P L Saroj

Prospects For Doubling Farmers' Income...

Exploring potential of arid horticulture

Traditional farming in arid and semi-arid regions is a risky proposition and production cost is also rising as compared to productivity gain, thereby eroding profit margins. It is, therefore, essential to exploit the potential of non-traditional areas with appropriate strategy and adoption of new technologies by lowering production costs, improving productivity, enhancing quality of the produce and reducing the post-harvest losses. In this context, market-driven diversification in a global perspective has become the new paradigm shift. Specialty commodities such as off-season varieties and production systems, new crops and novel varieties coupled with good management practices should be identified to capture new opportunities. Horti-business centres equipped with facilities like cold storage, processing units, packaging units, quality control facilities, financial support system, insurance facilities, etc. will catalyse better profit margin at producer level. Value-addition in horticultural produce offers good scope in domestic as well as export markets. Farmers' organizations, prospective entrepreneurs, cooperatives, and self-help groups need to be encouraged for better income of farmers. The production system models coupled with ancillary enterprises will be of immense use for doubling income of farmers in arid and semi-arid regions of the country, says Professor P L Saroj, Director, CIAH, Bikaner.

THE Indian arid zone is characterized by recurrent droughts, extremes of temperature, low and variable precipitation, poor soil fertility, high wind velocity *etc.* which limit the scope for commercial farming. Out of total hot arid region of 31.71 million ha, 49.61% area is alone in Rajasthan. The state can be broadly divided into arid, semi-arid and sub-humid regions, on the basis of annual rainfall. The arid region is mainly spread in western part of Rajasthan consisting of districts of Bikaner, Hanumangarh, Jaisalmer, Barmer, Ganganagar, Churu, Jhunjhunu, Sikar, Nagaur, Jodhpur, Pali and Jalore covering an area of 1,43,842 km^2. The region receives very low and highly variable rainfall, creating inhospitable living condition to both human and livestock population. An area of 9,290 km^2 in extreme western parts of the state has true desert conditions.

Moreover, with improvement in rainfall pattern from the west towards the east Rajasthan semi-arid conditions are created in an area of about 66,830 km^2 in Alwar, Jaipur, Bharatpur, Ajmer, Tonk, Sawai Madhopur, Bhilwara, Bundi, Kota, Chittorgarh, Udaipur, Sirohi, Dungargarh and parts of Jhalawar and Banswara. The soils in north-western arid region known as 'desert soils' and 'grey brown soils' are light textured, very poor in fertility and water holding capacity. Presence of subsurface hard layer/pan also limit the establishment of plantations. The vast area covered with sand dunes has coarse textured soil with $CaCO_3$ and gypsum.

Date palm : the pride of desert

JOURNEY OF RESEARCH IN ARID HORTICULTURE

The journey of arid horticulture began with the initiation of *adhoc* scheme, "Research on some selected fruits of arid and semi-arid areas of India" financed by AP Cess Fund of ICAR in 1976. The scheme was merged during 6th Five year Plan to form the Cell III of the All India Coordinated Fruit Improvement Project (AICFIP) in 1978. During the 7th Five Year Plan, Cell III of AICFIP was restructured to form an independent project entitled 'All India Coordinated Research Project on Arid Zone Fruits'. At present, project is having 18 centres, out of that four centres are located each in Rajasthan and Maharashtra; two each in Gujarat and Uttar Pradesh and one each in Tamil Nadu, Karnataka, Andhra Pradesh, Punjab, Haryana and Madhya Pradesh. Realizing the potential of horticulture in arid and semiarid regions for

Laden branch of ber Gola

nutritional and income security; the Planning Commission of India approved the establishment of National Research centre (NRCAH) at Bikaner during 7th Five Year Plan.

As a result, the NRCAH came into existence on 1 April, 1993 which was later upgraded to Central Institute for Arid Horticulture, w.e.f. 27 September, 2000. During the same year, Central Horticultural Experiment Station, Vejalpur, Godhra (Gujarat) was merged with this institute as its Regional Station on 1 October 2000 to work on semi-arid horticulture. Since then, the institute is working dedicatedly to develop technologies, which can bring nutrition and income security to the inhabitants of arid and semi-arid regions. For dissemination of technologies to farming community, a Krishi Vigyan Kendra was also established in 2005 at Panchmahal district of Gujarat.

In India, arid region is spread over 39.54 million ha including 31.71 million ha as hot arid region mainly in the states of Rajasthan, Gujarat, Andhra Pradesh, Punjab, Haryana and Peninsular region and 7.83 million ha as cold arid region in Jammu and Kashmir and Himachal Pradesh (Table 1). If arid and semiarid regions are put together, almost half of the total geographical area (53.4%) is covered under these regions. The resource situations of semiarid region are comparatively better in spite of several biophysical farming constraints. The hot arid region having 20 million population with population density of 61 persons per square km. The vast land resources in arid and semiarid regions offer great opportunity for horti-cultural development of the country.

Since last two and a half decade, considerable area has come up under fruits like aonla, ber, pomegranate, annona, fig, kinnow, date palm, phalsa, tamarind *etc.* in

Under-utilized Arid Crops

Under-utilized horticultural crops are another area which needs attention. There is a need to develop large orchards of under-utilized fruits like jamun, mahua, chironji, khirni, wood apple, fig, karounda, lasoda, manila tamarind etc. for commercial exploitation both for internal consumption and export as these fruits are of high nutritive value and are rich in anti-oxidants for health conscious populace of modern world. In arid region, farmers are also growing vegetables but confined to irrigated resource situation. Some traditional vegetables like guar, moth, mateera, kachari, tinda, snap melon etc. are grown under rainfed conditions. In India, vegetable seed industry is very much developed in the past decade, but the focus is primarily on a few vegetables like onion, tomato, brinjal, chilli, cauliflower, bell pepper, cucumber, okra etc. Public sector should come forward for diversification to specialized indigenous vegetables in each state for domestic market as well as for export.

Table 1. Area and production of arid fruit crops in India

Crop	1993-94		2016-17		2030 (Estimated)	
	Area (ha)	Production (tonnes)	Area (ha)	Production (tonnes)	Area (ha)	Production (tonnes)
Ber	41,256	3,30,048	85,500	8,95,000	1,10,000	12,10,000
Pomegranate	4,500	45,000	2,02,050	26,68,950	3,50,000	50,00,000
Aonla	26,000	2,86,000	75,000	8,25,000	1,00,000	13,00,000
Date palm	5,000	41,000	25,000	2,00,000	40,000	3,75,000
Sapota	49,000	6,44,000	80,000	9,13,000	1,10,000	12,80,000
Tamarind	10,500	52,500	15,280	82,300	20,000	1,20,000
Others (custard apple, fig and phalsa)	6,600	30,450	15,700	1,31,700	35,000	3,50,000
Total	1,42,856	14,28,998	4,98,530	57,15,950	7,65,000	96,35,000

different parts of the country. The ber has spread from northern states to the western and southern India from a mere 12,000 ha in 1978 to nearly 85,500 ha in 2016-2017 with a production of 8,95,000 tonnes. Similarly, the area under pomegranate has also leaped to over 2.06 lakh ha. Likewise aonla, presently cultivated on 75,000 ha with the production of 2,50,000 tonnes. The area under date palm cultivation is increasing very fast due to introduction of tissue culture plants. In Bikaner district alone, more than 250 ha area is under date plantation and presently more than 25,000 ha area is covered under date palm mainly in Gujarat, Rajasthan and Punjab (Table 1). This has become possible as a result of systematic research and developmental efforts.

Floriculture in Rajasthan

There is a vast potential of floriculture in some parts of Rajasthan because of low pressure of disease/insects and good market demand of cut flowers for decoration and other uses. At present, roses, marigold, *chrysanthemum* and other flowers are being cultivated in nearby cities of Udaipur, Ajmer, Jaipur, Kota and Sri Ganganagar districts in Rajasthan Series of forts, temples, hilly and sandy terrains etc. There is a good scope of tourism development coupled with gardening, landscaping and floriculture in the state besides associated industries.

Prospects of Arid Horticulture

At present, there is a tremendous scope for expansion of horticultural crops in arid and semi-arid regions as these regions are blessed with vast land resource, surplus family labours, increasing canal irrigated area, developing infrastructural facilities, plenty of solar and wind energy, etc. Further, minimum pressure of diseases and insects in these regions is another dimension for production of different horticultural produce. As far as vegetation is concerned, the arid horticultural crops have developed and/or modified their organs to perform certain vital physiological functions such as strong deep root system (ber, bael, aonla, wood apple, jamun, *etc.*), synchronize their flowering and fruit development with the season of moisture availability (ker, lasora, aonla, pilu, *etc.*) and other xerophytic characters *i.e.* leaf shedding in summer (ber), scanty foliage (ker), spiny cladode (cactus pear), mucilaginous sap in plant part (ker, gonda, pilu, bael, *etc.*), sunken stomata and fur/ hairiness and waxy coating on the leaf surface (phalsa, ber, lasoda, fig, etc.) thorny nature, and selective or reduced absorption of cation (Na^+) and anions (Cl^-, SO_4^-) for survival under adverse arid conditions. Therefore, cultivation of suitable species of fruit and vegetables in the arid and semiarid areas will increase the sustenance of the inhabitants and provide the alternate sources of income through development of various horticulture based enterprises including nurseries, processing units and small scale industries.

The fruits like ber and aonla are commercially grown but sometimes unit price is very low, thus it requires more attention for value addition otherwise it would not lure to the people. Pomegranate area is increasing very fast in dry part of the country, since, it has good scope as table fruit and also for export. The crops like custard apple, fig, tamarind, jamun, bael and lasoda are also coming very well under dry land conditions and having potential for processing in to various value added products. Now, looking to its nutritional and medicinal value, attention is being given on its commercial production. These fruits also require very less care, as they can tolerate certain degree of

Solar Radiation

The region receives high solar radiation. Multi-storey cropping models based on fruit trees can be developed to utilize this valuable resource for production of quality fruits, vegetables, spices and medicinal and aromatic plants. However, conditions of high radiation and temperature coupled with low humidity cause water stress in plants owing to water losses from soil and plant surface but by following proper soil and water management techniques, optimum productivity can be maintained. The high summation of heat units especially during the long summer is a valuable resource for development of high total soluble solids in fruit. Besides, the conditions of high temperature and low humidity help in solar drying of fruits and vegetables. The practice is already common for drying pods of khejri (sangri) and fruits of kachri etc. The sharp fluctuations in day and night temperatures during autumn, spring and summer help in development of sweetness in sweet orange, kinnow, ber and date palm; flesh colour and sweetness in pomegranate arils and mateera pulp. The use of chemicals in horticulture is much less in arid region than intensive cultivation of various horticultural crops under assured irrigated conditions of humid region. The farming in arid region largely supported by animals and the ratio of man and animal population is about 1:1. This is the biggest advantage for adoption of organic farming in arid region. The farmers can fetch better income through organic farming of horticultural crops in the arid and semi-arid regions.

Pomegranate in hot arid region

biotic and abiotic stresses. With increasing irrigation facilities, vegetable cultivation is also increasing in arid and semi-arid regions of the country. However, there is a need for development of heat, salinity and frost tolerant varieties of different vegetables. Also, with advances in production technologies, 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.

Enhancement in Income

The average monthly income per capita from farming increased from ₹1,060 in 2003 to ₹3,844 in 2013, according to the report 'Situational Assessment of Agricultural Households' by the NSSO with a compounded annual income growth rate of 13.7%. To double the income of farmers by 2022, in nominal (numerical) terms, which do not take inflation into account, would require a 15% compounded income growth rate, which is a marginal increase over the achieved increase from 2003 to 2013. However, to increase the income in real terms would imply restructuring agriculture processes and policy interventions. There is however, almost unanimity that the net income of farmers can surely be doubled well within the period of six years.

Doubling Farmers' Income

Our farmers are the backbone of the country's food security. Therefore, we need to think beyond food and nutritional security. We have to ensure income security of farming community for improving their living standard. Government will, therefore, reorient its interventions in the farm and non-farm sectors to double the income of the farmers by 2022. Based on the recommendations of National Commission on Farmers, Government announced measuring agricultural progress by real income of farmers and not by gross production of agricultural commodities. A Task Force Group has been formed by the Ministry of Agriculture to come out with detailed plans and its operationalisation. In this context, Indian Council of Food and Agriculture organized a national consultation on 30 April, 2016 in New Delhi, involving top experts from the Government, industry, research and academic bodies, farmers organizations, parliamentarians and NGOs. The meet was chaired by Prof. MS Swaminathan and co-chaired by the Secretary – Agriculture, Government of India.

Strategies

Honourable Prime Minister of India has outlined 7 broad strategies to help double the income of farmers. They are:

- Big focus on irrigation with large budgets, with the aim of 'per drop more crop',
- Provision of quality seeds and nutrients based on soil health of each field,
- Large investments in warehousing and cold chains to prevent post-harvest crop losses,
- Promotion of value addition through food processing,
- Creation of a national farm market and removing distortions,
- Introduction of a new crop insurance scheme to mitigate risks at affordable cost and,
- Promotion of ancillary activities like poultry, beekeeping and fisheries.

TECHNOLOGICAL APPROACHES

The success and failure of any technological approach depends on the concept of 3Ps *i.e.* i) The Place, ii) The Plant and iii) The Person Behind. This concept hold high prominence in arid horticulture, where complex, diverse and risk prone production system exist. Therefore, one cannot think about quality production and subsequent better income, if technology is not implemented in right perspective. In this context, besides technological knowledge, proper skill development plays key role. Specific to arid horticulture, some good horticultural practices are mentioned below.

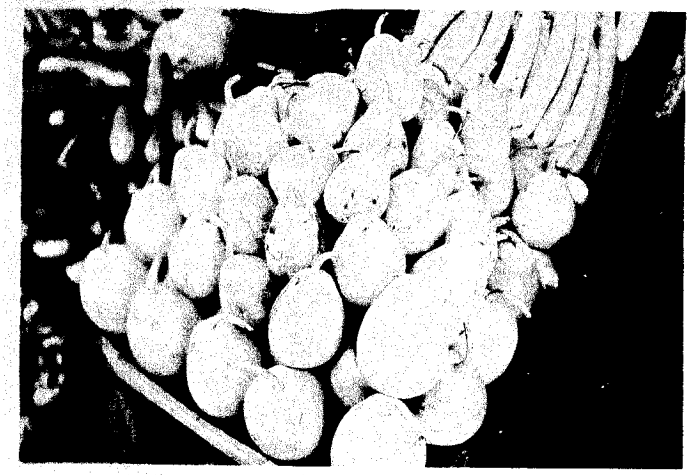
Establishment of Ber Orchard

For success of plantations in arid and semiarid regions, plants must have proper root architecture with a strong tendency to penetrate into the deep soil profiles. *In-situ* technique of orchard establishment is found suitable under arid conditions. Proper field development, preparation of pits and appropriate filling mixture (FYM + pond silt + soil in 1:1:1 ratio) are also important for orchard establishment in arid and semiarid regions. Before planting of the main crop, fast growing wind breaks like Sheesham, Jamun, Amaltas, Neem, Lasoda, Bael, Khejri *etc.* must be planted all along the field boundaries, which will not only act as wind breaks but also additional source of income by proving fodder, fuel, fruit *etc.*

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 is square or rectangular system. On sloppy 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. In a micro-catchment, which may be triangular or rectangular, trees are planted at the lowest point where runoff accumulates.

Selection of Suitable Crops

While selection of fruit crops for arid and semi-arid regions, one of the basic requirements is that crops should complete their vegetative growth and reproductive phase during the period of maximum moisture availability. The fruit such as ber, guava, pomegranate, custard apple, aonla



High temperature tolerant bottle gourd variety – Thar Samridhi

Mass multiplication of khejri plants by budding

and sour lime, conform to this prerequisite. Among vegetable crops, those who can survive in these regions belong to the cucurbitaceous and solanaceous groups. Cowpea, cluster bean and moth bean are also very drought hardy. In these crops also, there is need to select the most drought hardy cultivars for rainfed production. Some fruit specific varieties of fruits and vegetables are given in Table 2.

Quality Seed and Planting Material

For establishment of a good plantation, quality planting materials of recommended varieties should only be used. The quality planting materials refer the plants stock *i.e.* i) true-to type, ii) propagated by appropriate vegetative technique, iii) healthy and free from any biotic pressure and iv) should be as per standard. The vegetative propagation techniques in various arid fruits have already been standardized. In some fruit crops like ber, sapota, guava *etc.*, rootstocks used for multiplication have also been identified.

There are certain fruit crops which are still multiplied by seeds such as karounda, phalsa, lasoda, moringa, ker

Table 2. Trait-specific varieties of arid fruits and vegetables

Fruit	Varieties	Important traits
Aonla	NA-7, NA-6, Chakaiya, Goma Aiswarya	For preserve and candy purpose.
	Kanchan, Krishna, NA-10	For pickle and shreds.
Ber	Thar Sevika	First earliest maturing ber hybrid (Seb × Katha).
	Gola, Seb, Mundia, Banarasi Karaka	For preserve purpose.
Pomegranate	Goma Khatta, Amlidana	For *anardana* purpose.
	Bhagava, Super Bhagava, Jalore Seedless, G137, Ganesh	For table purpose.
Date palm	Medjool, Sewi, Khalas, Dayari	For dehydration purpose (*Chhuhara*).
	Halaway, Barhee, Khalas, Khunezi, Chip Chap, Zaghlool, Hayani	For fresh fruit.
	Halaway, Barhee, Zahidi, Khalas, Shamran, Khadraway, Zaghlool	Soft dates.
Basi	Goma Yashi	Semi dwarf type, spineless and suitable for high density planting.
	Thar Divya	Less spine, earliest maturity and suitable for rainfed conditions of semiarid region.
	Thar Neelkanth	Suitable for candy, powder and RTS purposes.
Lasoda	Thar Bold	Suitable for culinary purpose.
Karan	Thar Rituraj	Suitable for table and processing both.
Chirauji	Thar Priya	Precious and comparatively dwarf, suitable for high density planting.
Fig	Poona Fig, Diana, Excel	For dehydration purpose
Jamun	Anant Rudhira	High anthocyanin content.
Vegetable	**Varieties**	**Important traits**
Khejri	Thar Sobha	First thornless variety for commercial *sangri* production.
Mateera	Thar Manak	First early maturing selection of mateera.
Kachari	AHK 119	First variety of kachri for commercial production. Kachri powder is mainly used in spice industry.
Bottle gourd	Thar Samridhi	High yield potential (240-300q/ha) under hot arid conditions.
Ridge gourd	Thar Karni	Field resistant to mosaic disease and melon fruit fly.
Drumstick	Thar Harsha	Resistant to leaf eating caterpillar and moderately resistant to fruit fly.

Plant canopy management in jamun

etc., though to obtain uniform stock, vegetative multiplication is always recommended. Since, there is a high demand for quality planting materials, nursery could be a very good enterprise to provide opportunity of employment in rural areas. There is a lot of scope of nursery raising in arid region for production of quality plating materials.

The fruit plants propagated in the nursery are generally used to establish orchards. Such plants invariably lose their tap roots as a result of repeated transplanting. Therefore, proper nursery management and timely disposal of quality planting materials with appropriate plant standard are important considerations. Proper establishment of mother block, raising of rootstocks, use of poly-containers, rooting media and after care are also important considerations.

Besides, planting materials of perennial fruit crops, the seed of annual arid vegetables should be purchased only from authentic sources like government organizations, registered societies, registered seed chemical stores etc. Established private companies are also supplying quality seeds of vegetables. The seed availability of arid crops like mateera, kachri, snap melon, ridge gourd, bottle gourd, pumpkin etc. is limited, hence care should be taken while purchasing seed of these crops.

Canopy Management

The canopy of plant plays a vital role to increase quality production of fruit trees. Plant architecture can be maintained through proper training and pruning of fruit plants. Training at initial stages of growth gives proper shape and strong frame to the plants. 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 15-25 nodes, depending upon location, cultivar and age and vigour 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. Established phalsa bushes should be pruned at 20-30 cm height once in 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 karonda trees in the month of December-January produces early flowering and fruiting in arid region. The plant canopy management in custard apple has also been standardized.

Water Management

Water is a precious input in hot arid region of the country, as precipitation is extremely low and rainfall pattern is highly erratic. Water holding capacity of sandy soil is also poor. Therefore, the need of the hour is to develop technologies, which not only requires low water input but also have high water use efficiency. Water being a vital resource in arid eco-system, the first and foremost requirement is to conserve the available soil moisture 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 m length of run, and 72 m^2 and 54 m^2 catchment area per tree, respectively. Mulching with organic materials (e.g., hay, straw, dry leaves, and local weeds) has been found highly beneficial in reducing evaporation loss. The practice also suppresses weed growth, prevents erosion, and adds organic matter to the soil. 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. At ICAR-CIAH, Bikaner, the work on *in-situ* water harvesting has been undertaken in pomegranate, aonla and vegetable. It has been demonstrated that application of black polythene mulch and local weeds helps in conserving soil moisture status. Mulching studies with respects to soil hydrothermal regimes in brinjal revealed that organic mulches curtailed soil temperature during warm months, while an increase was recorded during the winter month. More than 50% fruit yield can be obtained through lasoda (*Cordia* sp.) and kheep (*Leptodenia pyrotechnica*) mulching.

Water loss due to transpiration can be reduced by use of radiation reflectants, stomata closing chemicals, and plastic films. Spraying of 4-6% Kaolin, 0.5-1.0% liquid paraffin, and 1.5% power oil, after occasional rains in low rainfall areas, considerably reduce plant water losses. Chemicals such as decinyl succinic acid (DSA), abscisic acid (ABA) and cetylalcohal cause stomata clousure and thereby reduce transpiration. Shelterbelt and windbreak plantations can reduce evapo-transpiration by reducing the wind speed and stabilizing microclimate. In western 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 and quality of fruits especially in aonla, lasoda, ber and bael. The citrus fruits are least affected, while the crops like date palm, ker, khejri are generally free from frost.

Water Conservation

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 water saving to the tune of 25% can be achieved if pressurized irrigation system is used as compared to conventional flooding or bubbler system. The average water requirement of some arid fruit crops by drip method is given in Table 3. Under semiarid conditions, the crops like tomato, brinjal, chillies, cauliflower and onion can be produced in dry lands by using runoff concentration technique by transplanting seedlings raised in a nursery at the onset of monsoon in early July.

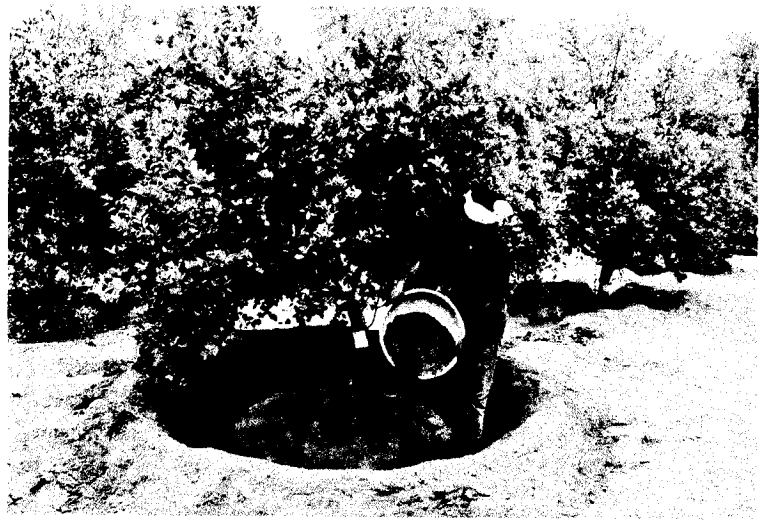
Bearing plant of karonda

Karonda fruits

Table 3. Average water requirement of fruit crops by drip method

Crops	Age (years)	Water requirement (litres/tree/day)											
		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Sapota, tamarind	1	-	-	-	-	-	22	23	27	24	22	25	21
	2	27	38	56	77	82	60	41	34	34	41	31	26
	3	45	63	93	128	137	94	68	56	56	62	51	43
	4	65	92	135	186	199	137	98	81	81	97	74	62
	5	76	107	158	217	232	159	195	101	101	114	86	73
Aonla	1	-	-	-	-	-	-	24	20	20	24	18	16
	2	18	25	36	50	54	37	27	22	22	26	20	17
	3	22	31	46	66	67	46	33	27	27	33	25	21
	4	32	45	66	91	97	67	48	40	40	48	36	31
	5	37	53	77	106	114	78	56	47	47	56	42	36
Orange, lime, guava	1	-	-	-	-	-	-	18	15	15	18	13	11
	2	13	18	28	37	40	27	20	16	16	19	15	12
	3	16	23	34	46	49	34	24	20	20	24	18	16
	4	23	33	49	67	72	49	35	29	29	35	27	23
	5	29	41	61	84	89	61	41	37	47	47	32	28
Ber, pomegranate, fig	1	-	-	-	-	-	-	13	10	10	12	9	8
	2	12	17	25	34	36	25	18	15	15	18	13	11
	3	16	23	34	46	50	34	18	15	15	18	13	11

Maintaining optimum soil moisture can minimize the problem of frost.



Manure application in citrus

Integrated Nutrient Management

The fertility status of sandy soils of hot arid region is very poor. Therefore, balanced nutrition of plants is very important for quality production. 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 P_2O_5 and 50 g K_2O 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 P_2O_5 and 225 g K_2O has been recommended for application to 5-year-old pomegranate trees. At Bengaluru, application of 500 g N + 250 g P + 125 g K produced six times higher yield than in the control. In 6 to 7 years old fig trees planted at 5m × 5m spacing, fertilization with 900 g N + 250 g K improved fruit production. The studies conducted on date palm at Abohar showed that application of 300-400 g N/tree/year 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 general, micronutrients are deficient in semi-arid and arid region 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% borax) has given beneficial results in these areas. 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. Foliar spray of zinc sulphate 0.5-1.0% improved fruit quality in ber cv. Seb in semi arid region.

In order to minimize the use of costly input such as fertilizer, attempts were made to supply this along with water under pressurized irrigation system. The studies conducted in pomegranate and ber has demonstrated that fertilizer saving to the tune of 25% can be achieved if plants are fertigated through drip. Keeping in view the export potential of pomegranate, attempts have been made to assess the organic production of this crop. In this pursuit, substitution of in-organic with organic fertilizers was attempted. The results have demonstrated that a good crop of pomegranate can be harvested by giving 50% recommended dose of NPK through vermicompost and 50% through inorganic fertilizers. Thus, the use of inorganic fertilizers can be reduced to half through this technology.

Plant Health Management

Besides wild animals, rodents and birds, there are many insects and diseases causing loss of horticultural crops. In hot arid region, termites cause considerable damage. Methyl parathion dust (5%) should be applied in the pits (50 g/pit) dug for planting fruit trees. Subsequently,

water soluble insecticides (Chlorpyriphos) 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 scyrodes*) 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 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.

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%) on various crops is 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.

Disease Control

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 intervals. For the control of leaf and fruit spot in pomegranate, four sprays with 0.25% Ziram and 1% Bordeaux mixture at 15 day intervals 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 intervals 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 intervals soon after initiation of symptoms give the best control.

Fruit Based Cropping System

Monoculture in arid zone is highly risk prone due to crop failures, hence a suitable tree crop combination is essential for alleviating the risk, generation of income, improvement in productivity per unit area/ volume by efficient use of natural resources and inputs. The integrated systems not only gives multiple outputs but also ameliorate and improve growing site. Agri-horticultural combinations with legume intercrops such as moong bean, moth bean, cluster bean, and cowpea are beneficial. Under rainfed orchards of guava and ber, cluster bean, okra, and cowpea in *kharif* (rainy season) proved good in semiarid region. Under South Indian conditions of Hyderabad, cowpea, green gram, cluster bean and horse gram in ber orchards and

Vegetable intercropping under khejri

Vegetable type cactus

bitter gourd, tomato and okra in acid lime orchards have been found as compatible 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 sindicus*).

Exploitation of Underutilized Crops

The recent awareness regarding the potential of these ecologically fragile lands for production of quality horticultural produce has not only opened up scope for providing economic subsistence for the people of these regions, but also for bringing new areas to increase fruits production. The underutilized fruits have a wide range

Harvested phalsa fruits

scope for making of export of various processed products. A wealth of flora harbours the arid and semi-arid ecosystem which should be optimally utilized. These includes lasoda (*Cordia myxa*), ker (*Capparis decidua*), phalsa (*Grewia subinaequalis*), pilu (*Salvadora oleoides* and *S. persica*), karonda (*Carissa carandus*), wood apple (*Feronia limonia*), bael (*Aegle marmelos*), jamun (*Syzigium cumini*), khirni (*Manilkara hexandra*), chironji (*Buchnania lanzan*), cactus pear (*Opuntia ficus indica*), mulberry (*Morus* sp.), marula nut (*Sclerocarya birrea* subsp. *caffra*) etc.

There are several underutilized fruits (jamun, chriounji, mahua, lasoda) which are very rich in vitamins, minerals, fat, carbohydrates and antioxidant which have not been exploited well. There are some fruits which are rich source of protein also (chironji, wood apple, ker) which are otherwise obtained from pulses and vegetables. Such fruit plants are very hardy to various biotic and abiotic stresses and thrive well under drought situations, which is common phenomenon in arid and semi-arid regions. Beside nutritional and social security, hitherto untapped export potential, underutilized fruit crops has a vast potential for production of value added products, with high therapeutic, medicinal values and antioxidant properties on one hand and free from the residue of toxic chemicals on the other as such crops are grown with minimum agricultural inputs. ICAR-CIAH has first developed varieties of lasoda, chronji, khrni and khejri; besides development of production technologies. Also, developed technology for culinary exploitation of Indian aloe and cactus pear.

POST-HARVEST MANAGEMENT AND VALUE-ADDITION

The post-harvest handling accounts for 20 to 40% of the losses at different stages of grading, packing, storage, transport and finally marketing of both fresh and processed products. Value addition of perishable commodities is needed to achieve better price of produce in the market. The horticulture produce suffers heavy post-harvest losses in the absence of adequate post-harvest and marketing infrastructure, viz pre-cooling units, packing and grading sheds, short and long term cold storage facilities, refrigerated containers, storage and phyto-sanitary facilities. Comparatively post-harvest losses are less in dry regions than humid regions, because of the less moisture content in the produce. Similarly, intense radiation and low relative

Multi-storey Cropping

Multi-storey combinations incorporating tall trees, medium trees and ground crops can be grown on the same piece of land. 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/ 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 tamarind/ guava + sour lime/ lemon/ pomegranate or aonla + vegetables can be adopted. Crop diversification studies in ber (*Ziziphus mauritiana*) and aonla (*Emblica officinalis*) based cropping studies led to the recommendations that in pre bearing phase of ber orchard, Indian aloe (*Aloe barbedensis*) and cluster bean (*Cyamopsis tetragonoloba*) are the low input and highly returning crops in arid region. Whereas, at bearing stage of ber, cluster bean-mustard was the best combination under limited water availability. In aonla based multi storey cropping system, the model-4 with crop combination of aonla-drumstick-senna-moth bean-cumin recorded highest net return followed by cropping model-I (aonla-ber-brinjal-mothbean–fenugreek) have 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.

humidity in the atmosphere is also conducive for dehydration.

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 by-products. Besides dehydration, brining, pickling, beverage making, preserve making, etc. are the other methods of value addition being adapted to various arid commodities. Proper packaging is an essential prerequisite to reduce losses of produce. For making dry dates (chhuhara), the doka fruits of date palm are dehydrated; whereas full mature sour fruits of wild pomegranate are dried for anardana.

Pre-drying treatments like blanching or brining or sulphitation improves the quality of dehydrated products. It has been found that blanching of aonla for 4 minutes in boiling water improved the quality of dried product. Peeling of doka fruits for 4-6 minutes in Medjool, Khadrawy and Shamran cultivars gave better quality dry dates. Curing of dates at low temperature had blistered skin, greater percentage of moisture and reducing sugars and lesser percentage of non-reducing sugars but by curing in boiling water, the product was of better quality without blisters. The cooking of doka fruits Khadrawy and Shamran date palm cultivars for 10-25 minutes was required for making dry dates (chhuhara). For making soft dates, curing for much shorter period i.e. for 20-25 seconds followed by dehydration at 30-40°C was required.

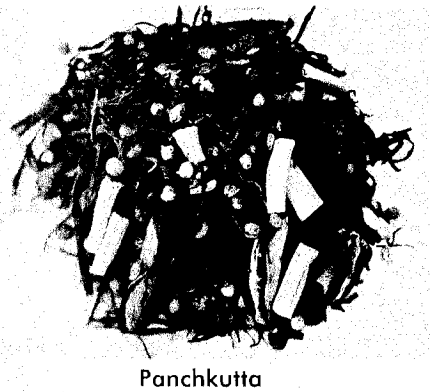
Dehydration

Dipping of ker fruits in 4-6% salt solution or 0.2% NaOH solution for about a week improves the quality of dehydrated product. Blanching of immature green pods (*sangri*) of khejri in 2% salt solution for 5 min retains light green colour of pods after rehydration. Further, it was observed that blanching of pods in 2% salt solution along with 0.6-0.8% potassium meta-bisulphite (KMS) improves the quality of dehydrated pods of khejri. Institute has developed large number of value added products like kachari based curry powder, aonla moth freshener, cookies from khejri and dates, pickles of lasoda, aloe, ker; laddu from aloe etc. which needs up-scaling on pilot scale. The farmers particularly rural youth are required to develop proper skill for preparation of different value added products, so as to establish small scale post harvest processing units for better income.

Ancillary Enterprises

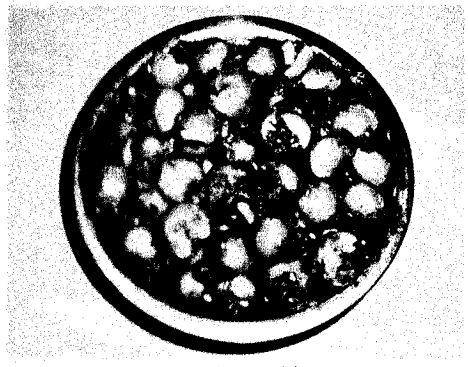
In horticulture sector, large number of crops like fruits, vegetables, flowers and ornamental plants, spices, tuber crops, medicinal and aromatic crops, plantation crops and various other activities can be taken for enhancing income of the farmers. Besides cultivation of main horticultural crops, there are several components like bee keeping, mushroom farming, fisheries, poultry, dairy, piggery, duck rearing, goat (for meat) and sheep (for wool) rearing *etc.* which can also be integrated as system approach based on edaphoclimatic requirement and resource situations. Moreover, these activities are complementary to each other and may be run both on farm and off-farm.

There are many other associated activities like; nursery, seed production, vermi-composting, wicker works, packaging materials, poly containers and shade net, bagging/ tagging materials, materials of pressurized irrigation system, flower arrangement, custom hiring field implements, seed, fertilizers, chemicals and other argri-inputs stores; where farmers particularly rural youths can earn better than traditional way of farming only. In arid and semiarid regions, there is good scope for processing mainly dehydrated products. Large variety of value added products can also be prepared from fruits and vegetables. There are several arid horticultural crops which are mainly grown for processing purpose, viz. aonla, bael, karounda, lasoda, ker, khejri, tamarind, mulberry *etc.* There is also good scope for organic farming, as the use of chemicals are very low in hot arid region. However, proper skill development is pre-requisite before integration of such activities.



Panchkutta

Kahcri based curry powder



Lasoda pickle

Indian aloe laddu

MODELS FOR DOUBLING FARMERS' INCOME

Intensification of Kinnow Cultivation

In India, kinnow is grown in Punjab, Rajasthan, Haryana and Himachal Pradesh. It is a commercial crop of Abohar, Hoshiarpur, Mansa, Muktsar and Bathinda districts of Punjab and Sri Ganganagar, Hanumangarh and Suratgarh districts of Rajasthan, where farmers are earning good income from its plantation. These regions are blessed with good irrigation facility and comparatively better soil conditions than hot arid region of Bikaner. The interest of farmers in adoption of kinnow has increased tremendously due to higher yield potential, better storage life and demand in the market. However, it was not introduced in hyper arid region. The first introduction was made in 2000 at CIAH, Bikaner on experimental basis. The crop has come up well beyond expectation and ripened about 15 days before than traditional growing areas. The fruit quality and longevity of plantation are also better. Now, intensive cultivation of kinnow under drip irrigation at 6m × 6 m spacing has been started by the farmers of Bikaner region with yield level of 20 t/ha. Farmers are getting average income of ₹1-1.5 lakh/ year.

Kinnow in hot arid region

Bearing tree of pomegranate

High-Density Planting of Pomegranate

Pomegranate is spreading in arid and semiarid regions at very fast rate. A decade before, the varieties like Jalore Seedless and G-137 were only grown in some pockets like Jalore, Sirohi, Pali and Jodhpur district of Rajasthan but with the introduction of tissue culture plants of cultivar Bhagwa, it has occupied >15000 ha area in Rajasthan alone. The high density planting of Bhagwa at spacing of 5m × 3m (666 plants/ha) and 4m × 2.5 m (1000 plants/ ha) under drip system has been adopted by the farmers. The farmers are harvesting fruit yield of 15 t/ha with net income of ₹1.50-2.0 lakh/ha. The management practices

High density planting of bael – Goma Yashi

Drying of Fruits

Drying of fruits and vegetables for utilization during off season is a long tradition in hot arid region. Various fruits like ber, date palm, aonla, fig and ker and vegetables such as kachri, snap melon (khelra), roundmelon peel (phophalia), khejri (sangri), kumat, cluster bean (guar), leafy vegetables, etc. are being dried in sun. Presently, the technologies of mechanical dehydration like solar, osmotic, freeze drying, etc. have been developed and attained sophistication. In fact, dehydration of fruits and vegetables in order to dough-tail the amount of spoilage caused due to gluts and inappropriate post harvest handling methods is very important.

To obtain a quality-dehydrated product, factors like composition of commodity, its maturity, pre-drying treatments and methods of dehydration have to be taken into consideration. It is mentioned that the physico-chemical composition with regard to moisture content, TSS, sugars, acidity, ascorbic acid, tannins, alkaloides, etc. determine the dehydration quality of the commodity. Moreover, still farmers are drying horticultural produce without much attention of hygienic standard and modern packaging, owing to poor market value.

High Density Planting of Aonla

Aonla has emerged as main crop of dryland areas after introduction of high yielding varieties and its increasing demand in processing and pharmaceutical industries. Under rainfed conditions of semiarid region of Gujarat, aonla variety NA-7 was grown

Double hedge row planting of aonla

in double hedge row system of planting by accommodating 260 plants/ha has given fruit yield of 226 q/ha. This system has given net return of ₹241035/ha at 11th year after planting. An increase in yield of 132.39% over conventional planting of square system (100 plants/ha) was recorded in double hedge row system of planting.

of growing pomegranate in arid region is altogether different than tropical region. Moreover, farmers are facing problem of fruit cracking and nematode in hot arid region of Rajasthan. The fertigation and crop regulation are another crucial factors in determining better productivity.

High Density Planting of Bael

The bael (*Aegle marmelos*) is considered for high medicinal, spiritual and religious significance. Bael plants are gaining popularity as a suitable crop for wasteland areas. The fruit is good source of vitamin, mineral and antioxidant value. The fruit pulp is utilized for preparation of various value added products which are good for stomach related ailments. ICAR-CIAH Regional Station, Godhra (Gujarat) has released a variety of bael namely 'Goma Yashi' which is thorn less and semi-dwarf in vigour. Growing of

Kachri cultivation

Potato in Arid Region

In non-traditional areas of hot arid region of Rajasthan, for the first time, potato cultivars like Kufri Chipsona-4 and Kufri Frysona (for processing) and Kufri Jyoti, Kufri Garima and Kufri Surya (for table purpose) were introduced to assess their production potential under microsprinkler system of irrigation.

After experimentation of three consecutive years (2015-16, 2016-17 and 2017-18), it was found that these cultivars are agronomically most efficient in resource poor conditions and had given high yield, better quality tubers and good return. With the cultivation of Kufri Chipsona-4 under sprinkler system, > 400 q/ha tubers were harvested in hot arid region of Rajasthan. With this level of production, farmers can get income of ₹1.17 lakh/ha. The quality of potato in terms of appearance and dry matter content is better than traditional potato growing areas. The farmers have already started potato cultivation under technical guidance of ICAR-CIAH, Bikaner scientists.

Goma Yashi at 5m×5m by accommodating 400 plants/ha has given fruit yield of 250 q /ha at the age of 8th year of plantation. The farmers are getting ₹1.0 lakh/ha by growing this variety under rainfed wasteland areas of Gujarat. The demand of planting material of this variety by farmers is increasing day by day.

Cultivation of Kachri

Kachri (*Cucumis melo*) is an industrial crop grown mainly in arid and semi-arid regions of the country. The dry powder of kachri is used as base ingredient of packaged

Kachri fruits

Low tunnel structures

Crop after removing low tunnels

spices. Earlier this cucurbit was found growing in maize field under rainfed conditions of western India. Now, a uniform fruit size and high yielding variety of kachri (AHK-119) has been developed by ICAR-CIAH, Bikaner. Under limited irrigation, farmers are harvesting about 95-115 q/ha fruits of kachri and earning ₹0.75 to 1.25 lakh/ha. This is very popular on farmers field and occupied more than 8600 ha area in Rajasthan, Haryana and Punjab. It is pertinent to mention that this variety alone occupies about 70% of total area under kachri cultivation. The seeds of this variety are in high demand, which is very well judged as institute is selling the seeds of kachri under police supervision. Institute is also giving training to the farmers to develop a seed village of kachri.

Low-Tunnel Technology

The low tunnel technology has revolutionized cultivation of cucurbits in hot arid region of Rajasthan. In fact, there are extremes of hot and cold both in arid region. During summer temperature goes up to 48°C while in winter falls to sub zero. Low tunnel technology can be used to raise off-season crop of cucurbits making cultivation more profitable. The use of low cost protected structures particularly low tunnels with some modification may become a viable option for successful cultivation of cucurbits in arid regions. Plastic low tunnels are miniature form of greenhouses to protect the plants from rains, winds, low temperature, frost and other vagaries of weather. They are very simple structures requiring very limited skills to maintain and easy to constructs and offer multiple advantages. For construction of low tunnels, film of 30-50 micron would be sufficient. The tunnel technology has made possible to grow cucurbits in spring season. The sowing of long melon variety 'Thar Sheetal' was done inside low tunnels in the month of January and maintained under drip system. The poly cover was removed when temperature started rising in the month of February, there after flowering fruiting was started. The fruits of long melon was available in the end of February to March. About 180 q/ha fruit yield was harvested which has given an income of ₹ 2.0- 2.50 lakh/ha.

Rabi onion cultivation in arid region

Onion Cultivation

Onion is another important vegetable becoming popular in arid region of Rajasthan since last few years. It is grown as *rabi* crop by planting in December-January and the crops are ready to harvest in the month of May. The productivity is better than traditional potato growing areas. In Rajasthan, the most popular varieties are Nasik Red and Durgapura RO-252 which are giving yield of 350-400 q/ha under pressurized system of irrigation. The quality of onion is excellent and cost of digging is also less due to pulverized sandy soil. At this yield level, farmers are getting income of ₹1.0-1.50 lakh/ha.

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