An ISO 9001: 2008 Certified Institute

ICAR-CIAH

An Overview

ICAR-CENTRAL INSTITUTE FOR ARID HORTICULTURE
BIKANER 334 006, RAJASTHAN

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From the Director's Desk

On account of its various strengths such as vast potential area, intense solar radiation, increasing canal command area, surplus family labour, low incidence of pest and diseases, and opportunities to establish agro-based and allied cottage industries, the arid region is gaining importance to promote as agricultural bowl.

Realizing the potential of horticultural productivity of arid zones, the compatibility of these crops to the arid ecosystem and the need to achieve balance nutrition and income security for the people, the Planning Commission of India approved the establishment of National Research Centre for Arid Horticulture (NRCAH) during VII Five Year Plan. As a result of this, the NRCAH came into existence on 1st April, 1993 and this was later on upgraded to Central Institute for Arid Horticulture w.e.f. 27th September, 2000. Since inception, the institute has contributed substantially on all fronts. The institute has developed agro-techniques for production of arid fruits and vegetables in hot arid environment which will help not only in improving productivity of horticultural crops but also providing income and nutritional security to the inhabitants of the region. Central Horticultural Experiment Station (CHES) – a Regional Station of ICAR-CIAH located at Vejalpur, Godhra, Gujarat is working on fruits and vegetables pertaining to the semi-arid region. Krishi Vigyan Kendra (KVK) at Vejalpur, Panchmahal (Gujarat) is also transferring the new technologies developed for the benefits of farmers of tribal belt of Gujarat. There is a tremendous scope of development of arid lands through crop diversification. This calls for research preparedness to meet the challenges putforth by the global market. In this pursuit, Central Institute for Arid Horticulture is dedicated to develop technologies suitable for high production of quality fruit and vegetable

for domestic and export market. The varieties having resistance to diseases and pests, good shelf life, processing quality are being developed and appropriate agro-techniques are being standardized to harness the maximum productivity. The Institute has released a total of 37 varieties of arid fruits and vegetables, standardized vegetative propagation method, protocols for micro-propagation of some arid fruits, standardized nutrient and water management for production of quality fruits and vegetables and a wide variety of value added products. The institute has recommended various fruit based cropping systems and multi-storey models for arid and semi-arid ecosystem, which ensure sustained yield round the year; thereby, improving socio-economic status of farming community.

The *ICAR-CIAH: An Overview* presents details of the significant achievements that Institute has made during the last 23 years. The document will act as a ready reckoner for researchers, teachers, NGOs and policy planners to develop future strategies for socio-economic upliftment of inhabitants of the arid and semi arid regions.

(P. L. Saroj)
Director

BACKGROUND

Large population in India still dependent on agriculture for their livelihood. The concern for sustainable increase in productivity of agricultural commodities, access to affordable price, income and ecological security is increasing due to burgeoning population pressure and diminishing natural resources. The situation in risk prone areas like arid and semi-arid regions is further alarming. The demand for quality produce is tremendously increasing both in domestic and international market. The productive agricultural land is shrinking day by day due to urbanization and industrialization. Thus, the only option available for agricultural production are either increase the productivity of the existing crops or to venture in non-traditional areas which can be made productive by providing adequate technologies. In this pursuit, arid ecosystem, which occupies nearly 12% of the geographical area in the country, qualifies to be an ideal home to develop horticultural production. To address this issue by generating technologies to convert arid region into horticulture bowl, National Research Centre for Arid Horticulture (NRCAH) was established at Bikaner during VII Five Year Plan on 1st April, 1993. Subsequently, it was upgraded to full fledged Institute as **ICAR-Central Institute for Arid Horticulture (ICAR-CIAH), Bikaner, Rajasthan** on 27th September, 2000 and Central Horticultural Experiment Station (CHES), Godhra, Gujarat (earlier under IIHR, Bengaluru) was merged as its Regional Centre on October 1st, 2000. Since then, the Institute is working dedicatedly to develop technologies, which can bring nutrition and income security to inhabitants of arid and semi-arid regions. The Krishi Vigyan Kendra (KVK) established at Panchmahal, Gujarat in 2005 is also under the administrative control of ICAR-CIAH, Bikaner. Since its inception, the KVK is helping farmers and farmwomen of Panchmahal district (Gujarat) by effective dissemination of technologies for socio-economic upliftment of rural folk.

MANDATE

1. Basic, strategic and applied research to enhance sustainable productivity, quality and utilization of horticultural crops of arid and semi-arid regions.
2. Repository of genetic resources and scientific information on horticultural crops of arid and semi-arid regions.
3. Transfer of technology, capacity building and impact assessment of technologies.
4. Coordinate research and validation of technologies on fruit crops of arid and semi-arid regions.

MANDATE CROPS

CIAH, Bikaner

Major fruit crops: Ber (*Ziziphus mauritiana*), Aonla (*Emblica officinalis*), Date Palm (*Phoenix dactylifera*), Bael (*Aegle marmelos*), Pomegranate (*Punica granatum*)

Under-utilized fruit crops: Mulberry (*Morus* sp.), Phalsa (*Grewia subinaequalis*), Cactus pear (*Opuntia ficus indica*), Lasoda (*Cordia myxa*), Ker (*Capparis decidua*), Karonda (*Carissa congesta*) etc.

Vegetable crops: Mateera (*Citrullus lanatus*), Snapmelon (*Cucumis melo* var. *momordica*), Kachri (*Cucumis melo*), Bottle gourd (*Lagenaria siceraria*), Round melon (*Citrullus vulgaris*), Muskmelon (*Cucumis melo*), Chillies (*Capsicum annuum*), Cluster bean (*Cyamopsis tetragonoloba*)

CHES, Vejalpur, Godhra

Fruit crops: Ber (*Ziziphus mauritiana*), Aonla (*Emblica officinalis*), Pomegranate (*Punica granatum*), Mango (*Mangifera indica*), Sapota (*Achras sapota*), Annona (*Annona squamosa*), Tamarind (*Tamarindus indica*), Jamun (*Syzygium cumini*), Bael (*Aegle marmalos*), Fig (*Ficus carica*), Karonda (*Carrisa congesta*), Wood apple (*Feronia limonia*)

Vegetable crops: Okra (*Abelmoschus esculentus*), Bottle gourd (*Lagenaria siceraria*), Pumpkin (*Cucurbita moschata*), Bitter gourd (*Momordica charantia*), Brinja (*Solanum melongena*), Tomato (*Solanum lycopersicon*), Chillies (*Capsicum annuum*), Cluster bean (*Cyamopsis tetragonoloba*), Drum stick (*Moringa oleifera*)

INFRASTRUCTURE

The headquarters of the Institute is situated on Bikaner- Sriganganagar highway. The institute has one centre -Central Horticulture Experiment Station at Vejalpur, Godhra (Gujarat) situated at Godhra-Vadodra highway. There are two major divisions i.e. Division of Crop Improvement and Division of Crop Production with well equipped laboratories on Fruit, Vegetable, Germplasm Conservation, Biotechnology, Molecular Biology, Soil and Plant Nutrition, Soil and Water Conservation, Plant Physiology, Plant Pathology, Entomology and Post-harvest Technology to undertake basic, applied and strategic research.

MANPOWER

Staff Strength (As on 31.03.2016)

Category	Sanction	Filled	Vacant
Director (RMP)	01	01	00
Scientific	35	25	10
Technical	42	36	06
Administrative	23	17	06
Supporting	33	26	07
Total	134	105	29

The institute having well developed laboratories, farm and central facilities including various Experimental Blocks, Nursery, Landscape & Gardening Unit, Agro-meteorology Unit, Water Reservoirs and Drip Irrigation System and Seed Sale Counter as well as Centralized facilities like Library, Conference Hall, Committee Room, Museum, PME Cell, PC Cell, Hindi Cell, AKMU, ITMU, Farmers' Call Cell, Canteen, Bank Extn. Counter etc. The major infrastructure facilities are as under:

CIAH RS-CHES, Godhra (Gujarat)

KVK, Panchmahal (Gujarat)

CIAH Library

ARIS Cell

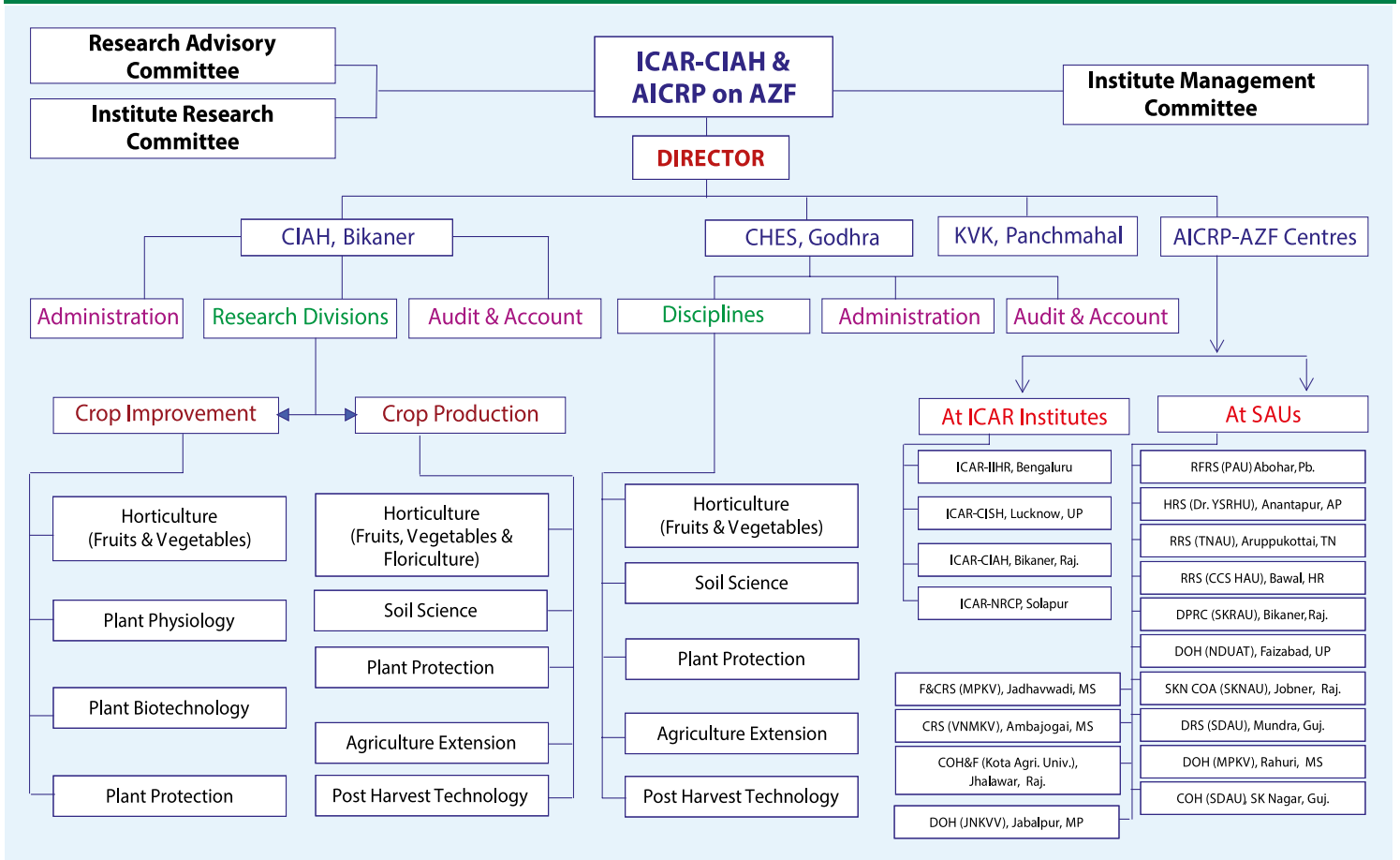
Biotechnology Lab

Museum

Nursery

Water Reservoir

ORGANIZATIONAL SETUP



RESEARCH ACHIEVEMENTS

GENETIC RESOURCE MANAGEMENT

Under the National Field Repository, a total of 457 germplasms of different fruit crops and 474 of vegetable crops have been collected and conserved at Bikaner. At Godhra, 571 germplasm accessions of arid and semi-arid fruits and vegetables are being maintained. The details are as under:

Fruit Crops					
Crops	***Scientific name***	**No.**	**Crops**	***Scientific name***	**No.**
Ber	*Ziziphus mauritiana*	154	Marula nut	*Sclerocarya birrea*	01
Bordi	*Ziziphus rotundifolia*	22	Sweet orange	*Citrus sinensis*	02
Jharber	*Ziziphus nummularia*	01	Argan	*Argania spinosa*	01
Pomegranate	*Punica granatum*	92	Karonda	*Carissa congesta*	05
Aonla	*Emblica officinalis*	15	Lasoda	*Cordia myxa*	15
Date palm	*Phoenix dactylifera*	64	Wood apple	*Feronia limonia*	03
Bael	*Aegle marmelos*	21	Ker	*Capparis decidua*	05
Cactus pear	*Opuntia ficus indica*	24	Manila Tamarind	*Pithocelobium dulce*	03
Phalsa	*Grewia subinaequalis*	05	Jamun	*Syzigium cumini*	02
Fig	*Ficus carica*	02	Mango	*Mangifera indica*	01
Mulberry	*Morus* sp.	15	Guava	*Psidium guajava*	03
			Dragon fruit	*Hylocereus undatus*	01
Vegetable Crops					
Kachri	*Cucumis melo*	68	Bottle gourd	*Lagenaria siceraria*	20
Mateera/ Water melon	*Citrullus lanatus*	46	Bitter gourd	*Momordica charantia*	05
Snap melon	*Cucumis melo var. momordica*	65	Ridge gourd	*Luffa acutangula*	20
Chilli	*Capsicum annuum*	45	Sponge gourd	*Luffa cylindrica*	16
Muskmelon	*Cucumis melo*	60	Indian bean	*Lablab purpureus*	30
Kakdi	*Cucumis melo var. utilissimus*	18	Cluster bean	*Cyamopsis tetragonoloba*	02
Ivy guord	*Coccinia indica*	01	Sword bean	*Canavalia gladiata*	01
Pumpkin	*Cucurbita moschata*	04	Khejri	*Prosopis cineraria*	14
Round melon	*Praecitrullus fistulosus*	10	Indian Aloe	*Aloe barbadensis*	4
Brinjal	*Solanum melongena*	30	Cowpea	*Vigna unguiculata*	01
Drumstick	*Moringa oleifera*	10	Velvet bean	*Mucuna pruriens*	01
Amaranthus	*Amaranthus* sp.	02	Palak	*Spinacia oleracea*	01

Germplasm conservation at CHES, Godhra

Crops	Scientific name	No.	Crops	Scientific name	No.
Ber	*Ziziphus mauritiana*	55	Phalsa	*Grewia subineaqualis*	25
Custard apple	*Annona squamosa*	15	Manila tamarind	*Pithocelobium dulce*	25
Pomegranate	*Punica granatum*	49	Wood apple	*Feronia limonia*	10
Aonla	*Emblica officinalis*	12	Karonda	*Carissa congesta*	40
Sapota	*Acharus sapota*	07	Mahua	*Madhuca latifolia*	30
Bael	*Aegle marmelos*	120	Chironji	*Buchanania lanzan*	30
Jamun	*Syzigium cumini*	68	Khirni	*Manilkara hexandra*	30
Tamarind	*Tamarindus indica*	25	Drumstick	*Moringa oleifera*	30

GERMPLASM EVALUATION

- Among ber (*Ziziphus mauritiana*) genotypes, Gola, Seb, Umran, Kaithali and Banarasi Karaka are performing well under the hot arid climate.
- Aonla (*Emblica officinalis*) is performing well with highest yield of NA-7 (51 kg/tree), followed by Chakaiya (34 kg/tree) and NA 6 (28 kg/tree) but frost is a limiting factor in hot arid region.
- Out of 92 genotypes of pomegranate (*Punica granatum*), Jalore Seedless (32 kg/tree), Ganesh (30 kg/tree), G-137 (29 kg/tree), P-23 (27 kg/tree) and P-26 (24 kg/tree) are promising for yield and quality traits.
- Bael (*Aegle marmelos*) NB-5 and NB-9 have performed well under irrigated hot arid ecosystem. A five-year old budded plant of NB-5 yielded about 40 fruits/ tree, while NB-9 yielded about 29 fruits/ tree.
- DUS guidelines for Aonla and Bael have been finalized.
- DUS guidelines for Ber, Watermelon and Muskmelon have been finalized and established DUS centres on these crops.
- Forty eight saplings of date palm varieties MIMI (19), MHN/B (24) and MRKS (5) have been procured from ICARDA, Amman, Jordan for evaluation.
- Eighty five tissue culture raised plants of supplied by different private companies through intervention of Department of Agriculture & Cooperation, Ministry of Agriculture, GOI, are under evaluation.
- Survey of Meghalaya and Nagaland states was carried out and 16 germplasm of aonla tolerant to frost/low temperature have been collected and are under evaluation.
- One elite germplasm of Jharber (*Ziziphus nummularia*) has been identified for low moisture tolerance and has been registered with ICAR-NBPGR, New Delhi.

- A physiological disorder styler end "brown tip" has been observed in ber cv. Chhuhara.
- A monoecious line of muskmelon (AHMM/BR-8) has been developed and registered with NBPGR with IC0599709 as INGR 14043.
- Muskmelon varieties/genotypes were evaluated for fruit fly infestation and it was recorded that AHMM/BR-1, RM-50 and AHMM/BR-8 were highly resistant.
- Two superior ridge-gourd genotypes *viz.*, AHRG-29 and AHRG-41have been selected, which set fruit under high temperature during May-June. The line AHRG-57 has been deposited with ICAR-NBPGR, New Delhi with IC-0599708.

CROP IMPROVEMENT

The Institute has released 29 varieties of arid fruits (12) and vegetable (17) crops. The details are given below:

Characters of varieties hybrids developed and released by ICAR-CIAH.

S.No.	Crop	Variety released	Photographs	Characteristics
			Fruits	
1	Aonla	Goma Aishwariya		A selection from plus tree. It is an early and drought tolerant. The average yield potential is 105 kg/tree.
2	Bael	Goma Yashi		Semi-dwarf tree and suitable for dry land areas. Fibre 2.0-2.45 per cent, Fruit weight : 1.25 kg per fruit, Fruit yield: 50 kg/plant, Fruit shell weight: 180g, Pulp 68.0%, TSS: 35-39 ^{0}Brix, Maturity range (days): 310-335 days Suitable for processing purpose.
		Thar Divya		Vigorous in growth and semi-spreading growth habit, compact canopy, very less spines, fruit ripens in 270 days from fruit set. Comparatively earliest in maturity (second fortnight of February), precocious bearer and highly suitable for growing under rainfed hot semi-arid ecosystem. Attractive dark yellow colour of pulp at complete ripening.

S.No.	Crop	Variety released	Photographs	Characteristics
		Thar Neelkanth		Drought tolerant, fruit ripens in 320 days, yield 70 kg/tree. Fruit weight: 1.50 kg, shell thickness 0.18 cm, total number of seed: 98.00, TSS 41.20 ^{0}Brix, suitable for candy, powder and RTS.
3	Ber	Thar Sevika		Developed by the hybridization from a cross of Seb x Katha. Thar Sevika is an early maturing variety. Average fruit yield is 30-32 Kg/tree.
		Thar Bhubharaj		A selection from local material of Bhusavar area of Bharatpur district of Rajasthan, having an average yield potential of 30-36 kg/tree. The fruits are very juicy, sweet with a TSS content of 22-23 ^{0}Brix.
		Thar Malti		A selection having plant height (3.6 m), semi-erect growth habit, late maturing, fruit ripens in 145-150 days from fruit set, greenish-yellow coloured oval fruits, high yield (65-70 kg/plant) and soft pulp texture, less thorny, fruits are moderately rich in sugars and ascorbic acid. The fruit yield remain unaffected due to temperature related stresses.
4	Lasoda	Thar Bold	 	A prolific and early bearing lasoda (*Cordia dichotoma*) has been identified as "Thar Bold" (CIAH/ LS-3) through selection. It bears bold fruits in cluster with production of 1.5-2.0 q tender fruits/ tree/ year. The tender fruits are suitable for making vegetable, pickles and for dehydration purpose. Fruits can be also utilized as table fruit and also for processing purpose. This variety is recommended for commercial cultivation both as block plantation and a component of agro-forestry system in arid and semi-arid regions.

S.No.	Crop	Variety released	Photographs	Characteristics
5	Jamun	Goma Priyanka		A selection with good taste of fruits having 16.86 TSS ^{0}Brix. Fruit are rich in Vitamin C (45.44 mg/100g). Yield potential is 30 kg/plant.
		Thar Kranti		It is dwarf, fruit ripens in 75 days from fruit set. Fruit yield: 65 kg/ tree. Fruit shape: Oblong, Fruit color: Deep purple, Flesh colour: Dirty white, Fruit weight: 20.10g, Pulp weight: 17.20 g, Pulp per cent: 85.57%, TSS: 17.10 ^{0}Brix, Acidity: 0.40%, Total sugars: 12.50%, Reducing Sugars: 6.20%, Vitamin C: 48.45 mg/100g.
6	Pome-granate	Goma Khatta		The variety is developed for Anardana purpose. Yield potential is 6.59 kg/plant and anardana yield is 1.18 kg/plant. Seeds hardness is medium. Fruit having 46.7% of Juice and TSS is 14.5 ^{0}Brix. Acidity is 7.3%.
7	Tamarind	Goma Prateek		A good quality fruit of tamarind having long pod of 16.70 cm and 1.25 cm breadth in size. Pod weight is 26.70 g having TSS 71 ^{0}Brix and acidity 14.06 %. Vitamin C-17.53 mg/100g.Yield: 58.50 kg/tree (at 9th year).
8.	Chironji	Thar Priya		Plant height (3.43 m), semi-spreading growth habit, thick trunk, dense foliage and dropping branches, umbrella shape, fruit ripens in 50-65 days from fruit set. It is comparatively dwarf, precocious bearer (4th year) and suitable for high density planting. It is suitable for table and processing purpose. TSS 23.90 ^{o}Brix, 1.24% acidity, 13.06% total sugars, 6.67% reducing sugar, 48.70 mg/100g vitamin C and 31.36% kernel protein. The fruit yield is 11.90 kg/tree.

S.No.	Crop	Variety released	Photographs	Characteristics
9.	Khirni	Thar Rituraj		Plant height (4.36 m), semi-spreading growth habit, thick trunk, evergreen & dense foliage umbrella shape. It is semi-dwarf, precocious bearer (4th year), fruit ripens in 120-125 days from fruit set. It is suitable for table and processing purpose. It recorded 24.73 °Brix TSS, 0.32% acidity, 17.80% total sugar, 28.33 mg/100g vitamin C. The fruit yield is 10-16 kg/plant.
10	Karonda	Thar Kamal		The variety is developed through selection from existing germplasm. Plant height (1.77 m), semi-spreading growth habit, thick trunk, evergreen, dense foliage and drooping branches. Flowering start, in 3rd year, regular bearer, ripens (55-56 days from fruit set) in the month of June and recorded 4.97 g average fruit weight, 93.64% pulp and 9.54 °Brix TSS, 0.64% acidity, 30.41 mg/100g vitamin C. Fruit yield 13.00 kg/plant (9th year). It is suitable for processing purpose.
11	Mulberry	Thar Lohit		Plant height (3.07 m) with spreading growth habit. Skin colour of fruit is deep red. Low (frost) and high temperature tolerant (-2°C to 49 °C). Yield: 12.4 to 26.5 kg/tree, fruit ripens in 32-36 days from fruit set, TSS: 20.8 °Brix, Acidity: 1.6%, Vitamin C-11.2 mg/100g. total flavonoids: 0.96 mg/g FW, total polyphenols 1.19 mg/g FW. total antioxidant activity (CUPRAC): 6.81µM TE/g
	Thar Harit			Plant height (2.90 m), short stature and spreading growth habit. Green-white colour, pendulous shape fruits, Fruit ripens in 38-42 days from fruit set. The plant growth and fruit yield remain unaffected due to temperature related stresses. Suitable for both table and processing purposes

S.No.	Crop	Variety released	Photographs	Characteristics
12	Mahua	Thar Madhu		Plant height (4.40 m), semi spreading growth habit, thick trunk with dense foliage, Dried flowers are used by tribal farmers. Starts bearing in 5th year. Yield: 20.10 kg per plant. Yield of dry flower: 6.30 kg per plant. Fruit weight: 29.0g Fruit ripens in 90-105 days from fruit set.
13	Phalsa	Thar Pragati		Plant height: 2.20 m, spreading growth habit, thick stem, dense foliage and drooping branches. Fruit ripens in 60 days from fruit set. It is dwarf, early precocious bearer (bearing in 3rd year), drought tolerant and suitable for high density planting. It is suitable for table and processing purpose.
		Vegetables		
1	Khejri	Thar Shobha		High yielding and better quality variety. It has been recommended for uniform tender pod harvesting for vegetable use. A grafted khejri plant yields a harvest of about 4.25 kg tender pods (*Sangri*) and 6 kg dry fodder per year.
2	Mateera	Thar Manak		It is an improvement over AHW 19 for quality. Developed through selection from the local land races found in arid region. It is very early. First marketable harvesting 75-80 DAS. The yield potential is 50-80 tones/ha under arid conditions.
		AHW-19		Medium-early maturing variety, produces 3.0-3.5 fruits per vine, flesh dark pink, solid (firm) with good eating quality and taste having 8.0 to 8.4 ^{0}Brix TSS. High yielder (460-500 q/ha) and tolerates high temperature.

S.No.	Crop	Variety released	Photographs	Characteristics
		AHW -65		Very early maturing variety, produces 3-4 mature fruits per vine and gives yield of 375-400 q/ha. The flesh is delicious, pink, solid (firm) having 8.0-8.5 ^{0}Brix TSS.
3	Kachri	AHK-119		Fruits are small, egg shaped weighing 50-60 g. Fruits are ready for picking in 68-70 days after sowing, 22 fruits per vine, and yields of 95-100 q/ha.
		AHK-200		The fruits are 100-120 g in weight, become ready for harvest in 65-67 days after sowing, bears about 20 fruits per vine, yield of 115-120 q/ha.
4	Kakdi	AHC-2		Very early maturing and bearing uniform, medium long fruits. Fruits are light green, skin without furrows. Harvesting of tender fruits can be done 8-12 days after fertilization for salad or for garnishing vegetables. Fruits become ready for harvest in 53-55 days after sowing and harvesting continues upto 95-110 days. Fruits weighing 275-300g are suitable for slicing when their length is 30-35 cm and diameter is 3.0-3.5 cm. The flesh is crisp textured. Produces 12-15 tender fruits i.e. 4 kg/ vine and 175-202 q/ha.
		AHC-13		Very early and highly productive variety with profuse hermaphrodite flowers. For slicing, the fruits can be harvested at very early stage (3-6 days after fertilization). First harvest can be obtained 50 days after sowing and harvesting continue upto 95-100 days. Continuous picking results in higher yield.

S.No.	Crop	Variety released	Photographs	Characteristics
				About 20-25 fruits are borne/vine. The tender fruits weighing 75-110 g are harvested when the length is 5.5-7.0 can and diameters are 4.4-5.0 cm. The flesh is crispy and tasty. On an average 2.15 kg tender fruits/vine and 85-125 q/ha. can be harvested. The variety also has high heat tolerance.
5	Snap-melon	AHS- 10		Fruits can be harvested 68 days after sowing, fruits are oblong and medium in size (900 g), flesh whitish pink, sweet in taste having 4.5-5.0 ^{0}Brix TSS. Bears 4.0-4.5 fruits vine each giving an yield of 225-230 q/ha under arid conditions.
		AHS- 82		Fruit harvest starts 67-70 days after sowing, each vine bears 4.5-5.0 fruits giving an yield of 245-250 q/ha. The flesh is light pink, sweet having 4.3-4.9 ^{0}Brix TSS.
6.	Bottle gourd	Thar Samridhi		High yield potential (3.82 – 5.82 kg/ plant) under hot arid environment. Fruits weighing 450 – 700 g are ready for first harvesting after 50 to 55 days from sowing. The fruit yield potential is 240-300 q/ha.
7	Cluster bean	Thar Bhadavi		High yielding vareity. Pod yield poentital is 75 g/plant and 9.0 cluster/ plant. Plant height is 65-70 cm. First harvest is 55-60 days after sowing.
8	Sword bean	Thar Mahi		The pod yield potential is 56.0 q/ha. First harvest 90-95 days after sowing. Pod yield is 1.73 kg/plant. In 40% pod yield is increasing through.

S.No.	Crop	Variety released	Photographs	Characteristics
9	Indian bean	Thar Kartiki		Days to flowering, DAS is 70-75 after 5.94. First harvest is 90-95 DAS. Pod yield is 1.75 kg/plant and yield 110 q/ha.
		Thar Maghi		It is high yielding, stable and found to be the most potential for commercial cultivation. For first marketable harvesting, it took 90-95 days in comparison to AHDB-3 (95-100 days). Average pod yield 1.77 kg/plant and tender post yield is 113.25 q/ha.
10	Ridge gourd	Thar Karni		Profuse branching with vine length of 3.51 m. Long ovary (6.39 cm), fruit cylindrical with 10 shallow ridges and light green colour. Takes 51-55 days to first picking from sowing. Resistant to mosaic disease and melon fruit fly under field condition. Its fruit set at high temperature during April-May. Fibre content in fruits at edible stage is 1.4-1.6g/100g. Fruit length (21.24 cm), fruit weight (95.74 g), fruit diameter (2.88 cm), number of marketable fruits/plant (21.03). Fruit yield 10-15 kg/plant.
11	Pumpkin	Thar Kavi		Fruits are dark green to yellowish, pulp creatm to orange colour, number of fruits 8 per plant, yield 8 kg/plant TSS 8.5 ^{0}Brix
12	Drumstick	Thar Harsha		Plant height: 4.0 m, spread: 3.6m, Late maturing type (160-180 DAS), Flowering from Dec-Jan and harvesting from Apr-June. Straight green pods (1.0 m long) pointed towards tip, drought hardy. Fruit yield 45 kg/plant, pod weight 155.3g. Resistant to leaf eating caterpillar and moderately resistant to fruit fly, Tolerant to moisture and heat stress. Pods suitable for culinary purpose and leaves for both vegetable and fodder purpose.

Besides above, following materials are in the final stage of release:

Bael: CHESB-11: Spineless, average yield of 35 kg per tree (5 year old plant), fruit weight (1.0 to 1.50 kg), suitable for sharbat, candy and powder making.

Wood apple: CHESW-4: Average yield 115 kg/plant, fruit weight 550 g.

Brinjal: CIAH-1 (AHB04 x PPC): It can be harvested at 45 DAT, has marketable yield of 60 tonnes per hectare. Fruits are medium in size, dark purple in colour. It is suitable for cultivation under rainy-winter-spring-summer season.

CROP PRODUCTION

Agro-techniques for fruit crops

- Under microsite improvement, to establish orchard in sandy soils of arid region, the pit size of 60 cm^3 filled with top soil, manure and pond silt in equal ratio is recommended for better establishment and growth of pomegranate plants.
- High density planting in aonla cv. NA 7 having a spacing of 5 x 5 m accommodating 400 plants / ha have been recommended under rainfed semi-arid conditions.
- Studies on high density planting systems revealed that different planting systems significantly affected the vegetative growth, yield and quality of aonla variety NA-7 under rainfed conditions of semi-arid environment. Among different planting systems (square- 100 plants, hedgerow- 200 plants, double hedge row-260 plants, cluster-169 plants and paired-130 plants/ha), highest yield/ ha (225.90 q) and net return of Rs. 243 035.00/ha) was recorded in double hedge row cropping at 11^{th} years of planting. An increase in yield of 132.39% over square system was recorded in double hedgerow planting system.
- Canopy management in *karonda* by medium pruning (retaining of 4-6 scaffold branches) during the month of February-March registered improved yield i.e. 12-14 kg fruit per tree in comparison to 7-9 kg fruits in unprunned plants. Further, the harvesting period was also hastened by about three weeks (first week of August) in comparison to mild pruned plants.
- Application of different mulches in aonla demonstrated that bacterial population in basin soil was highest in paddy straw mulch, which has better impact on yield of aonla.
- The allelopathic effect of over-storey crop on under-storey crops have been studied. It has been demonstrated that the aqueous extract of ber leaves have adverse effect on the growth of understorey crops such as mustard. It is therefore advised to use only decomposed biomass of ber, in order to minimize the adverse effect on germination of mustard crop.

Crop diversification

- Crop diversification studies in ber (*Ziziphus mauritiana*) and aonla (*Emblica officinalis*) based cropping studies led to the recommendation that initial phase of ber orchard (4 years), Indian aloe (*Aloe barbedensis*) and cluster bean (*Cyamopsis tetragonoloba*) are the low input and highly remunerative crops giving net returns of Rs. 65,802 and Rs. 26,144/ ha, respectively. Under ber based cropping system, it has been demonstrated that ber plantation brings down bulk density, increases porosity and organic carbon content of soil.

- The studies on multistorey cropping system have shown that the crop combinations such as Aonla- Ber- Brinjal - Moth bean- Fenugreek, Aonla- Bael- Karonda- Moth bean- Gram, Aonla- Khejri- Suaeda- Moth bean- Mustard and Aonla- Drumstick- Senna- Moth bean- Cumin were found to be sustainable and remunerative under arid ecosystem. In aonla based multi storey cropping system, brinjal (*Solanum melongena*) was identified as potential crop giving an average net return of Rs 56,000/ha.
- Inter-cropping of cucurbits in aonla is economically viable under rainfed semi-arid ecosystem. Among the different cucurbits (bottle gourd, pumpkin, bitter gourd, sponge gourd and cucumber), aonla + bottle gourd fetches highest net return to the tune of Rs. 1,47,312/ha with the B: C ratio of 4.44.
- Economic analysis of mango based cropping system at CHES, Godhra revealed that the maximum yield per plot was recorded with mango + bottle gourd followed by mango + pumpkin.

Integrated nutrient and water management

- DRIS norm has been developed for sapota and aonla.
- To minimize the use of chemical fertilizers, use of vermicompost and inorganic fertilizers (50:50) had given good response in terms of plant vigour, leaf nutrient content and fruit yield of pomegranate under hot arid region. The use of organic manures in sandy soil have better influence on soil moisture retention for longer period in the root zone, which increases the availability of nutrients to the crop. Use of poultry manure along with *Azotobacter* gave the highest yield in bottle gourd.
- Under prevailing soil and climatic conditions of arid ecosystem, the water use efficiency is extremely poor in arable cropping in general and for fruit crops in particular. In case of pomegranate and ber alternate day irrigation through drip at 0.75 CPE with 75 per cent and

recommended dose of nitrogen had given promising response in terms of plant vigour, fruit yield and leaf nutrient content. By drip fertigation, there was saving of 25 per cent fertilizer and more than 25 per cent of irrigation water with maximum water use efficiency as compared to pipe irrigation.

- In Kinnow fruit crop, 50 per cent N, 80% P and 30% K of recommended dose (N:1250g, P:500g and K:750g / plant / year) should be given from February to July and remaining 50% N, 20% P and 70% K should be given during August to November with solid soluble fertilizers through drip fertigation for obtaining higher yield and better quality fruits.
- A double ring method was devised and applied for water management in aonla plants. This saved 50-60 per cent of water application in plants. Effect of different mulches (maize straw, paddy straw, rice husk, grasses, subbabul lopping and black polythene) showed that application of organic and synthetic mulches increased soil moisture status.
- Analysis of microbial population of 0-0.15 and 0.15-0.30 m depth revealed that total microbial population was minimum in absolute control and maximum in treatment recommended dose of N,P,K+FYM and consortium of biofertilizer. Similarly in Kinnow, the best fruit weight, fruit yield. TSS, acidity and juice recovery were observed in above treatment.
- In mango, application of FYM+standared dose of NPK+Azotobactor+PSB showed better growth of plant. In an experiment conducted to study the effect of different forms of compost revealed that in tomato and cluster bean compost made from neem gave the highest yield.

Propagation

- In order to optimize the production of arid horticultural crops, some agro-techniques have been standardized/ refined for hot arid ecosystem. Propagation techniques of Aonla, Ker, Lasoda, Ber, Jamun, Tamarind, Khejri, Pomegranate, Sapota, etc. have been standardized. Various fruit crops, where propagation techniques have been standardized and given below:

Propagation techniques standardized

Crops	Propagation method	Time of propagation
Aonla	Patch budding	June- July
Bael	Soft wood grafting and patch budding	June- July
Ber	T-Budding	June- July
Chironji	Soft wood grafting	July- August
Jamun	Soft wood grafting and patch budding	July- August
Ker	Cutting and micro-propagation	August - September
Khejri	Patch budding	June- August
Lasoda	Patch budding and micro-propagation	June- August
Pomegranate	Cutting	February and July
Tamarind	Soft wood grafting and patch budding	July- August

- Hi-tech nursery complex has been established for hardening of tissue culture plants and vegetative propagation of arid fruits and clonal root stocks. Preliminary studies were conducted on greenhouse propagation of khejri, ber, aonla, pomegranate, citrus species and *Aloe vera* (vegetable type) under green house. The results so far obtained with all the species were encouraging and remarkable improvement in efficiency of vegetative propagation either by stem cutting or by budding technique has been obtained. Innovative results were obtained in case of pomegranate, khejri and aonla. Adventitious root formation was obtained in microcutting of pomegranate, citrus and in microsucker of *Aloe vera*. Several inherent limitations of conventional propagation techniques such as season dependency, requirement of hormonal treatments, rooting in difficult-to-root fruit crops like ber and aonla were overcome under preliminary propagation studies conducted under hi-tech glasshouse and mist chamber.

Agro-techniques for arid vegetables

- The agro-techniques developed or improved for maximizing returns per unit area in vegetables under environmentally stressed areas are related to site selection, field micro-climate management, seed treatment, method and time of sowing, maintenance of plant population, soil-water conservation, irrigation systems and scheduling, foliar feeding and crop protection measures. Besides, post-harvest management, on farm value additions, organic and hi-tech farming and marketing have also been taken up for remunerative cultivation of arid vegetables.

- Among the controlled irrigation systems, drip irrigation is the most suitable for cucurbitaceous crops under arid conditions. Single lateral lines (12-14 mm size) at 1.5-2.0 m distance with on-line drippers (4 litre/h) at 50 cm distance was found to be the most suitable for kachri, snap melon and watermelon (mateera). Increased fruit yield of about 25-30 per cent was obtained in these crops in comparison to the channel system of irrigation under arid conditions. Based on seasonal agro-climatic and weather situations, crop potentiality and available resources, a complete production technology adopting drip irrigation has been developed and recommended for commercial cultivation of arid zone cucurbits.
- The protocol for cultivation of cucumber and tomato under controlled environment condition has been standardized. An average yield of 6.5 kgm^{-2} was obtained from cucumber variety Isatis under naturally ventilated green house conditions followed by the Hilton and Kian.

PLANT PROTECTION

Pathology

- Diversity in ber powdery mildew isolates from various locations of the country was identified. The perpetuation and survival mechanism of this major pathogen (*Oidium erisiphoides* f. sp. *zizyphi*) was studied. The role of oxidative enzymes, constitutive phenolics, calcium, protein, etc. as the *in vitro* indices for screening of ber germplasm in addition to protein profile of ber genotypes has been investigated.
- Various isolates of *Trichoderma* and *Pseudomonas fluorescens* were isolated from soil and plant samples from arid horticultural ecosystem and diversity among these isolates has been reported. After a sequence of basic research including inherent tolerance to major fungicides, some of the elite isolates, *viz.,* CIAH-111, CIAH-196 and CIAH-311 of *P. fluorescens* and CIAH-151, CIAH-240 of *Trichoderma* were mass multiplied for formulation. Promising isolate of *Trichoderma* (CIAH-240) and *P. fluorescens* (CIAH-196) with different treatment combinations along with 50 per cent less quantity of Dinocap were tested under field conditions for the management of ber powdery mildew under AICRP on AZF centres. Performance of *Trichoderma* isolate CIAH-240 was better at Rahuri center showing PDC of 86.23 with 58% of powdery mildew incidence. Field experiments for the management of virus disease in watermelon (mateera) also resulted that isolate, CIAH-196 of *P. fluorescens* influencing high seed germination (80.1%) followed by 78.5% in isolate CIAH-240 as compared to 60.5% in check. Bioagents were also tested for the management of date palm sucker rot, fruit rot and stem blight in ber under laboratory conditions.
- Under semi-arid conditions, control of *Cercospora* leaf spot of pomegranate was achieved by 3 fortnightly sprays of Topsin-M (0.1%), Captaf (0.2%) or Dithane M-45 (0.2%). Fruit rot of aonla was found to be controlled by 2–3 sprays of Dithane M-45 (0.2%) or Kavach (0.2%).
- Schedule involving two applications of either Fenvalerate (0.005%) or Dimethoate (0.05%) at 21 days interval commencing from second fortnight of September followed by two applications of 5% Neem Seed Kernel Extract (NSKE) at 10 days interval proved to be effective against fruit fly and fruit borer infestation in ber. Management schedules have been worked out for hairy caterpillar, leaf miner, fruit fly and fruit borer, which are the important pests of ber in arid region. In addition to these, ber butterfly, leaf webber, stone weevil and grey weevil were also identified and their season wise damage intensity was worked out.
- The coat protein (CP) gene primer was designed for leaf curl disease of chilli. This gene was cloned and sequenced. The length of this gene was 747bp. The sequence has been submitted to National Centre for Biotechnology Information.
- Disease severity of *Alternaria* blight and *Cercospora* leaf spot of bottle gourd was found from 4.0-24.0% and 2.0-13.0%, respectively in Bikaner, Sriganganagar and Hanumangarh districts.
- Among watermelon genotypes, 'Asahi Yamato' showed less disease severity (<10%) against mosaic disease.
- 06 varieties of bottle gourd *viz.,* (Pusa Naveen, Pusa Samridhi, Pusa Sandesh, Pusa Santushti, Arka Bahar and PSPL) showed moderate resistance against *Alternaria* leaf blight disease.
- Four varieties such as Pusa Naveen, Pusa Santushti, Pusa Samridhi and Pusa Sandesh showed moderate resistance and 04 (PSPL, Arka Bahar, PN-22 and DBG-6) were moderately susceptible against *Cercospora* leaf spot in bottle gourd.

- Imidacloprid (0.05%) was found the most effective treatment as seed treatment + foliar spray against mosaic disease followed by acephate (0.06%) in *mateera* variety 'Thar Manak'.
- Mancozeb (0.25%) was the best fungicide as foliar spray for reducing *Alternaria* leaf blight of *mateera*.
- Combined treatment of carbendazim @ 0.1% (seed treatment) + mancozeb @ 0.25% (foliar spray) + *Pseudomonas fluorescens* CIAH- 196 @ 5% (foliar spray) + neem leaf extract @ 5% (foliar spray) was most effective for integrated management against *Alternaria* leaf blight in bottle gourd var. 'Thar Samridhi'.
- Combination of mancozeb @ 0.25% (seed treatment) + carbendazim 0.1% (foliar spray) + *Pseudomonas fluorescens* CIAH- 196 @ 5% + neem leaf extract @ 5% (foliar spray) was recorded the most efficient for integrated management of *Cercospora* leaf spot and powdery mildew in bottle gourd.

Entomology

- Control measures have also been worked out for the important pests for pomegranate *viz*., thrips, semilooper and anar butterfly. The incidence of major pests of brinjal and chilli were found to be reduced to manageable levels by adjusting the date of planting. This technology was specially suitable for adoption by tribal farmers of the region. Population dynamics of major insect pests on arid fruits and vegetables were also worked out as mentioned below:

Ber

- The pests such as fruit fly (*Carpomyia vesuviana* Costa), stone weevil (*Aubeus himalayanus* Voss), ber butter fly (*Tarucus theophrastus* Fabricius), bark eating caterpillar (*Indarbela* sp.), termite (*Odontotermes* sp.) and grey weevil (*Myllocerus* sp.) were recorded. The damage of leaf feeder's *viz*., ber butterfly, leaf webber and grey weevil damage was more during June to September and stone weevil damage was noticed from October to February. The fruit fly was recorded from November to February.
- In case of natural enemies, the fruit fly parasitoids *Fopius* sp. and other hymenopterans, braconids (*Apanteles* sp.), *icheuunimonid* wasp; neuropterans, green lace wing (*Chrysoperla* sp.) and spiders have also been reported during this period. In addition to ber fruit fly, stone weevil and ber butter fly seems to be serious pests of ber in this region.

Bael

- The swallow tail butterfly *Papilio demoleus* was recorded on Bael from September to February. The population peak (egg and larvae) was in November and December. Beside this, damage of tephritid fruit fly *Bactrocera zonata* during August was noted. This seems to be emerging problem in bael. The severe fruit dropping was noticed in the fruit fly infested cultivars.

Date palm

- In date palm, the scale (*Parlatoria blanchardii*) was noticed as an important pest and it was found throughout the season. The violet colour crawlers suck the sap on under surface of leaves, pinnules, main veins and fronts. Due to sap loss, it affects the vitality of tree fruit setting and development. In addition to this, the damage of lesser date moth, *Batrachedra amydraula* has also been noticed. The larva starts the infestation at inflorescence stage, feeds on fruits and immature seeds. In severe cases, it leads to fruit dropping during June-August. The non-insect pests (birds) were also severe during June to August.

Acid lime

- The swallow tail butterfly *Papilio demoleus* was recorded on acid lime during September, 2010. Some of the plants leaves were totally damaged by this pest. Due to the high rain fall in 2015, the swallow tail butterfly *Papilio demoleus* has caused major damage to acid lime plants.

Round gourd

- The fruit fly (*D. cucurbitae*), mealy bug (rainy season), cucumber moth (*Diaphania indica*) were recorded at CIAH farm.

Snap melon

- *Epilacna* beetle and whitefly incidence was more on 30 days old crop and fruit fly, (*D. cucurbitae*) and leaf eating caterpillar, *Diaphania indica* at flowering and fruiting stage and its damage continues upto the harvest.

Source of resistance against fruit fly in muskmelon

- AHMM/BR-1, RM-50 and AHMM/BR-8 were found to the resistant; MHY-5, Durgapura Madhu and Pusa Sarabati moderately resistant; AHMM/BR-13, Pusa Madhuras and Arka Jeet susceptible and Arka Rajhans and GMM-3 were highly susceptible genotypes to fruit fly infestation. The per cent fruit infestation and larval density had significant positive correlations with fruit diameter and days to first harvest and negative correlation with fruit toughness, rind thickness, flesh thickness and length of ovary pubescence. Total soluble solid and pH were lowest in resistance and highest in susceptible genotypes whereas tannins, phenols, alkaloids and flavonoid contents were highest in resistant and lowest in susceptible genotypes. Maximum variation in fruit infestation and larval density was explained by length of ovary pubescence (63.3 and 45.7%, respectively) followed by fruit toughness (6.7 and 13.7%, respectively) and fruit diameter (8.6 and 10.5%, respectively). Flavinoid and tannin contents explained (96.4 and 88.7%, respectively) of the total variation in fruit fly infestation and in larval density per fruit.

Dictyla cheriani on lasora

- Lace bugs were observed on Indian cherry tree in the hot arid region of north-western India, (i.e. Thar Desert) and identified as *Dictyla cheriani* (Drake). The average incidence of lace bugs on trees ranged between 11.67 to 51.67 per cent in bold seeded plants and 21.67 to 76.67 per cent in small seeded plants. The female was distinctly larger than the male in respect to all body parts. This lace bug was typically characterized as having body oblong, pale testaceous with brownish or fuscous markings, with collar and hood yellowish brown, body beneath reddish dark with thoracic sterna darker. Antenna is yellowish brown; 1/3 part of 4 segment blackish. Antenna is rather slender, segmental measurements: I, 0.12 mm; II, 0.09 mm; III, 0.80 mm; IV, 0.22 mm. Length of body is 2.25 mm and width 0.88. Head is very short, strongly deflexed, bucculae wide, areolate, closed in front. Legs are fairly slender and yellowish brown. Hemelytra are wider than width of pronotum across humeral angles, longer than abdomen. The mean body lengths of males and females were 2.17 mm and 2.74 mm, respectively.

Anarsia triaenota Meyrick on khejri

- This moth, *A. triaenota* (Gelechiidae: Lepidoptera) was recorded on khejri in the month of April to September, 2013 at experimental farm of ICAR-Central Institute for Arid Horticulture, Bikaner. This moth is looking a new threat and it was a severe problem during this year. The larvae damages to new leaves and make the gallery inside the leaves of the khejri plant. Due to attack of this pest,

the growth of khejri plant is suppressed and the new leaves dries. Larval and pupal development took place inside gallery of leaves. The incidence of moth was recorded from 14.67 % to 80.33 %. The incidence was started from the month of April to end of September and the highest intensity was recorded in the month of June to July.

Pupal Parasitism of Pioneer Butterfly, *Anaphaeis aurota* by *Brachymeria albicrus* (Klug) in Rajasthan

- The ker, *Capparis decidua* (Forsk.) was found to be heavily infested with *Anaphaeis aurota* Fabricius, commonly known as the Pioneer or Caper white, in various parts of arid region of Rajasthan. It is found that the grown caterpillars of *A. aurota* Fabricius easily strip off the branches, devouring leaf causing great damage. The pupae of *A. aurota* Fabricius were found to be parasitized with *Brachymeria albicrus* (Klug). *B. albicrus* (Klug) has been earlier reported from southern India. The mean per cent parasitism of the Pioneer by *B. albicrus* (Klug) at ICAR-CIAH farm and at Desnok, Bikaner was 49.5 and 47.5, respectively and the mean per cent emergence of the mature adult parasitoids from the parasitized pupae was 15.5 and 14.0, respectively.

Coreid bug, *Homoeocerus variabilis* a pest of khejri

- This coreid bug, *Homoeocerus variabilis* Dallas was a new record for first time on khejri, *P. cineraria,* in the month of August 2010 at experimental farm of ICAR-Central Institute for Arid Horticulture, Bikaner. The body is ochraceous with a broad basal fascia to the pronotum between the lateral angles. The scutellum is small and pale in color. Antennae four segmented, the basal part of second and third segment is pale yellow, and third segment of antennae is flattened at tip portion. The fourth segment of antennae is shorter in all segments. The sucking type mouth part is found in coreid bug. It damages the new flowering/ leaves/ stem of the khejri plant. Due to attack of this pest, the growth of khejri plant was suppressed and new branches/ leaves dries. In winter season, the coreid bug was found on stem/ branches of plant in gregarious stage. The intensity of coreid bug in three years old khejri plant was recorded from 135 to 550 adult/ nymph per plant.

Antixenotic and allelochemical resistance traits of watermelon against fruit fly

- The varieties/ genotypes, Asahi Yamato (12.73%), AHW/BR-16 (15.10%) and Thar Manak (18.27%) were found resistant; Durgapura Lal (23.03%), Sugar Baby (26.67%), AHW/BR-12 (29.73%), Arka Manik (34.15%), Charleston Grey (38.70%), AHW-65 (35.80%), AHW-19 (48.97%) were found moderately resistant and IC 582909 (53.18%), AHW/BR-60 (55.52%), BSM-1 (59.10%), AHW/BR-137 (60.58%) and AHW/BR-9 (67.37%) were found the susceptible varieties/ genotypes to fruit fly infestation. The per cent fruit infestation and larval density had significant positive correlation with fruit length (r=0.57 & 0.55) and days to first fruit harvest (r=0.75 & 0.76) and negative correlation with length of ovary pubescence (r= -0.91 & -0.91), rind hardness (r= -0.86 & -0.87) and rind thickness (r= -0.77 & -0.75). Maximum variation in fruit infestation and larval density was explained by length of ovary pubescence (82.50 and 83.60%, respectively) followed by fruit length (4.3 and 3.0%, respectively) and rind thickness (3.2 and 2.0%, respectively). Free amino acids were the lowest in resistant (Asahi Yamato) and the highest in susceptible variety/ genotype (BSM-1), whereas phenols, tannin, total alkaloids and flavonoid contents were the highest in resistant and lowest in susceptible varieties/ genotypes. Flavonoid and total alkaloid contents explained (88.4 and 92.0%, respectively) of the total variation in fruit fly infestation and in larval density per fruit.

BASIC SCIENCES

A. Biotechnology

- Micropropagation protocols have been developed in ker (*Capparis decidua*), lasoda (*Cordia myxa),* mulberry (*Morus alba*), citrus (*Citrus limon*), vegetable type cactus pear (*Opuntia ficus indica*) and *Aloe vera*. Photoautotrophic *in vitro* conservation technique for conservation of germplasm of cactus pear, *Aloe vera* and mulberry has been developed.
- PCR based diagnostic probe to detect begomovirus infection in chilli has been developed to utilize the breeding programme and validated by PCR amplification, cloning and sequenceing (HM004433). RAPD based marker, OPA 16 was identified to detect inter-specific hybrids between *Citrullus lanatus* and *C. colocynthis*.
- The primers for characterization of khejri cv. Thar Shobha were standarized. It was recorded that Thar Shobha had specific bands 200 bp with OPBA-13; 350 bp with OPBE-05; 550 bp with OPA 12 & 300 bp with OPA-14.
- Somatic embryo of date palm formation through suspension culture technique was developed. Liquid media containing different concentrations of NAA and BA with replenishing media at 15 days interval were found to enhance the proliferation of somatic embryo. These embryos further germinated on hormone free media and produced shoots and roots.

B. Physiological and biochemical investigations in arid horticultural crops

- Studies on photosynthesis and associated parameters were undertaken in 40 cultivars of ber. It was observed that the ber cultivars could be classified into two major groups i.e. (a) showing mid-day depression in photosynthesis, and (b) which do not show mid-day depression. Similarly, the cultivars were also screened for corboxylation efficiency and water use efficiency. Cultivars Seb, Banarsi Pewandi, Banarasi Karaka, Mundia, Dandan, Alwar Desi, Govindgarh Special and Kala Gola were found to be superior over other cultivars. Absence of mid-day depression has been adopted as an adaptive parameter in ber for drought resistance.
- In order to understand the mechanisms of adaptation by cucurbitaceous crops to tide over water stress in arid ecosystem, comparative study was under taken using mateera (stress tolerant) and watermelon (stress susceptible) as test crops. It was revealed that under stress conditions, mateera plants are able to maintain growth whereas, the growth was checked in watermelon plants. Moreover, the dry matter accumulation was maintained to vegetative parts (leaves-45-60%) in mateera, whereas in watermelon, the dry matter accumulation to leaves was reduced (30%).
- Similarly variation in photosynthesis and water use efficiency in mateera and watermelon has demonstrated that the net photosynthesis in mateera was reduced only by 30% when grown under water stress condition compared to 50% in case of watermelon. Another interesting adaption, which mateera has acquired is faster rate of regeneration on re-watering. This feature enables to regain the vigour in short span on re-watering.
- The activity of various enzymes such as peroxidase, amylase and protease were assayed under control and water stress and it was demonstrated that tolerant species have mechanism to retain enzyme activity even under low water potential.
- Phylogenetic relationships among ber, pomegranate and date palm cultivars have been ascertained using foliar flavonoid spectrum.

- In order to understand mechanism of drought tolerance of arid horticultural crops the studies were undertaken to assess the changes in plant metabolites such as soluble sugars, starch content, enzyme levels in mateera and muskmelon seeds. The results demonstrate that in drought tolerant plants, the magnitude of plant metabolites are maintained high even under drought tolerance conditions. More soluble sugars are accumulated in roots under water stress condition in tolerant plants.
- Studies on seed priming demonstrated that priming of seeds with PEG or KNO_3 gave positive response in growth and development of watermelon and muskmelon seeds under water stress.
- RAPD profiling of pomegranate, aonla, bael, date palm have been completed and their phylogenetic relationships worked out.

POST-HARVEST TECHNOLOGY

- For improving storage life of ber fruits cv. Gola, the fruits were packed in perforated polythene bags after treating with calcium nitrate (0.5%) and Virosol (2.5%). The treatment had reduced physiological weight loss at ambient temperature (28 ±2 ^{0}C). Fruits treated with Bavistin reduced the pathological loss upto 10.60 per cent. Calcium nitrate could maintain the colour up to 9 days under ambient temperature.
- For dehydration of *sangri* (tender pods of *Prosopis cineraria*), blanching in 2% salt solution has given the best quality after rehydration. Attempts were also made to prepare biscuits from dried pods (*khokha*) of khejri.
- Packaging materials for long distance transportation and maturity standards in ber and aonla have been worked out. It was observed that in aonla, the minimum spoilage loss was found when the fruits were stored in corrugated fiber board box with newspaper liner.
- Bael powder was prepared from pulp and stored at room temperature. It was observed that bael pulp powder can be stored up to 6 months at room temperature and more than 12 months under refrigerated conditions without change in colour. Bael RTS (ready-to-serve) was prepared from powder was found acceptable on score basis. Barfi from bael pulp was also prepared and it was found acceptable among testers.
- Date RTS was prepared from doka stage fruits of date palm and it was acceptable. Date biscuits from cv. Sabiah and Medjool using 10 and 20% pulp powder was prepared and organoleptic testing was carried out on the basis of score. Date biscuits (adding of 20% powder of pulp) were found acceptable and rich in protein and sugar.
- Aonla shreds were prepared by solar drying after treatment with salt. Similarly, oil less pickle of aonla was prepared with 10-15% salt.
- Candy from water melon was prepared.
- Ber slices have been prepared using ber cultivar Goma Kirti.
- Natural dye was extracted from karonda fruits of genotype CIAH-Sel. 1 which can be used for dying cotton fabric. Premordanting with mordants such as PEG, tannic acid, ferrous sulphate and cupric sulphate followed by dying gave various shades like grey, yellow and red to cotton fabric.
- A natural colourant cum nutraceutical- supplement was extracted from fruits of Karonda genotype CIAH- Sel.1. The formulation has been christered as Lalima.

TRANSFER OF TECHNOLOGY

- The preliminary survey in IGNP area of Bikaner district revealed that 32 per cent farmers grow mateera, snapmelon, kachri, 18 per cent farmers grow brinjal, bottle gourd and 14 per cent grow ber and aonla. In this area the major constraints in development of arid horticulture are: poverty, low income, high cost of inputs, poor communication, lack of transport facilities, lack of seeds/ planting material, lack of farmers training and erratic rainfall.
- For transfer of arid horticultural technologies, on- campus and off- campus training programmes and group discussion were arranged for farmers and farm women. Presently, few demonstrations have been laid out on the farmers field to demonstrate the technologies developed at the Institute. These are being regularly monitored by the scientists of the Institute.
- Field days and field visits were conducted to impart the knowledge to farming community about arid horticulture. Other extension activities like Radio and T.V. talk, organizing exhibition during Kisan Mela, distribution of literature, etc. are being done by the Institute for the welfare of farming community.
- The information on rural wisdom in utilization of arid fruits and vegetables have been documented and attempts to scientifically produce them on small scale is in progress.
- The information on traditional vegetable cultivation, utilization and marketing system, change in cropping patterns and socio-economic characteristics of farmers, ITKs were investigated. The major constraints faced by the farmers in adopting the technologies were also enlisted.
- The institute has conducted about 40 on campus/ off campus training to impart the technologies generated at the institute. As a result of this, the area which was mostly having animal husbandry as their occupation has taken up the cultivation of arid horticultural crops as their livelihood. The major impact observed on farmers and farm-women attitude are :

Attitude	Impact
Change in cognitive behavior	Directly/ indirectly increased > 60% knowledge, awareness, and interest of > 10000 farmers about modern/improved technologies of arid horticultural crop production
Adoption of improved technologies and economic gain	More than 7 – 10 % area increased under improved varieties of arid vegetables. More than 70 % farmers are very eager to produce the crop of improved varieties of *kachri* (AHK- 119) and snap melon (AHS-82) at commercial scale. The farmers who have adopted improved technologies (improved varieties and their agro-techniques) of arid horticultural crop production; their income has increased more than 50 %. At present, Kachri (*Cucumis callosus*): AHK-119 is being grown in an area of above 3000 ha in western Rajasthan during rainy & summer seasons. The farmers are earning more than 1,00,000/ha. / season. The farmers (10 -15 %) have started to produce the seeds of improved varieties of *kachri* (AHK- 119) and snap melon (AHS-82) to earn money by selling the same to fellow farmers.
Social changes	Increased horti-based commodity interest groups in social system. Increased cosmopolitism and scientific orientation of the farmers. Increasing flow of farmers from laggardism to innovatism, etc

LINKAGES AND COLLABORATIONS

- At the national level, the Institute collaborates with the ICAR-NRC on Plant Biotechnology, ICAR-NBPGR, New Delhi, Department of Horticulture, Govt. of Rajasthan, Maharana Pratap University of Agriculture and Technology, Udaipur, SK Rajasthan Agriculture University, Bikaner, NGOs (Gaushala Santhan, Khadi Gramodyog, Bikaner, Ambhuja Foundation, Marwar Mundwa, Nagaur, Urmul Setu, Bikaner, Pasari Social and Rural Development Research Foundation, Chidawa, (Jhunjhunu) and KVKs situated at Bikaner and Sardarshahr.
- At the international level, the ICAR-CIAH collaborates with Hebrew University of Jerusalem, Israel, Government of Egypt and Govt. of UAE, etc.
- PG research and teaching at SK Rajasthan Agricultural University, Bikaner by scientists of the Institute.

KVK, PANCHMAHAL, GUJARAT

- The Krishi Vigyan Kendra (KVK) was established at Vejalpur, Panchmahal district of Gujarat in 2005 under the administrative control of ICAR-CIAH, Bikaner. KVK is helping the farmers and farm women of Panchmahal area for improving horticultural scenario and in turn ensure nutrition and income security to inhabitants. For this, KVK has conducted training programmes, laid out front line demonstrations, on farm trials, organized Kisan Gosthi, exhibition and group meetings, etc. to impart latest technologies to farmers.

SERVICES TO STAKEHOLDERS

- **Seed & Planting Materials:** Institute is multiplying seeds of arid vegetables like; kachari, mateera, snap melon and guar, planting materials of ber, bael, aonla, pomegranate, jamun, phalsa, karonda, Kinnow, sweet orange, mulberry, lasoda, mango, guava, moringa, khejri, Indian Aloe etc. for the farmers of arid and semi-arid regions of the country. Besides, All India Coordinated Research Project on Arid Zone Fruits centres are also producing planting materials. About 2.5 lakhs of planting materials are produced by the institute every year for the distribution among farmers and line departments.
- **Preparation of Soil Health Card:** Institute is also facilitating in preparation of soil health cards to the farmers of arid region, so as to improve productivity and fertilizer use efficiency in various crops of arid and semi-arid regions. Institute has already distributed soil health cards to the farmers of Bikaner.
- **Scientific Literature in Regional Language:** Institute is regularly preparing folders and leaflets in hindi on various crops, varieties and technologies for the farmers and distributing free of cost.
- **Training and Skill Development Programmes:** Institute is imparting training to the farmers on crop specific good agricultural practices, nursery management, protected cultivation, plant protection, post-harvest and value addition of various arid and semi-arid fruits and vegetables. Similarly, various skill development modules have been prepared to develop entrepreneurship among rural youth, progressive farmers and extension workers.

- **Technical Advisory Services:** The scientists of the institute are also guiding to the farmers and nurserymen as and when desired in different ways like field visit, organizing field days, interactive meetings, through electronic/print media etc.
- **Technology Demonstrations:** Institute is also demonstrating new varieties and technologies on farmers field in participatory mode for quick dissemination of technologies.

Off Campus Training

Technology Demonstration

Field Visit

Empowering Rural Youth

CIAH Exhibition

Scientist-Farmers interaction

राजभाषा प्रकोष्ठ

- संस्थान में राजभाषा कार्यान्वयन समिति की तिमाही बैठक, हिन्दी कार्यशाला का आयोजन एवं हिन्दी चेतना सप्ताह कार्यक्रम आयोजित करता है, जिससे राजभाषा का प्रचार–प्रसार एवं हिन्दी में कार्य को बढ़ावा मिलता है। राजभाषा अनुभाग प्रत्येक वर्ष ''मरू बागवानी'' पत्रिका का प्रकाशन करता है जो पाठकों के लिए बागवानी में शोध, खेती की नई तकनीकें, साहित्य, लेख व कविताओं इत्यादि जानकारियों से सुसज्जित होता है। इसके अतिरिक्त हिन्दी में किसानों के लिए बागवानी विषयक पर बुलेटिन, पत्रक व फोल्डर तथा वार्षिक प्रतिवेदन प्रकाशित करने में अग्रणी भूमिका है। संस्थान में हिन्दी में अधिक से अधिक कार्य करने, पत्रावली टिप्पण लिखने हेतु कर्मचारियों/अधिकारियों को प्रोत्साहित एवं प्रशिक्षित करने का कार्य भी करता है। हिन्दी में उत्कृष्ठ कार्य करने के लिए संस्थान को न.रा.का.स., बीकानेर द्वारा पुरस्कृत भी किया जा चुका है।
- राजभाषा के लिये संस्थान को मिले पुरस्कार व प्रशस्ति पत्र
  1. वर्ष 2008 के दौरान संस्थान की राजभाषा पत्रिका मरु बागवाणी को भाकृअनुप, नई दिल्ली द्वारा गणेश शंकर विद्यार्थी हिन्दी कृषि पत्रिका पुरस्कार का प्रथम पुरस्कार प्रदान किया गया।
  2. वर्ष 2007–08, 2009–10 एवं 2011–12 के दौरान नगर राजभाषा कार्यान्वयन समिति, बीकानेर द्वारा हिन्दी की प्रगति में उत्कृष्ट कार्य करने के लिये प्रशस्ति पत्र प्रदान किया गया।
  3. वर्ष 2014–15 के दौरान नगर राजभाषा कार्यान्वयन समिति, बीकानेर द्वारा हिन्दी की प्रगति में उत्कृष्ट कार्य करने के लिये 'नगर राजभाषा शील्ड' प्रदान किया गया।

FUTURE THRUST AREAS

1. **Genetic Resource Management:** There is need to collect, characterize and evaluate the natural biodiversity available in this region and develop a strong gene bank on which the country can depend for its future needs.
2. **Genetic Improvement:** There is a need to transfer the genes from available gene pool into standard cultivars for resistance against biotic and abiotic stresses and other quality characters.
3. **Improving Production and Productivity of Arid Horticultural Crops:** The productivity and production of arid horticultural crops in India is very low compared to many advanced countries. Hence there is an urgent need of technological interventions for increasing production and productivity.
4. **Exploitation of Biotechnology in Arid Horticultural Crops:** Use of molecular markers for gene tagging, transfer of genes from wild taxa, development of transgenes resistant to the biotic and abiotic stresses, micropropagation, etc. are the potential areas. Biotechnological interventions for mass multiplication and gene transfer, identification and sequencing of genes are required to be generated on which the country will rely on for resolving its problems for food security.
5. **Basic and Strategic Research:** To provide a strong information base to develop appropriate technologies, the basic research is utmost important. Since arid ecosystem has its unique

problems, basic aspects on biotic and abiotic stress tolerance mechanisms, seed and plant vigour, canopy architecture, etc. need to be investigated.

6. **Hi-Tech Crop Production:**
    - Hi-tech nursery raising for production of quality planting materials.
    - Protected cultivation of high value crops for off-season production.
    - Efficient use of water and nutrients through drip/sprinkler irrigation and fertigation and use of organic/degradable biomass for mulching. This will stabilize the soil temperature, economize irrigation water, retain moisture and minimize weed growth and subsequently provide higher quality produce.
    - Promotion of precision farming for maximizing input use efficiency to get higher produce.
7. **Off-season Crop Production:** Off-season production of horticultural crops particularly vegetables need to be promoted to enhance the availability of quality produce throughout the year and maximize the use of natural resources for growing crops out of the normal season.
8. **Crop Diversification:** There is great necessity to develop agro-techniques for sustainable cropping systems, integrated pests and disease management so that these lands can be fruitfully utilized for production of fruits and vegetables for domestic and export purpose.
9. **Resource Management:** Efforts are required to develop integrated approach for water harvesting, substrate management, nutrient management and cropping models, which can make best use of these strengths and convert them in to the biomass for consumption.
10. **Organic Farming:** There is a need for conducting research on the efficient use of organic inputs. Standardization of norms for certification of organic products and deciding the certification agency must be addressed immediately.
11. **Plant Protection:** Integrated management strategies are required for the management of major pests and diseases in arid and semi-arid horticultural crops. Use of chemicals should be minimized and emphasis on bioagents, botanicals, exploitation of inherently resistant genotypes in breeding and development of new varieties would be in priority. Post-harvest management of major pests and diseases using chemicals and residues analysis in harvested produce are also required.
12. **Transfer of Technologies**: Institute has developed various innovations in arid horticultural technologies which have to be transferred to farmers field with modern tools through training and field demonstrations.
13. **Human Resource Development:** For achieving the higher productivity, trained manpower in various facets of horticulture production system and post- harvest management is definitely required. For this, the staff of the Institute will be encouraged to participate in national/ international training programmes, seminar, symposium and workshops.
14. **Post-Harvest Management:** All efforts are required to minimize post-harvest losses by developing appropriate technology. In addition to this, dehydration of produce can be undertaken since area has high solar radiation and low humidity coupled with low incidence of diseases and pests. Varieties suitable for processing must be developed.

Tomato: Heat tolerant line

Long melon crop after removal of tunnel

Low tunnel cultivation of vegetables

Kachri: An under utilized arid vegetable

Mulching Technology

Datepalm in desert

High Density plantation of Aonla

Cucurbit: Blooming in desert


C I A H