hardy fruit tree which gives income from multiple products such as fruits, fodder and fuel wood even in severe drought conditions to the resource deficient farmers. It is the only fruit crop which can give good returns even under rainfed conditions and can be grown in a variety of soils and climatic conditions ranging from sub-tropical to tropical.

2.1.2 Indian Gooseberry (*Emblica officinalis* Gaertn.)

The Indian gooseberry (aonla) of family Euphorbiaceae is being cultivated in India since Vedic Era. As a result of intensive research and development, it has attained commercial status and also proved to be potential fruit crop for arid ecosystem. It is hardy, prolific bearer and highly remunerative even without much care and can be grown in variable agro-climatic and soil conditions. The fruits are recognized for their nutritive, medicinal and therapeutical values and are rich source of vitamin C (4–9 mg g^{-1}), pectin, iron, calcium and phosphorus. The fruit is the main ingredient in Chayvanprash and triphala used in Ayurvedic medicine.

2.1.3 Indian Cherry (*Cordia myxa* L.)

Indian cherry of family Boraginaceae, locally known as lasoda is another important fruit plant suitable for arid and semi-arid regions of India. Its fruits and other parts have multiple uses in human health, nutrition and other uses. Green unripe fruits are important as fresh vegetable and pickles during April–May when availability of conventional vegetables is scarce. The species is also important ecologically in providing vegetative cover as tree component of arid farming system, preventing soil erosion and promoting biodiversity. The advantage with this species for agro forestry system is that it offers least competition with rainy season crops since its fruiting season is during summer season when main crops are already harvested. This plant also offers scope in using harvested rain water for fruit production since it requires irrigation only for 2–3 months period during summer season (April–June).

2.1.4 Pomegranate (*Punica granatum* L.)

Pomegranate (anar) of family Lythraceae is an economically important commercial fruit crop of arid and semi-arid regions. Commercial plantations of pomegranate exist in Maharashtra, Gujarat, Rajasthan, Andhra Pradesh and Karnataka owing to its preference for arid climate. Its xerophytic characteristics and hardy nature makes

it suitable crop for dry, rainfed, pasture and undulating land, where other fruit crops cannot grow successfully. Besides, being a favorite table fruit it is also used for preparation of juice and squash. Dried seeds give an important condiment coined as anardana. It also has medicinal value and rind is being used for dyeing cloths.

2.1.5 Indian Mesquite (*Prosopis cineraria* (L.) Druce)

Indian mesquite (khejri) of family Fabaceae is an important component of farming system and plays significant role in the economy of Indian desert. It is found growing in the arid and semi-arid parts of Rajasthan, Gujarat, Haryana, Punjab, Delhi and some parts of southern India. This tree grows well in all sorts of climatic constraints which is evidenced by the fact that new foliar growth, flowering and fruiting occur during extreme dry months (March–June) when most other trees of the desert remain leafless or dormant. Because of its multiple economic value and suitability in agro forestry systems, it is conserved in arable land where its population is regulated by the farmer (Saxena 1977). All arid land forms except hills and saline depression receiving an average rainfall of 150–500 mm are having good density of the tree. The immature pods are rich in crude protein, carbohydrates and minerals. Duhan et al. (1992) recorded 18% crude protein, 56% carbohydrates, 0.4% each of phosphorus and calcium and 0.02% iron in immature pods, which are used as vegetable both fresh as well as after dehydration, while ripe dried pods having 9–14% crude protein and 6–16% sugar (Arya et al. 1991) can be powdered and used in the preparation of bakery items such as biscuits and cookies. The variability in pod quality traits is most important from the horticultural quality point of view. Diversity was observed in pod characteristic such as taste, tenderness, fiber content, color, length, thickness, seed number, seed size, protein content and mineral constituents (Dwivedi et al. 1997; Pareek 2002).

2.1.6 Kair (*Capparis decidua* (Forsk.) Edgew)

Kair is a multipurpose, perennial, woody shrub or small tree of family Capparaceae which grows widely without much care in the Thar Desert of western Rajasthan. It is much branched, leafless bushy and thrives well in the most adverse climatic conditions and in the soils of poor fertility. It is highly suitable for stabilizing sand dunes and controlling soil erosion by wind and water. Due to its xerophytic adaptive nature, the plant grows successfully under harsh climatic conditions. Its berry-shaped unripe fruits are rich in carbohydrates, proteins and minerals used as fresh vegetables and in the preparation of pickles. Dehydrated fruits are used in the off season as vegetable either alone or in combination with other dried vegetables. In general, it is highly valued by inhabitants of hot arid areas. Natural propagation occurs through seeds and root suckers, though vegetative propagation through hard wood cuttings has been tried (Meghwal and Vashishtha 1998).

2.1.7 Karonda (*Carissa carandas* L.)

Karonda is an evergreen spiny shrub or a small tree up to 3 m height and suitable for arid tropics and sub-tropics. It grows successfully on marginal and wastelands. The plant is also useful for making attractive thorny dense hedge around any fruit orchard. It yields a heavy crop of attractive berry like fruits which are edible and rich in vitamin C and minerals especially iron, calcium, magnesium and phosphorus. Mature fruit contains high amount of pectin and, therefore, besides being suitable for making pickle, it can be exploited for making jelly, jam, squash, syrup and chutney, which are of great demand in the international market. Its main flowering season is March–April with fruits maturing during August–September which enables the plants to make best use of monsoon rain. However, some varieties/plant types also flower during October–November.

2.1.8 Bengal Quince (*Aegle marmelos* (Linn.) Correa)

Bengal quince (bael) of family Rutaceae is an indigenous hardy fruit crop and can be grown successfully in dry areas. It is well known for its nutritional and therapeutic properties. The ripe fruits are laxative and unripe ones are prescribed for diarrhea and dysentery and are in great demand for native system of medicine such as Ayurvedic. Various chemical constituents, viz. alkaloids, coumarins and steroids have been isolated and identified from different parts of bael tree such as leaves, wood, root and bark by various workers. The marmelosin content of fruit is known as the panacea of the stomach ailments.

2.1.9 Kinnow (*Citrus reticulata* Blanco)

Kinnow mandarin is a hybrid cultivar of citrus developed by crossing King (*Citrus nobilis*) with Willow leaf (*Citrus deliciosa*) and is extensively grown in Punjab and Rajasthan states of India. This easy peel citrus developed has assumed special economic importance and export demand due to its high juice content, special flavor, and as a rich source of vitamin C. Its beautiful golden orange color, abundant juice, excellent aroma and taste have contributed greatly to the success of this fruit.

2.1.10 Kachri (*Cucumus callosus* (Rottl.) Cogn)

Kachri, a drought hardy cucurbit grows naturally and is also cultivated with rainfed crops. It is a short duration crop; flowering starts just after 30–35 days of sowing and produces 2–8 kg per vine small sized edible fruits of high nutritive value with little care. The fruits are rich in minerals specially calcium and used fresh in garnishing of vegetables. Most desert inhabitants store fruits round the year as dried slices, whole dried or in powder form for use. This is generally grown in all farming systems in combination with other rainy season crops without any competition for available soil moisture.

3 Traditional Production Systems

Arable cropping enterprise in dry lands of arid and semiarid regions of India is often un-remunerative due to aberrations of monsoon like late onset, prolonged dry spell, early withdrawal and unequal distribution of rainfall (Gill et al. 1998). Hence an integrated approach of land management is essential for efficient utilization of natural resources to meet the requirements of farmers without deteriorating the land productivity and also to stabilize the income (Gill and Deb Roy 1998). Even the traditional cropping system has multi species character example pearl millet, green gram, guar, moth bean, sesame between Indian mesquite and between fruit trees like Indian cherry, jhar ber, kair, pilu (*Salvadora oleoides*). Leaves of these fruit trees are lopped and fed to livestock during the lean period. The prevalence of this system reveals its potential advantage in production, stability, resiliencies and ecological stability. Farmers are often seen mixing the seeds of above arable crops altogether for sowing in their fields as mixed cropping with an optimism to harvest at least some produce even when the conditions are not congenial for one or another crop. Under such a situation, horticultural based production systems are considered an ideal strategy for the overall development and wellbeing of its farming community of the region.

3.1 Agri-horti System

Intercropping of agricultural crops with woody species is an age old practice in traditional farming systems in our regions. Growing of arable crops in association with horticultural plants is one of the viable approaches to sustain the agricultural production and stabilize the rural economy in the region. Suitability of intercrops depends primarily on soil and climatic conditions, however, compatibility aspects deserve prime consideration. Crops of competitive nature are largely not preferred and such crops are usually not grown as intercrop. Exhaustive crops like maize, wheat, sugarcane, cotton, etc. are not worth cultivation with horticultural plants (Krishnamurthy 1959; Naik 1963). By contrast, crops with companion and synergistic attributes are considered compatible to accentuate early income, optimize land use efficiency, facilitate better harness of solar energy, reduce the soil erosion, increase biological efficiency both in time and space dimensions in horticulture/fruit based production systems (Table 2).

Jujube plants after planting cover the entire inter-row spaces in a period of about 5 years under rainfed conditions. During this period, considerable loss in soil health particularly soil erosion occurs from these barren interspaces. By inclusion of suitable intercrops during rainy season, these losses can be minimized and additional income may be generated. Inter cropping in newly developed jujube orchard had no adverse effects on plant growth up to 5 years. However, in subsequent years, tall growing crops like pearl millet and guar were adversely affected and the effect was perceptible up to 2.5 m distance. Studies revealed that the yields of both jujube and

Table 2 Recommend agri-horti crops component for Indian arid regions

Growing conditions	Horticultural component			Crop component
	High storey	Medium storey	Ground storey	
Rainfed (150–300 mm)	Bordi and Indian mesquite	Jhar ber	Cucurbits and guar	Guar, moth bean, pearl millet and sesame
Rainfed (300–500 mm)	Indian cherry, Indian jujube and Indian mesquite	Jhar ber	Cowpea, cucurbits, guar and Indian bean	Cowpea, guar, green gram, moth bean, pearl millet and sesame
Irrigated	Bengal quince, Indian gooseberry Indian jujube and Indian mesquite	Guava, kinnow, karonda, lime, pomegranate and sweet orange	Brinjal, chilli, cole crops, cucurbits, garlic, okra, onion, peas, root/leafy vegetables and tomato	Chickpea, green gram, groundnut mustard and seed spices

the intercrops were higher than in monoculture (Singh 1997). Intercropping of guar, green gram and sesame with jujube (cv. *Seb*) increased the fruit yield to 14.8 from 5.2 kg tree^{-1}. Cultivation of guar in this system gave additional advantage of 782 kg seed yield, which was higher than that obtained from green gram and cowpea in drought years. However, Gupta et al. (2000) reported that 3-year old plantation of jujube at a density of 400 plant ha^{-1}in association with green gram performed well with seasonal rainfall of 210 mm. Intercropped green gram yielded only 160 kg ha^{-1} as against 620 kg ha^{-1} from pure crop, but the fruit yield from intercropped system increased the net profit to INR 2886. The economic analysis of cost and returns of jujube and Indian goose berry based agri-horti systems revealed that highest net profit of INR 13,487 from one hectare was realized from jujube with guar followed by 11,700/- from jujube with green gram (Meghwal and Henry 2006). Jujube, being a multipurpose species provided better income and interspaces were best utilized for growing of leguminous crops. Least gross return and negative profits were obtained from Indian gooseberry with guar, since fruit plants were just 3 years old without bearing of fruits; nevertheless an additional income of INR 3720 from a hectare was obtained just by growing guar, which met out 79% of the expenditure on maintaining this system. The highest B:C ratio (2.15) was achieved in jujube and guar followed by sole plantation of jujube (2.10) and jujube with green gram (2.02), which was higher than the B:C ratio obtained by either of sole crops. This shows that agri-horti system minimizes the risk and helps in imparting economic stability. Cover cropping with lobia (*Dolichos biflorus*) was found to increase water holding capacity of light soils as a result of increased organic carbon content in these regions (Pareek and Vishal Nath 1996). The legume, Caribbean stylo (*Stylosanthes hamata*) is a good cover crop in the semi-arid regions (Raturi and Chadha 1993). Studies on standardization of jujube based production system revealed that 5 × 5 m spacing (400 plants ha^{-1}) for cultivation of jujube (cv. *Gola*) was ideal for legume intercropping. To develop viable agri-horti model for the Kachchh region of Gujarat state, a study was conducted with Indian gooseberry, jujube and pomegranate as fruit crops

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