CIAH Perspective Plan

VISION-2025

भाकृअनुप
ICAR

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

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FOREWORD

Indian agriculture must continuously evolve to remain ever responsive to manage the change and to meet the growing and diversified needs of different stakeholders in the entire production to consumption chain. In order to capitalize on the opportunities and to convert weaknesses into opportunities, we at the ICAR attempted to visualize an alternate agricultural scenario from present to twenty years hence. In this endeavour, an in-depth analysis of the strengths, weaknesses, opportunities and threats (SWOT) was undertaken to place our research and technology development efforts in perspective so that we succeed in our pursuit of doing better than the best. Accordingly, the researchable issues are identified, strategies drawn and programme indicated to have commensurate projects and relevant activities coinciding with the launch of the 11th Five Year Plan.

Central Institute for Arid Horticulture, Bikaner has identified the researchable issues and suggested strategies of research programme with major emphasis on genetic improvement for production, quality and drought and heat tolerance through conventional breeding methods and application of bio-technology and undertaking studies on physiological adaptation mechanisms in fruit, vegetable, medicinal and ornamental crops. It has given emphasis on developing cost-effective technologies in crop production and crop protection including IPM and biological control for powdery mildew in *ber*, leaf and fruit spot disease, fruit fly and fruit cracking in pomegranate and control measures for fruit cracking in *bael* and frost injury in *aonla.* In post-harvest management, emphasis has been given to standardize technologies for proper handling, standardization of maturity standards and development of processing technologies and product diversification. The suitable national and international linkages have been suggested for exchange of scientific information and genetic material.

It is expected that realizing the Vision embodied in the document would further ensure that the CIAH, Bikaner continues to fulfil its mandate to make Indian agriculture locally, regionally and globally competitive. The efforts and valuable inputs provided by my colleagues at the ICAR Headquarters and by the Director and his team at the Institute level for over an year to develop Vision 2025 deserve appreciation.

(Mangala Rai)
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and
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PREFACE

In recent years, the Horticulture Sector is emerging as one of the prime sector in agriculture since this has the potentiality to provide nutrition, income, employment and social security to the inhabitants of rural and urban areas. It contributes to the tune of 28% of the GDP from about 13% of area and 37% of the total export commodities in the country. Despite the fact that India is the second largest producer of fruits and vegetables in the world, the per capita availability of fruits and vegetable is very low which is due to low productivity. The situation is expected to decline further since it is predicted that the population will take a quantum jump and will reach 1500 million by the end of 2025. This calls for research preparedness to produce higher quantity fruits and vegetable so that the demand can be fulfilled. Since, the land available for agriculture is shrinking due to increase in population pressure, attempts are being made to select non-traditional areas for commercial cultivation of fruits and vegetables. In this pursuit, arid ecosystem which is marked by its unique strengths and weaknesses, has qualified to be an ideal site which can be developed into horticultural bowl.

Realizing the potential of horticultural productivity of arid zones, the compatibility of these crops to the arid zone ecosystem and the need to achieve nutrition and income security for the people, The Indian Planning Commission approved establishment of National Research Center for Arid Horticulture (NRCAH) during VII Five Year Plan. As a result of this the NRCAH came into existence in April, 1993. This was later upgraded to Central Institute for Arid Horticulture w.e.f. September, 2000. Since, the inception of NRCAH now CIAH, Bikaner, the Institute has contributed substantially on all fronts. It has released a total of 16 varieties of arid fruits and vegetables, standardized protocols for micro-propagation and vegetative propagation of arid fruits, developed agro-techniques for production of quality planting material and produce and made a wide variety of value added products for better utilization and avoid market gluts of horticultural produce. The Institute has recommended four multistrata cropping models for arid ecosystem that will provide sustainable income to the framers.

With the introduction of GATT, the global scenario of agriculture and particularly of Horticulture has changed with more emphasis on quality production and market demand. Thus, there is a need to undertake SWOT analysis with greater emphasis on market intelligence to develop appropriate strategies to complete in global market. In view of above, the Perspective Plan of the Institute in Vision-2025 an attempt has been made to quantify the strengths, weakness, opportunities and threats in Arid Horticulture which Institute may face in years to come and accordingly identified the major areas of research to be addressed to remain competitive in the market.

Dr. Mangala Rai, Secreatray , DARE and Director General, ICAR took very keen interest and is providing the much need guidance in development of vision document and in bringing it out in its present form. I convey my gratefulness to him. I am also thankful to Dr. H. P. Singh, present D.D.G. (Horticulture) and Dr. G. Kaloo, Former D.D.G. (Horticulture) for providing the guidance in development of Vision-2025 document.

(T. A. More)
Director

EXECUTIVE SUMMARY

To achieve nutrition and income security for the people of arid and semi-arid regions, suitable horticultural production technology is of vital importance. Although, the Indian Council of Agricultural Research (ICAR) started multi location collaborative research in 1976, but the major initiative on this aspect was taken in 1993 with the establishment of National Research Centre for Arid Horticulture (NRCAH) at Bikaner, which was upgraded as full-fledged "Central Institute for Arid Horticulture, Bikaner on 27th September, 2000. This strategic plan for arid zone horticultural research updates the ongoing programme under the CIAH, which is a part of the ICAR system under the Department of Agriculture Research and Education (DARE). The Institute has the following mandate:

1. To undertake basic and strategic studies for developing technologies to enhance productivity and utilization of arid horticultural crops.
2. To act as national gene bank of arid horticultural crops.
3. To develop the multistorey horticulture based sustainable cropping system under arid environment.
4. To act as national repository of scientific information related to arid horticulture.
5. To coordinate network research with State Agriculture Universities and line departments and act as centre for Human Resource Development in arid horticulture.
6. To provide consultancy in research and development of arid horticulture.

To achieve this, the following objectives have been identified:

- To introduce, collect, characterize, conserve and evaluate the biodiversity of horticultural crops under arid and semi arid environments.
- To utilize the available biodiversity and improve the target fruit crops such as *ber*, pomegranate, *aonla*, date palm, sapota, custard apple, tamarind, fig and cucurbitaceous, leguminous and solanaceous vegetables to develop high quality and productive types having tolerance to biotic and abiotic stresses.
- To study the factors related to rapid multiplication of propagules in case of established as well as new crops and the problems related to their growth and fruit development.
- To standardize agro techniques with respect to efficient use of soil, water and nutrients for increased horticultural productivity involving water harvesting and conservation techniques under rainfed conditions, efficient use of the scarce irrigation water and nutrient management.
- To study the eco-physiological parameters of cropping system models for utilization of high temperature and radiation resources.

- To develop post harvest technology package for extended use of the horticultural produce of arid region.
- To develop integrated pest and disease management technologies for horticultural crops under arid environment.
- To transfer the innovative technologies generated on the above aspects to farmer's fields for effective horticultural development and socio-economic upliftment of the farmers.
- To carry out the impact assessment of the technologies & constraints analysis.
- To serve as a repository of information related to arid and semi arid horticulture.
- To collaborate with relevant national and international agencies for achieving the above.

The programme will be built on the basis of multidisciplinary projects comprising a series of activities. The developed technologies will be tested at relevant locations under the instrument of an All India Coordinated Research Project already in operation under the CIAH. Linkages to augment and strengthen execution of the programme will be maintained with several national and international organizations and developmental agencies.

The present provision of professional staff of 129 needs to be raised up to 140 during X Plan and in XI Plan 200. In XII Plan 350 and by 2025, institute will require about 500 professional staff to support the expanded activities. Accordingly, the budgetary requirements needs to be raised from Rs. 1180 lakhs at the present level to Rs. 12000 lakhs by XIIIth Five Year Plan. Efforts will be made to generate internal resources to met part of the funding. Activities such as human resources development for research and development activities will also need to be strengthened.

1. PREAMBLE

To conduct mission oriented research for improvement of horticultural crops and development of horticulture based cropping system under arid environment and to act as a repository of information related to arid horticulture, the National Research Centre for Arid Horticulture (NRCAH) was established at Bikaner, which became functional in April, 1993. Considering the peculiar agro-climatic conditions of arid region, the large number of horticultural crops and a wide range of disciplines that are involved to develop usable technologies for horticultural sustenance in the region, holistic approach could not be taken under the limited mandate of NRCAH. Therefore, the working Group on Agricultural Research and Education for formulation of IXth Five Year Plan of ICAR/DARE, Ministry of Agriculture, proposed up gradation of NRCAH to a level of an Institute. Thus, on the recommendation of a High Power Committee and with the concurrence of Planning Commission, Govt. of India, the NRC for Arid Horticulture was upgraded into an Institute namely Central Institute for Arid Horticulture w.e.f. 27.09.2000, so as to broaden its mandate from the present mission oriented research to inclusion of research on holistic basis incorporating work on potentially economic crops of arid region. Further, to consolidate the research in the region the Central Horticultural Experiment Station, Godhra (earlier functioning under the administrative control of IIHR, Bangalore) was also merged with CIAH w.e.f. 01.10.2000.

Further, the Council had approved the establishment of a new Research Centre for Pomegranate (NRC for Pomegranate) in Maharashtra State, in the IX Five Year Plan period, so as to conduct mission mode basic and strategic research for increasing productivity and profitability of pomegranate and its utilization by breeding superior varieties, developing better production technology and solving biotic and abiotic stresses. However, as decided by the Planning Commission, Govt. of India, the Council has decided to setup a Regional Research Station of CIAH in Maharashtra State and finally the Regional Research Station was upgraded as NRC on Pomegranate, Solapur during Xth Five Year Plan, which will provide better research output on pomegranate production.

2. MANDATE

Considering the upgradation of organization from NRC to Institute, it is most essential to enlarge the mandate of the Institute. The proposed mandate for R & D activities of the Institute will be as follows:

1. To undertake basic, applied and strategic studies for developing technologies to enhance productivity and utilization of arid horticultural crops.
2. To act as national gene bank of arid horticultural crops.
3. To develop the multistorey horticulture based sustainable cropping systems under arid environment.
4. To act as national repository of scientific information related to arid horticulture.
5. To coordinate network research with State Agriculture Universities and line departments and act as centre for Human Resource Development in arid horticulture.
6. To provide consultancy in research and development of arid horticulture.

3. GROWTH

3.1 INFRASTRUCTURE

3.1.1 RESEARCH SET UP

A. Divisions

A.1. Crop Improvement

Fruit Breeding: This unit is to work on genetic improvement through selection and hybridization in selected crops like ber, pomegranate, aonla, tamarind, anona etc. with a view to produce quality fruits to impart resistance to biotic and abiotic stresses. This laboratory will also work on improvement of indigenous and under-exploited fruit crops through collaboration with relevant Institutions.

Vegetable Breeding: The unit is to work on genetic improvement of vegetable crops of cucurbitaceous, some legumenions crops such as khejri and beans and some solanaceous crops like chilli and brinjal. Besides this, the laboratory will also work on development of biotic and abiotic tolerant varieties of arid and semi-arid vegetables.

Biotechnology: This unit will work on tissue culture with major emphasis on micro-propagation and genetic engineering for improvement of arid and semi arid horticultural crops. The regeneration protocols for development of transgenic plants in horticultural crops will also be developed.

Genetic Conservation: This unit will work on conservation of genetic resources of horticultural crops *in vitro* and in field gene banks. For medium and long-term conservation of genetic resources, cryo preservation facilities will be developed at this centre.

A. 2. Crop Production

Fruit Culture: This unit is to work on agro-techniques such as propagation, planting systems, canopy management, fruit growth and development, crop diversification, protected cultivation, tissue sampling techniques, organic cultivation, soil culture fertigation, weed management in perennial crops, etc.

Vegetable Culture: This unit is to work on nursery techniques, planting systems, crop rotations, inter culture, off-season production, role of plant growth regulators, seed production, organic cultivation, water management through micro-irrigation system, protected cultivation etc.

A.3. Post Harvest Management

Studies on post harvest techniques to improve storage life of arid and semi arid horticultural crops, post harvest handling and development of valued added products from horticultural crops.

A.4. Crop Protection

Plant Pathology: This laboratory will work on basic and applied research on integrated disease management of commercial arid and semi-arid fruit and vegetable crops.

Entomology: This laboratory will work on development of biological control of major for economically important pests of arid and semi-arid fruit and vegetable crops.

Plant Virology: This laboratory work on assessment of loss due to virus and their management through different techniques.

Nematology: This unit will work on development of integrated control measures of diseases caused by nematodes in fruit and vegetable crops of arid and semi-arid regions.

A. 5. Natural Resource Management

Soil and Water Conservation: This unit is to work on soil and water conservation measures through rainwater harvesting (*in-situ*), water harvesting through micro-irrigation systems (*ex-situ*) and wind erosion management.

Soil and Plant Nutrition: This unit is to work on integrated nutrient management including fertigation and organic cultivation.

Stress Physiology: This laboratory is to work on adaptations to stress caused by drought, cold, heat and salt.

A. 6. Extension and Social Sciences

The division will consist of the disciplines of Extension, Economics, Computers and Statistics. The division will work on project planning, data processing, constraint analysis, transfer of technology, impact assessment, technology assessment and refinement, capacity building, creating job opportunities and socio-economic up liftment by providing technical knowledge and skills to the farmers, rural masses and development at agencies particularly in the field.

B. Centralized units

Technical Cell

The Cell will coordinate the research activities, documentation of research achievements, coordination and linkage of research and education with other organizations.

Farm

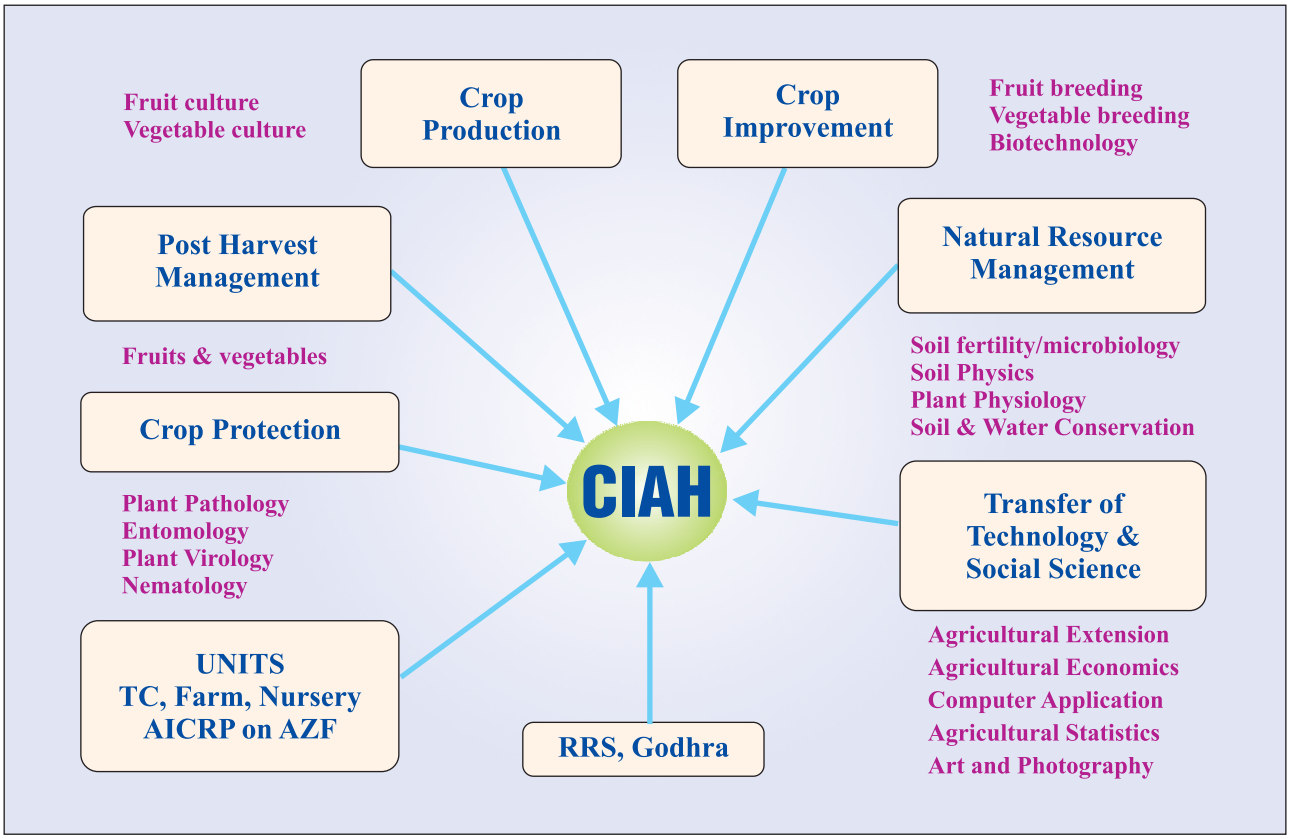
The Institute has an experimental farm of about 125 ha. The farm has canal irrigation facility for more than 50 ha area. To ensure regular water supply, two open water reservoirs and a covered water storage structure are available. Facility of two tube wells to ensure water supply to the laboratories, residential quarters and the research blocks during erratic water supply of the lift canal has been developed. There will be a well equipped high-tech modern nurseries to provide the required amount of quality planting material to the farmers and additional water resources to develop the cultivation in remaining uncultivated area. The Institute will also strengthen the same facilities at CHES, Godhra, Gujarat to cater the need of the farming community of the semi-arid region. Efforts will also be made to establish the water saving devices like sprinkler, micro-sprinkler, drip and rain guns, etc in all research farms.

Informatics Cell

The Institute has developed library with CD ROM facility for providing latest information on research, education and extension in the field of horticulture. An Agriculture Research Information System (ARIS) Cell with latest computer systems, an Internet, e-mail, LAN and LCD facility is also developed. The library subscribes national and international journals and has a collection of a large number of reference books.

C. AICRP on AZF Coordinating Cell

Under the AP Cess Fund Scheme entitled, "Research on some selected fruits in the semi-arid areas in India" was initiated as an *ad hoc* project in 1976 at 10 centres in the country, viz. Abohar (PAU), Jodhpur (CAZRI), Chandan Well near Jaisalmer (Govt. of Rajasthan), Hisar (HAU), Khedoi (GAU) now at Mundra, Rahuri (MPKV), Yercaud (TNAU), Lahaul (HPKVV), Bangalore (IIHR) and Udaipur (RAU). During the VI Five Year Plan, this *ad hoc* scheme was merged as such and samed as Cell-III of the AICFIP. During the VII Five year Plan, Cell III of the AICFIP was restructured to form an independent project entitled "All India Coordinated Research Project on Arid Zone Fruits (AICRP-AZF)". The center of Chandan Well was shifted to Bikaner under the Rajasthan Agricultural University in 1983. The center Yercaud was shifted to Aruppukottai (TNAU) w.e.f. 01.04.1983 and from Udaipur



Proposed setup of CIAH, Bikaner

to Jobner w.e.f. 24.09.1982. Two centers, one at anantapur (APAU) and the other at Dantiwada (GAU), were established w.e.f. 15.03.1983. The center in Lahual (HPKVV) was closed w.e.f. 1.3.1986 and two new centers were established w.e.f. 1.3.1986 at Faizabad (NDUAT) and w.e.f. 1.3.1987 at Bhojka (RAU) Bhojka Centre was closed w.e.f. 1.4.1993. At present, there are 13 centres functioning under the SAUs and ICAR Institutes.

3.1.2 BUILDINGS AND OTHER INFRASTRUCTURES

CIAH, Bikaner

The CIAH has double storey Lab-cum-Office building covering a floor area of about 3,500 m^2. A farm laboratory and farm sheds covering a floor area of 600 m^2 have also been constructed, besides two security guard rooms, one at the gate and other in the heart of the farm complex. One Bank extension counter, Sale counter, Sheds/parking for vehicles, Electricity powerhouse rooms are also available. Residential quarters (Type I-5; Type II-2; Type III-4, Type IV-4, Type V-1), labour rest house, central store, high-tech glass houses have been provided.

CHES, Vejalpur (Godhra), Gujarat

A master Plan of the campus has been developed and modern office cum laboratories building has been constructed which includes fruit culture, vegetable culture, plant pathology, entomology, soil science, soil and water conservation engineering and plant physiology laboratories and administrative wing. A field laboratory has also been constructed in Block III. Besides these, some residential quarters, Plant propagation unit, one polyhouse, two greenhouses and one net house have been constructed to facilitate the plant propagation under different schemes. Three check dams; five open wells have been constructed for water harvesting.

3.2 BUDGET

The budget provisions on arid horticultural research started towards the end of V Plan, which grew considerably from VII Plan onwards as a result of an independent, All India Coordinated Research Project on Arid Fruits followed by establishment of the National Research Centre for Arid Horticulture at Bikaner.

Details of budget of Institute and AICRP on AZF

Plan	Period	NRCAH/CIAH* (Rs in Lakh)	AICRP(AZF) (Rs in lakhs)	Total (Rs in lakhs)
Annual Plan	1978–1980	–	11.02	11.02
VI Five Year Plan	1980–1985	–	63.52	63.52
VII Five Year Plan	1985–1990	–	124.64	124.64
Annual Plan	1990–1992	15.00	89.89	104.89
VIII Five Year Plan	1992–1997	350.00	225.00	575.00
IX Five Year Plan*	1997–2002	1,021.68	438.65	1,460.33
X Five Year Plan	2002–2007	1,180.00	547.00	1,727.00

*NRCAH upgraded to CIAH with merger of CHES, Godhra

3.3 MANPOWER

The manpower provision for arid horticultural research increased from 52 in 1978 to 158 in 1992 and subsequently 224 in Xth Five Year Plan.

Details of manpower enrolled in Institute and AICRP on AZF

Plan	Period	NRCAH/CIAH	AICRP(AZF)	Total
Annual Plan	1978–1980	–	52	52
VI Five Year Plan	1980–1985	–	88	88
VII Five Year Plan	1985–1990	–	103	103
Annual Plan	1990–1992	08	103	111
VIII Five Year Plan	1992–1997	55	103	158
IX Five Year Plan*	1997–2002	129	95	224
X Five Year Plan	2002–2007	129	95	224

*NRCAH upgraded to CIAH with merger of CHES, Godhra

4. SALIENT RESEARCH ACHIEVEMENTS

4.1 GERMPLASM CONSERVATION

Under National Field Repository of CIAH, Bikaner following germplasms are maintained after massive survey and collection of arid fruits and vegetables:

Details of germplasm maintained at Institute

Fruit Crops			Vegetable Crops		
Name	**Scientic name**	**Access. No.**	**Name**	**Scientic name**	**Access. No.**
Ber	(*Ziziphus mauritiana*)	318	Kachri	*Cucumis melo* var. callosus	75
Bordi	(*Z. rotundifolia*)	22	Mateera	*Citrullus lanatus*	65
Pomegranate	*Punica granatum*	150	Snap melon	*Cucumis melo* var. *momordica*	65
Aonla	*Emblica officinalis*	50	Chilli	*Capsicum* spp.	45
Date palm	*Phoenix dactylifera*	55	Musk melon	*Cucumis melo*	60
Gonda	*Cordia myxa*	65	Gourds		45
Bael	*Aegle marmelos*	16	Beans		40
Cactus pear	*Opuntia ficus indica*	80	Brinjal	*Solanum melonganum*	30
			Khejri	*Prosopus cineraria*	
			Indian aloe	*Aloe barbedensis*	02

In addition to above, rich germplasm of sapota, pomegranate, ber, mango, custard apple, aonla, jamun, chiraungi, mahua, moringa, tamarind, etc. are being maintained and evaluated at CHES, Vejalpur, Godhra.

4.2 GERMPLASM EVALUATION

Among 318 ber (*Ziziphus mauritiana*) genotypes, the ber varieties Gola, Seb, Umran, Kaithli and Banarasi Karaka are performing well under hot arid climate. Out of 150 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 the better genotypes from yield and quality point of views. The varietal evaluation of aonla (*Emblica officinalis*) revealed that the NA-7 is a prolific bearer (51 kg/tree) followed by Chakaiya (34 kg/tree) and NA-6 (28 kg/tree). Among 9 bael (*Aegle marmelos*) genotypes, NB-5 and NB-9 are performing well under irrigated hot arid ecosystem. A five-year old budded plant of NB-5 yields about 40 fruits/tree while NB-9 yields about 29 fruits/tree. The fruit size of NB-5 is smaller (1.0 kg/fruit) than NB-9 (1.4 kg/fruit). The fruit quality is excellent in both the varieties.

Varietal performance studies carried out at the CHES, Godhra revealed that varieties, viz. NA-7 of aonla, Umran and gola of Ber, Ganesh of pomegranate, Kesar and Rajapuri of mango and Kalipatti of sapota were to be found most suitable for commercial cultivation.

Realizing the importance of vegetable crops particularly under exploited and less popular, and having commercial production potentials in arid and semi arid regions, systematic research work on germplasm collection, conservation and utilization was started since 1994 at CIAH, Bikaner, In this direction, intensive crop specific surveys in target variability pockets and explorations were undertaken in arid and semi arid regions and a large number of land races, semi-cultivated and popular types of mateera, *kachri,* snapmelon, beans and some perennial horticultural species of vegetable potentials were made over the years for systematic evaluation, characterization and conservation of indigenous germplasm.

4.3 IMPROVEMENT

Fruit crops

Ber (*Ziziphus mauritiana* Lamk)

(a) Goma Kirti: Goma Kirti is highly yielding early maturing variety, which fetches good price in the market. It is resistant to various diseases and pests by virtue of its earliness.

(b) Thar Sevika: Hybrid (Seb × Katha) is precocious and prolific bearer and early in fruit maturity (first week of January). Tree size is medium with spreading growth habit, foliage is dark green and dense. Petiole length is 1.2 cm and thickness is about 0.23 cm. Fruit size is 4.3 × 3.2 cm, yellowish green in colour, average fruit weight is 26 g and flesh thickness is 1.1 to 1.2 cm, TSS is about 25.3 °Brix, fruit are juicy. The incidence of fruit rot is only 1.5 to 3.3%.

Ber Thar Sevika

Thar Bhubhraj

(c) Thar Bhubhraj: Tree size is medium with upright growth habit. Foliage is green with medium density. Petiole length is 1.2 cm with the thickness of 0.2 cm. Average fruit weight is 25 g, yellow in colour, TSS is about 24 °Brix with excellent taste. It is resistant to fruit rot.

Aonla (*Emblica officinalis*)

Goma Aishwariya: A selection from plus tree, Goma Aishwariya is an early, drought tolerant. The average yield potential is 102.9 kg/tree. It has low fiber content and is suitable for processing and export.

Goma Aishwariya

Vegetable crops

Systematic production of vegetable crops is rare in the hot arid regions mainly because of lack of suitable varieties for the cultivation under prevailing agro-climate. Realizing the importance of arid cucurbits, non-availability of standard varieties for commercial cultivation and also to supply uniform and good quality produce in the market, systematic research efforts were started at this Institute from 1994. After evaluation of large number of collections of mateera (*Citrullus lanatus*), *kachri* (*Cucumis melo*), snap melon or *phoot* (*Cucumis melo* var. *momordica*) and *salad kakdi* (*Cucumis* spp.), two varieties each of these cucurbitaceous vegetables were released at Institute level in 1998, which have excellent yield potential under hot arid conditions and are recommended for the cultivation in Rajasthan. Important characteristics of newly released varieties of cucurbitaceous vegetables at CIAH, Bikaner are given here under.

As a result of systematic purification followed by selection and hybridization work at CIAH, Bikaner, some high yielding and high quality genotypes have been developed and recommended for commercial cultivation in arid vegetables. The promising varieties/selections are in mateera (AHW 19, AHW 65 and F_6/a), *kachri* (AHK 119 and AHK 200), snapmelon (AHS 10 and AHS 82), *kakdi* (AHC 2 and AHC 13), bottle gourd (AHLS Round 1 and AHLS Long 1), round melon (AHRM 1), cluster bean (AHG 13), Indian bean (AHDB 3 and AHDB 16) and sword bean (AHSB 1) (Pareek and Samadia, 2002 and Samadia, 2004). Besides, intensive research and development work for the commercialization of under utilized horticultural species such as khejri, *kair, lasora, shejana, guarpatta, phog,* etc. have been undertaken by identifiying superior genotypes, developing agro-techniques for the systematic orchards establishments and also by value addition for the product diversification.

Mateera (*Citrullus lanatus*)

Mateera is one of the most important rainy and summer season cucurbitaceous vegetables in the hot arid ecosystem where it appears to have acquired the drought hardy characteristic. The ripe fruits are predominantly eaten as a dessert while immature small green fruit (l*oyia*, 80-100 g weight) are used as vegetable. Till recently, there was no standard variety of mateera available to obtain uniform and good quality fruits on commercial scale.

(a) AHW19: It is a medium-early maturing (75–80 days after sowing) variety developed through selection from the local land races found in arid region. Vine produces 3.0–3.5 fruits. The flesh is dark pink, solid (firm) with good eating quality and taste having 8 to 8.4% TSS. The variety gives heavy yields (460–500 q/ha) and tolerates high temperature.

Mateera AHW 19

(b) AHW 65: It is a very early maturing (72 days after sowing) variety developed by selection from local germplasm and is suitable for dessert and vegetable purpose. Harvesting of tender fruits (100 g weight) is recommended for use as vegetable. Yields 3–4 mature fruits per vine and 375–400 q/ha. The flesh is delicious, pink, solid (firm) having 8–8.5% TSS.

Mateera AHW 65

(c) Thar Manak: For fruit quality improvement in drought hardy mateera (watermelon), intensive breeding work was taken at CIAH, Bikaner, and resulting to this a new high yielding and better quality variety named as Thar Manak has been released in 2007 for the cultivation in arid region. It is very early for first marketable harvesting (75–80 DAS). The yield potential is 50–80 tonnes/ha under arid conditions.

Bottle gourd (*Lagenaria scieraria*)

Thar Samridhi: It is exhibited 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.

Khejri (*Prosopis cineraria*)

Thar Shobha: In khejri (*Prosopis cineraria*), the first high yielding and better quality variety Thar Shobha has been recommended for uniform tender pod harvesting for vegetable use. A five year grafted khejri plant yields a harvest of about 4.25 kg tender pods (*sangri*) and 6,027 kg fodder (*loong*) per year.

Kachri (*Cucumis melo*)

Kachri, is a very drought hardy cucurbitaceous vegetable, found growing in the arid region during rainy season. The mature fruit are usually cooked with various vegetable preparations, *chutney,* pickles and is also used for garnishing the vegetables or as *salad. Kachri* is one of the components of the delicious vegetable popularly known as *Panchkuta* in the desert districts of north-western India.

(a) AHK 119: The fruits are suitable for dehydration. The fruits are small, egg shaped weighing 50–60 g Harvesting begins 68–70 days after sowing and continues up to 110–120 days. On an average, 22 fruits are borne per vine giving an yield of 95–100 q/ha.

***Kachri* AHK 119**

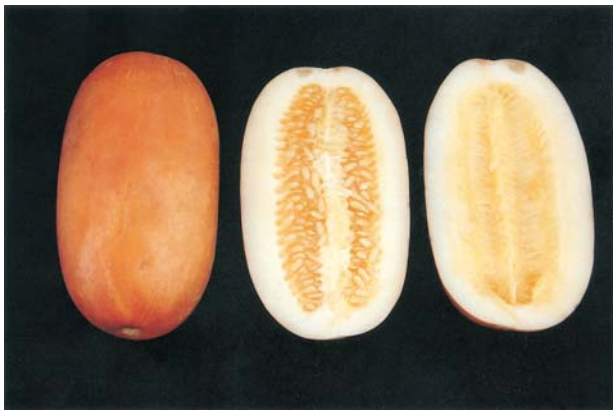
(b) AHK 200: The fruits are suitable for garnishing the vegetables and *salads.* The fruits are 100–120 g in weight. Fruits become ready for harvest in 65–67 days after sowing and harvesting continues upto 90–100 days. On an average, 20 fruits can be harvested from a vine giving a yield of 115–120 q/ha.

***Kachri* AHK 200**

Snap melon (*Cucumis melo* var. *momordica*)

Snap melon is a very common cucurbitaceous vegetable in the arid region. Its unripe fruits are used as vegetable and to prepare *rayta.* Ripe fruits are used as dessert fruit or as *salad*. Snap melon is cultivated mixed as well as self-sown with other rainfed crops in arid region during rainy season. It can also be cultivated in summer season.

(a) AHS 10: Fruits can be harvested 68 days after sowing. The fruit are oblong and medium in size (900 g weight). The flesh is whitish pink, sweet in taste having 4.5–5.0% TSS. The vine bears 4.0–4.5 fruits giving an yield of 225–230 q/ha under arid conditions.



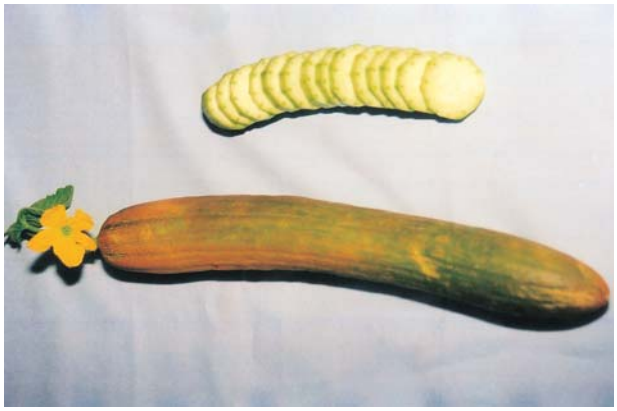
Snap melon ASH 10

(b) AHS 82: Fruit harvest starts 67–70 days after sowing and continues upto 110–115 days. Each vine bears 4.5–5.0 fruits giving a yield of 245–250 q/ha. The Fruits are 925 g in weight. The light pink flesh is very sweet and tasty having 4.3–4.9% TSS.

Snap melon AHS 82

Kakdi (*Cucumis melo* spp.)

Out of the six *Cucumis* species found in India, *C. sativus* and *C. melo* are widely cultivated. North- western arid part of Rajasthan is rich in the land races of *C. melo* var. *momordica* and *C.* melo. As a result of natural crossing among different species of *Cucumis*, several new forms have stabilized which are quite different from the traditional forms. Some of the natural combinations of *Cucumis* species resemble cucumber or long melon and are commonly used for salad purpose and are thus called *salad kakdi.* Besides *salad,* the tender fruits can be used for garnishing the vegetables. The unripe mature fruits are cooked as vegetable.



***Kakdi* AHC 2**

(a) AHC 2: It is a very early maturing variety 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 275–300 g are suitable for slicing when their length is 30–35 cm and diameter is 3.0–3.5 cm. The flesh is crisp textured, solid and 1.4–1.5 cm thick. About 12–15 tender fruits can be harvested giving a yield of 4 kg per vine and 175–202 q/ha under arid situations.

(b) AHC 13: It is a 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

***Kakdi* AHC 13**

harvesting continues upto 95–110 days. Continuous picking results in higher yield. About 20–25 fruits are borne per vine. The tender fruits weighing 75–100 g are harvested when the length is 5.5–7.0 cm and diameters are 4.4–5.0 cm. The flesh is crispy and tasty which is about 1.0 cm in thickness. On an average 2.15 kg tender fruits can be harvested per vine giving a yield of 85–125 q/ha. The variety also has high heat tolerance.

Goma Manjiri

Cluster bean (*Cyamopsis tetragonoloba*)

Goma Manjiri: Plants are erect, single stemmed, non-branching, bearing from base in cluster upto 35 with 8 to 10 pods per cluster, yielding 88 to 103 q/ha, photo insensitive, crop period 75 to 80 days, tolerant to drought.

4.4 CROP PRODUCTION

In order to optimize the production of arid horticultural crops, some agro-techniques have been standardized/refined for hot arid ecosystem which are as under:

(i) Standardization of plant propagation in arid fruits


Ber root stocks

Aonla: Patch budding in aonla during middle of July had given >90% success under irrigated arid ecosystem. The seeds sown in perforated polybags (40 ×15 cm) in February were ready for budding in July, hence about 6 month time can be saved against conventional method (budding on one year old root stock). It was also observed that the girth of rootstock matrix should be more than 0.5 cm at the time budding for better success.

Ker: In case of ker (*Capparis decidua*), about 50% success was obtained when cuttings were treated with 7,000 ppm IBA + 1,000 ppm Thymine in the month of September under shade net house.

Lasora: The lasoda (*Cordia myxa*) can be successfully propagated through budding in middle of August (95.59%), though it can be propagated starting from middle of July to end of August with about 80% success.

Tamarind: Patch budding in tamarind during third week of July and first fortnight of August has been standardized with more than 75% success and 70% survival under arid environment.

Pruning timing in ber under hot arid eco-system of Rajasthan had been standardized with the recommendation that pruning during second week of April with 50% intensity gives maximum fruit yield.

(ii) Crop diversification

Crop diversification studies in ber (*Ziziphus mauritiana*) and aonla (*Embica officinalis*) based cropping studies led to the recommendations that in pre-establishment phase of ber orchard, Indian aloe (*Aloe barbedensis*) and cluster bean *(Cyamopsis tetragonoloba- Brassica campestris*) are the low input and high returning crops giving net returns of Rs 65, 802 and Rs 26,144/ha. While in aonla based multi storey cropping system, moth bean (*Phaseolus accontifoilus*) and brinjal (*Solanum melongena*) were identified as potential crops giving an average net returns of Rs 850 and Rs 26,144/ha.

(iii) Micro-site improvement

To establish orchard in sandy soils of arid region, the pit size of 60 cm^3 filled with topsoil, manure and pond silt in equal ratio is recommended for better establishment and growth of pomegranate plants.

(iv) Allelopathic studies

In a preliminary investigation, the allelopathic influence of ber leaf aqueous extracts was studied on four test crops, viz. ground nut, cluster bean, wheat and mustard under laboratory conditions. Among different groundstorey crops, the water soluble allelochemicals of ber leaf extracts had maximum inhibitory effect on mustard and minimum on cluster bean with respect to germination, seedling vigour and seedling phytomass while other crops showed variable response exhibiting sensitivity in one character and tolerance in another.

Based on allelopathic studies, moth bean has been recommended as a suitable intercrop with aonla because the water soluble allelo chemicals of aonla have minimum inhibitory effect on mothbean with respect of seedling germination, seedling vigour and seedling phytomass.

(v) Agro techniques for arid vegetables

As a result of germplasm utilization and improvement programme in horticultural crops in India, a large number of high yielding selections, varieties and hybrids suited to different agro climatic conditions have been developed and recommended under national and regional net work. In recent past at CIAH, Bikaner, a large number genotypes in commercially potential and under-exploited crops have been evaluated and suitable selections, varieties or lines have been developed and recommended for the resource based crop cultivation under arid conditions. These improved cultivars are also increase the productivity of high quality produce if used in the traditional systems of 'Bari cultivation' and mixed cropping. The agro-techniques developed or improved for maximizing higher 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.

Sowing techniques for arid zone cucurbits: In the trials conducted at CIAH, Bikaner, cultivation in channel system was found to be most practicable as it saves losses of both water and nutrients, and helps in better care of young seedlings and ease in cultural operations such as plant protection sprays and weed management. This system also reduces pre-harves losses of fruits by restricting the water flow only in the channels. The vine spread area remains kept dry. During rainy days, it is observed that in the channel or furrow of 60–75 cm width water collection within the channel or furrow and in nearby area is more than in the remaining field area making maximum water harvesting and availability to the root zone of the sown crop.

Prior to 15 days of crop sowing, the selected field plot should be cross-ploughed two times followed by planking. Then 60–75 cm wide and 20–25 cm deep channels are made at appropriate distance (1.5–2.5 m), depending upon season, crop and cultivars (Table 2). The seeds are sown in the inner northern slope of each channel at 50 to 75 cm spacing depending on crop and varieties. The details on the time of sowing and seed rate for different crops are given in Table 2. Before sowing, seeds should be soaked in fungicide solution having 2 g bavistin per litre of water. This is done for about 6-8 hours for snapmelon, kakri and kachri and for 10–12 hours for mateera, *tinda* and gourds. For early germination in bold seeded cucurbits, viz. mateera, *tinda* and gourds the soaked seeds should be wrapped in wet gunny cloth and buried for 10–12 hours about 30 cm deep in soil or in FYM pit, prior to sowing. Two-three sees are sown at each point. When the germinated seedlings are 8–10 cm in height, thinning should be done keeping one or two plants at each point. Proper care should be taken to protect the young seedlings from birds, wild lizards, squirrels and insects pest particularly beetles.

Drip Irrigation for cucurbits: Among controlled irrigation, drip system of irrigation is the most suitable for cucurbitaceous crops under arid conditions. At CIAH, a series of experiments were conducted to assess the feasibility of different combinations under the drip and micro sprinkler systems in cucurbitaceous crops. In conclusion, single lateral lines (12–16 mm size) at 1.5–2.0 m distances with on-line drippers (4 lph) at 50 cm distances was found to be the most suitable for kachri, snapmelon and mateera. Increased fruit yield of about 25–30% is obtained in these crops in comparison of 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. Drip irrigation is the most efficient method of irrigation when it comes to water saving. Since the drippers deliver water directly to the soil adjoining to the root system, which absorb the water immediately. The efficiency of drip irrigation systems in the Indian arid zone would only be at the highest level if it is planned, layout and maintained after understanding the prevailing climatic situations, crops under cultivation and competency in the resource management.

Crop management: To keep the cucurbitaceous crop free of weeds inter-culture operations are started 20–25 days after sowing and depending upon the season 2 to 3 weeding and hoeing operations may be required. Mulching with the locally available materials such as hay, straw, weeds etc. improves fruits yield in cucurbitaceous vegetables. In summer season crop of bottlegourd, mulching with dry hay (or *khimp*) resulted increase in fruit set and there by 30% higher yields under hot arid conditions of western Rajasthan. Mulching reduces water evaporation, delays the drying of the soil and reduces

the soild thermal regime during the daytime under extremely high temperature conditions. It also checks weed population and improves the microbial activity of the soil by improving the environment around the active root zone. Continuous use of organic mulches (*bui, keemp* or dry hays) is helpful in improving the organic matter content of the soil, which in turn improves the water holding capacity of the sandy soil. In arid zone cucurbits, mulching should be done at 30–35 days after sowing in vine spared areas. Mulching with locally available dry hays and weeds have given significant improvement in quality furit yield by 58% over control (5.18 kg/plant) in snapmelon cultivar AHS 82. Among the bio-regulators imposed for the improvement in fruit set and high quality early yields under irrigated or rainfed mixed crop cultivation practices, spraying of GA_3 @ 20 ppm at 2–4 leaf stage (18–20 days after sowing) significantly increased yield potential by 63% over the control (5.05 kg/plant) in snapmelon.

(vi) Plant protection

Diversity in ber powdery mildew isolates form various locations of the Country was identified. The Perpetuation and survival mechanisms of this major pathogen was studied. However, artificial inoculation under field and laboratory conditions was tried. The oxidative enzymes, constitutive phenolics, calcium, protenin etc., were supportive as the *in vitro* indides for screening of ber germplasm in addition to protein profile of ber genotypes differing powdery mildew reactions could be used Biochemical markets.

Various isolates of *Trichoderma* and *Pseudomonas fluorescens* were isolated from soil and plant samples form arid horticultural ecosystem and diversity among these isolates was studied. 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 cultiplied for formulation. Promising isolate of *Trichoderma* (CIAH 240) and *P. fluorescens* (CIAH 196) with different treatment combinations along with 50% less quantity of Dinocap, were tested under field conditions for the management of ber powdery mildew at CHES, Godhra. Based on the performance, during two consecutive years these two bioagents were promoted to multi location testing evaluated under AICRP (AZF) centers (Anantapur, Bawal, Jobner, Faizabad, Sardarkrushinagar and Rahuri). In Anantapur center, liquid culture of CIAH 196 (10%) in combinatrion with karathane recorded 19.25 PDC where the powdery mildew incidence was 67.4%. Performance of *Trichoderma* isolate CIAH 240 was better at Rahuri center showing PDC of 86.23 with 58% of powdery mildew incidence. After two years performance, these two test isolates are being supplied to different cetres. Field experiments for the management of virus disease in 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. Further studies are in progress in formulation as bio-priming in arid vegetables seeds. Bioagents were also tested for the management of date palm sucker rot, fruit rot and stem blight in ber under laboratory conditions. The germplasm collections and advanced lines/varieties of ber, pomegranate, aonla and arid vegetables are being evaluated for diseases resistance under field conditions. In arid vegetables, kachri has been noticed as multiple disease resistance source.

4.5 NATURAL RESOURCE MANAGEMENT

(i) Integrated nutrient management

To minimize the use of chemical fertilizes, 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 arid region. The use of organic manures in sandy soils has better influence on soil moisture retention in the root zone for longer period, which helps to supply the available nutrients.

Ber cultivation under micro-irrigation system

(ii) Fertigation in arid fruit crops

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

(iii) Stress physiology

Studies on photosynthesis and associated parameters were undertaken in 40 cultivars of ber. The observations on photosynthesis were recorded at 10 AM, 1 PM and 3 PM. It was observed that the ber cultivars could be classified into two major groups, i.e. (a) those showing mid-day depression in photosynthesis and (b) those, which do not show mid-day depression. Similarly, the cultivars were also screened for corboxylation efficiency and water use efficiency. Thus based on these results, cultivars Seb, Banarsi Pewandi, Banarsi Karaka, Mundia, Dandan, Alwar Desi, Govindgarh Special and Kala Gola were found to be superior over other cultivars. The study further revealed that absence of mid-day depression has been adopted as adaptive parameter in ber for drought resistance.

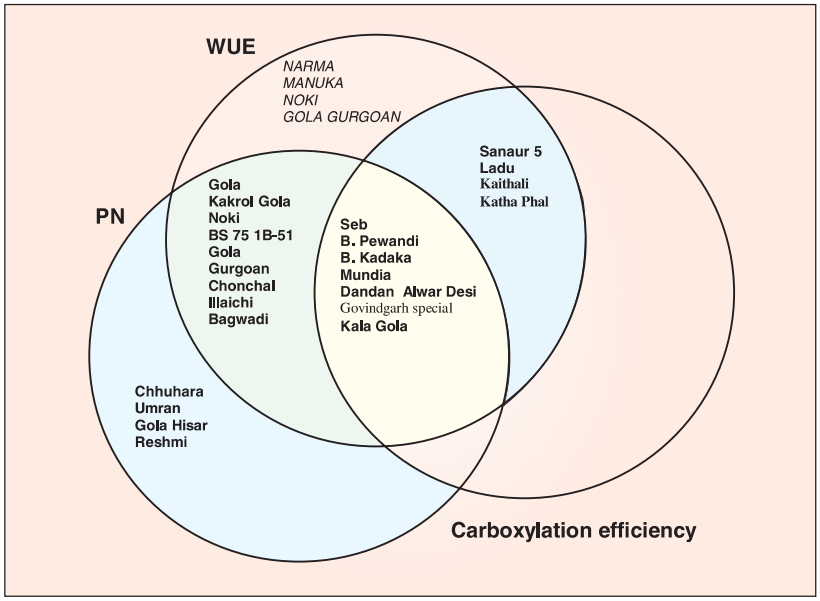


Diagram for classification of ber cultivar

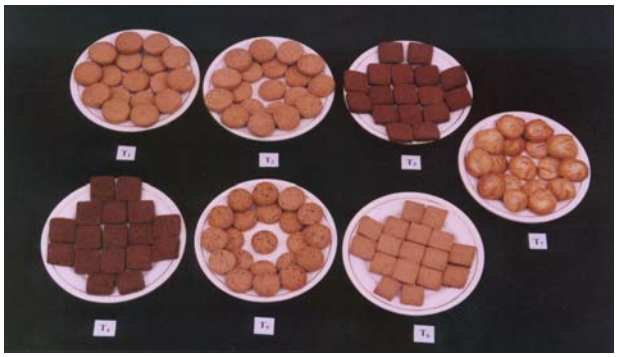
In order to understand the mechanisms of adaptation by cucurbitaceous crops to tide over water stress in arid-ecosystem, comparative study was under taken using mateera (stress tolerant) and watermelon (stress susceptible) as test crops. It was revealed that under stress conditions mateera plants are able to maintain growth whereas, the growth in watermelon plants was checked. 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 mateera plants compared to 50% in case of watermelon. This illustrates that mateera has developed mechanism by which it can maintain its photosynthetic rate under water stress condition. 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.

In order to identify the stress tolerant strains, attempts were made to develop the screening parameters. Among various parameters identified in different crops, it was found that plant height stress index, dry matter stress index and reduction in relative water content prove to be reliable indices for screening for drought tolerance.

(iv) Post harvest technology

For improving storage life of ber fruit cv. Gola; the fruits were packed in perforated polythene bags after treating with calcium nitrate (0.5%) and Virosil (2.5%). The treatment had reduced physiological weight loss at ambient temperature (28 ±2°C). Fruits treated with bavistin reduced the pathological loss upto 10.60%. Calcium nitrate could maintain the colour upto 9 days under ambient temperature.



Value-added product of khejri-biscuits

Value-added product of khejri-Sangri

For dehydration of *sangri* (tender pods of *Prosopis cineraria*), blanching in 2% salt solution has given best quality after rehydration. Attempts were also made to prepare biscuits from dried pods (*khokha*) of khejri.

Preparation of kachri powder without peel is recommended as ingredient for garam masala. Aonla shreds with 4% common salt and black salt are used as mouth freshner.

4.6 TRANSFER OF TECHNOLOGY

For transfer of innovative arid horticulture technologies, on-campus and off-campus training programmes and group discussion technological demonstration, trials are conducted for farmers, farmwomen and extension functionaries.

Field days and field visits of farmers and extension functionaries are arranged to impart the knowledge to farmers fields among them about arid horticulture. Other extension activities like Radio and TV Talk, Press publicity, organizing exhibition during Kisan Mela, distribution of literatures, seeds planting material etc. are being done by the Institute for transfer of innovative horticultural

Farmer-Scientist interaction at Research Farm

technologies for the welfare of farming community. In the year 2000, a short course was conducted for scientists, teachers and extension workers on "Changing Scenario in Arid Horticulture". Institute also participated in Krishi Vigyan Mela organized by Rajasthan Agricultural University, Bikaner on 24 March 2002 and bagged first prize for best stall, display of exhibits and promoting moringa cultivation in hot arid region.

4.7 PUBLICATIONS (2000 ONWARD)

Publication	Number
Research paper	60
Popular article	40
Technical document	14
Books	11

4.8 TECHNIQUES/TECHNOLOGIES GENERATED

(i) New drought hardy watermelon variety mateera F_6/a, bottle gourd (AHLS Round 1), Cluster bean (AHC-13) and sword bean (AHSB 1) were identified and are under testing at farmer's field.

(ii) Complete agro-techniques for cucurbitaceous crop cultivation under arid agro-climatic conditions have been standardized and recommended.

(iii) *In-situ* bud grafting techniques to established khejri orchards for uniform and quality Sangri production has been standardized.

(iv) Vegetative propagation techniques in aonla (Patch budding in middle of July), ker (by cuttings in month of September and treatment with 7,000 ppm + IBA 1,000 ppm Thymine), *Cordia myxa* (budding in middle of August) and ber (First fortnight of June) have been standardized.

(v) For maximum flowering and fruiting in phalsa, it should be pruned during 1st week of December up to the height of 50 cm under hot arid conditions.

(vi) Technique for production of vermicompost in arid ecosystem has been standardized.

(vii) Integrated Nutrient Management (INM) for pomegranate has been standardized.

(viii) Fertigation through micro-irrigation in ber, pomegranate and kinnow have been standardized.

(ix) Intercropping of okra and cluster bean between the rows of ber and mango has been recommended for obtaining good returns under rainfed conditions.

(x) *Cercospera* leaf spot of pomegranate can be controlled by fortnightly spray of Topsin M (0.1%), Captaf (0.2%) or Dithane M-45 (0.2%).

(xi) Anthracnose was found to be controlled by 2 sprays with Blitox (0.3%) or Bavistin (0.1%) or Kavach (0.2%) at fortnightly interval commencing from second week of August in pomegranate.

(xii) Spray with Bayleton (0.1%) or Bavistin (0.1%) during second week of September followed by second spray with Sulfex (0.2%) during middle of October provided effective control of powdery mildew of ber.

(xiii) Application of 2 sprays of Acephate (0.05%) or Dimethoate (0.05%), Fenvalarate (0.05%) or Dimethoate (0.0015%) at fortnightly interval followed by 2 sprays of NSKE (5%) at 7 days interval proved effective and consistent in suppressing the pest population (Trips and anar butterfly).

(xiv) Schedule involving 2 applications of Fenvalarate (0.005%), Decamethin (0.0015%), Acephate (0.05%) or Dimethoate (0.05%) at 10 days interval commencing from second fortnight of September followed by 2 applications of NSKE (5%) at 10 days interval proved to be effective against fruit fly and fruit borer in ber.

(xv) Thrips attack was effectively controlled by 2–3 fortnightly sprays with Monocrotophos (0.05%), Demethoate (0.05%) or Phosphamidon (0.05%) followed by weekly sprays with NSKE 95%) in chilli.

(xvi) Jassid was effectively controlled by fortnightly application of Phosphomidon (0.05%), Monocrotophos (0.05%) Endosulphan (0.07%) or Fenvalerate (0.05%) followed by weekly sprays with NSKE (5.0%). Even half dose of fenvalerate (0.0025%) with half dose of NSKE (2.5%) was equally good in suppressing the population of jassid (Brinjal).

(xvii) The shelf life of ber cv. Gola can be improved by giving dip treatment either with Calcium nitrate (0.5%) or Virosil agro (2.5%).

(xviii) For dehydration of *Prosopis* pods, blanching in 2% salt solution gave the best quality rated pods.

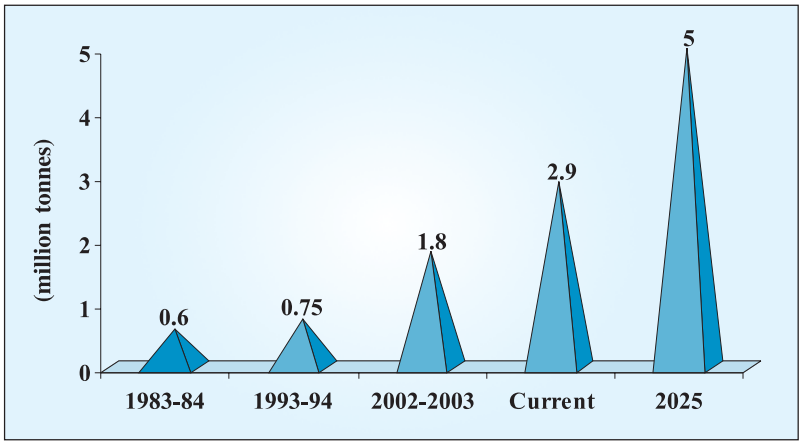
(xix) Preparation of value added product (i.e. biscuits) from *Prosopis cineraria* pods has been standardization.

5. IMPACT ASSESSMENT

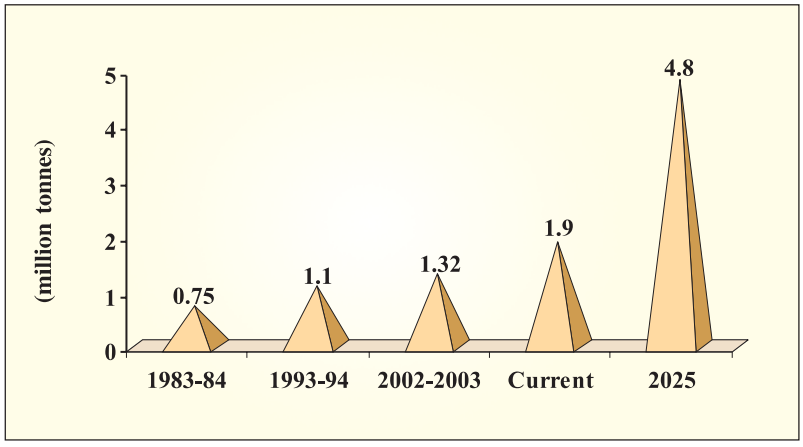
Considerable knowledge in field of arid and semi-arid horticulture has been generated as a result of intensive research carried out during last three decades. There has been definite impact in terms of (i) awareness regarding potential of income generation by growing fruits and vegetables in arid and semi-arid regions, (ii) increase in area and production of these fruits and vegetables in arid and semi arid regions, (iii) supply of fruits and vegetables for internal as well as export markets and (iv) improvement in the living standard of the inhabitants of arid and semi-arid regions.

5.1 GROWTH OF THE COMMODITIES

Although, India is having a big share in the production of fruits and vegetables in the world market and is next to the China. In Indian arid regions, the production of fruits and vegetables was 0.6 and 0.75 million tonnes respectively during 1983–84. This has increased to 0.92 and 1.32 million tones respectively during 2002–03. The current requirements of fruits and vegetables for this region are 1.3 and 1.9 million tonnes respectively. Considering the current trends in population growth, these requirements are expected to reach 2.5 and 5.0 million tonnes respectively during the next two decades. This calls for concerted efforts to increase the production and productivity. Although the recent scenario indicates an increasing trend in the production of both fruits and vegetables, but the growth rate has been rather slow.



Current status and future requirement of fruits in arid region of India (million tonnes)



Current status and future requirement of vegetables in arid region of India (million tonnes)

In arid region, the area under fruits increased from about 50,000 ha in 1984–1985 to about 290,000 ha in 2004–2005 and that of vegetables from about 63,000 ha in 1984–85 to 190,000 ha in 2004–2005. Considerable area has brought up under fruits like ber, pomegranate and aonla in different part

of the country, which had negligible spread in the recent past. This haas become possible as a result of the research and developmental efforts made by this Institute and transferred the relevant technologies to the farmers for adoption

5.2 INPUT/OUTPUT ASSESSMENT

In case of ber under irrigated conditions, the benefit cost ratio comes to about 6 : 1 whereas, in rainfed conditions, it is nearly 2.4 : 1. In case of pomegranate, aonla and date palm the benefit ratio is 2.4 : 1, 2 : 1, 3.2 : 1 respectively. In ber based cropping systems, ber + Indian aloe and ber + clusterbean-mustard, the benefit cost ratio is 2.57 : 1 and 3.67 : 1 respectively.

5.3 ITEM BY ITEM ASSESSMENT

Fruit crops

Ber

The promising varieties for arid and semi-arid regions have been identified and are being multiplied by vegetative means for commercial plantation by the farming community. The identified varieties are in great demand. As a result, area under ber has considerably increased all over the dry areas of the country including peninsular region where it was almost non-existent earlier. The production technologies related to pruning, moisture conservation, fertigation, management of pests and diseases have been standardized. Some new varieties are being process of release.

Pomegranate

The farmers are planting the identified cultivars as well as the new hybrids. The production technologies related to nutrient application, training and optimum fruit load, control schedules against insect pests and diseases, the Institute has developed water and moisture conservation measures. There is urgent need to translate them on the farmers' field. Under extreme hot arid condition, the fruit cracking, under sub humid conditions diseases (blackening of arils, oily spot, wilting) and pests (anar butter fly, fruit borer) are the limiting factors for export of the fruits.

Aonla

Among arid fruits aonla has gained considerable position both in area and production in the recent years. The identified cultivars are spreading in different locations in India. The agro-techniques for the commercial production of aonla have been standardized and are being popularized among the farmers. The different value added products of aonla are gaining popularity and thus to establish industries of aonla based products are becoming as remunerative enterprise. Frost has become the main limiting factor in increasing area and production of this crop in hot arid region.

Date palm

The identified varieties have not yet spread in spite of great demand due to lack of sufficient

planting material. The cultural techniques related to fruit thinning and control of insect pests have been standardized. Though cultivation of date palm is arid region is considered as remunerative but due to poor irrigation facilities and lack of planting material, the area under date palm in not increasing at the faster rate. However, the crop has good potential in canal command areas, particularly in regions where salinity has become a problem.

Other fruits

The under utilized fruits like bael, ker, khejri, lasoda, karonda, kaith, etc. are also gaining popularity among farmers because of their multiple utility.

Vegetable

Some of the arid vegetables like mateera, kachri, tinda, snap melon, bottle gourd, kakri, moth bean and cluster bean are also gaining popularity among the farmers with the development of new varieties having high yield and better quality.

Other horticultural crops

The farmers require technologies specific to arid areas for other horticultural crops such as vegetable, medicinal, aromatic and ornamental crops.

5.4 LESSONS LEARNED, SUGGESTIONS AND OPTIONS FOR FUTURE

Lessons/constraints	Suggestions/options
Full exploitation of the potential of arid and semi-arid areas for the production of a large number of horticultural crops was not possible since technologies specific to these areas were not available.	There is need to enlarge the programme of work to incorporate the fruit, vegetable, medicinal and ornamental crops which can provide nutrition security to the people along with economic and ecological sustainability to the region
The available biodiversity, which faces danger of erosion, could not be properly conserved in the absence of repositories.	Well-defined germplasm, repositories and gene banks should be established at appropriate locations.
Crop failures and productivity losses are common as a result of extremely high aridity leading to drought conditions.	A major programme should be directed to genetic improvement for drought and heat tolerance besides the study of physiological adaptation mechanisms to these conditions.
In arid environment, monoculture system is risk prone as well as less productive.	For sustainability and profitability, multistorey compatible crop combinations need to be worked out.

Lessons/constraints	Suggestions/options
The fruit crops which have already established in the region face some productivity constrains, e.g. Powdery mildew in ber, leaf and fruit spot disease, fruit fly and fruit cracking in pomegranate and bael, frost injury in aonla, etc.	There is need to give emphasis on integrated approach for management of such problems incorporating bio control agents.
Absence of standard varieties for some indigenous/ established fruit crops that come in the way of their systematic production.	Use of biotechnological tools for evolving varieties of arid and semiarid horticultural crops for specific purpose.
Absence of propagation technique for mass multiplication of fruits like date palm and standardization of nursery management activities.	Development of fast multiplication techniques is required utilizing micro propagation and tissue culture approaches as well as standardization of nursery management.
Need of low input cost technology for sustainable horticulture production	Intensive research would be undertake to develop low cost production technology.
Poor adoption of improved technologies	Development of location specific technologies and their transfer to the farmers through modern extension methods/tools.

6. SCENARIO

On account of increase in population, industrialization and urbanization, the arable area is shrinking rapidly. Field crops, where the productivity has reached a plateau and efforts are needed to increase productivity, mainly occupy the cultivable area. In order to feed the growing population, the alternative to increase production is to bring non-conventional areas into cultivation by incorporating appropriate crops and cropping systems. In view of this the arid regions of the worlds which occupies 254 lakhs square kilometers (19.6% of total land area of world) qualifies ideal home to introduced new crops and cropping systems make them green and provide nutrition and income security to the inhabitants.

In India too, a large portion of landmass amounting to 3.87 lakhs square kilometers (12% of the total geographical area) is under ecosystem, which spreads in Rajasthan (19.6 million hectare), Gujarat (6.2 m ha), Haryana (1.3 m ha), Punjab (1.5 m ha) and peninsular India (3.1 m ha). Part of the above area can be brought under cultivation of quality produce by harvesting ample natural resources and low incidence of pests and diseases, provided adequate technologies are developed to make best use of available strength and opportunities in this area.

High temperatures, low rainfall, low relative humidity, high potential evapotranspiration, high sunshine, abundant solar energy, sparse vegetation and high wind speed during summer characterize this area. Soils are dry for most part of the year, having aridic moisture regime and high temperature. The region consist of vast sandy and other wastelands, which have productivity constraints such as

salinity in soil and irrigation water, low soil fertility and extreme climatological stress conditions. Therefore, cultivation of annual crops is always a gamble unless substituted by irrigation and therefore, tree based land use system will have to utilize.

The present cropping pattern of arid region can be classified into two categories (i) where assured irrigation is available fruits like pomegranate, lime, kinnow mandarin, grapes, etc are grown, (ii) the areas which are under rainfed conditions, the crops like ber, lasora, aonla, karonda, salvadora, etc are grown.

To develop arid and semi-arid region, a number of Institutes under National Agriculture Research System and SAUs are involved in the development of technologies. The major Institutes, which are stakeholders in this programme are Central Institute for Arid Horticulture, Bikaner; Central Horticultural Experimental Station, Godhra, National Research Centre on Pomegranate, Solapur; Indian Institute for Horticultural Research, Bangalore; All India Coordinated Research Project on Arid Zone Fruits, Bikaner; Central Research Institute for Dryland Agriculture, Hyderabad; Central Arid Zone Research Institute, Jodhpur; NRC on Seed Spices, Ajmer and SAUs of State Agricultural Universities of Arid and Semi-arid region of the country.

The above research organizations have developed the improved varieties of ber (Gola, Umran, Seb, Goma Kirti), aonla (NA 6, NA 7, Ckaikiya, Kanchan), pomegranate (Ganesh, Jalore Seedless, Phule Arakta, Bhagwa, Mridula), date palm (Halawy, Khuneiji), bael (NB 5, NB 9), custard apple (Arka Sahan, APK(ca)-1), fig (Poona fig, Conadrio), cluster bean (Goma Manjiri), mateera, snap melon, kachri, pumpkin, etc.

Very limited technologies are available which can harvest the ample resources available in this region even these technologies are either under experimentation or have not reached to the farmers' field.

6.1 STRENGTH

Availability of vast area

Indian arid zone is one of the largest sub-tropical deserts of the world of which 20% is arid and rest is semi-arid with varied habitats. The arid region covers nearly 12% land surface of India and spread over 39.54 million ha area, out of which 31.71 million ha is under hot arid region and 7.83 million ha under cold arid region. The hot arid region occupies major part of north-western India and occurs in small pockets in southern India. The cold arid region mostly occurs in Jammu and Kashmir and in Himachal Pradesh.

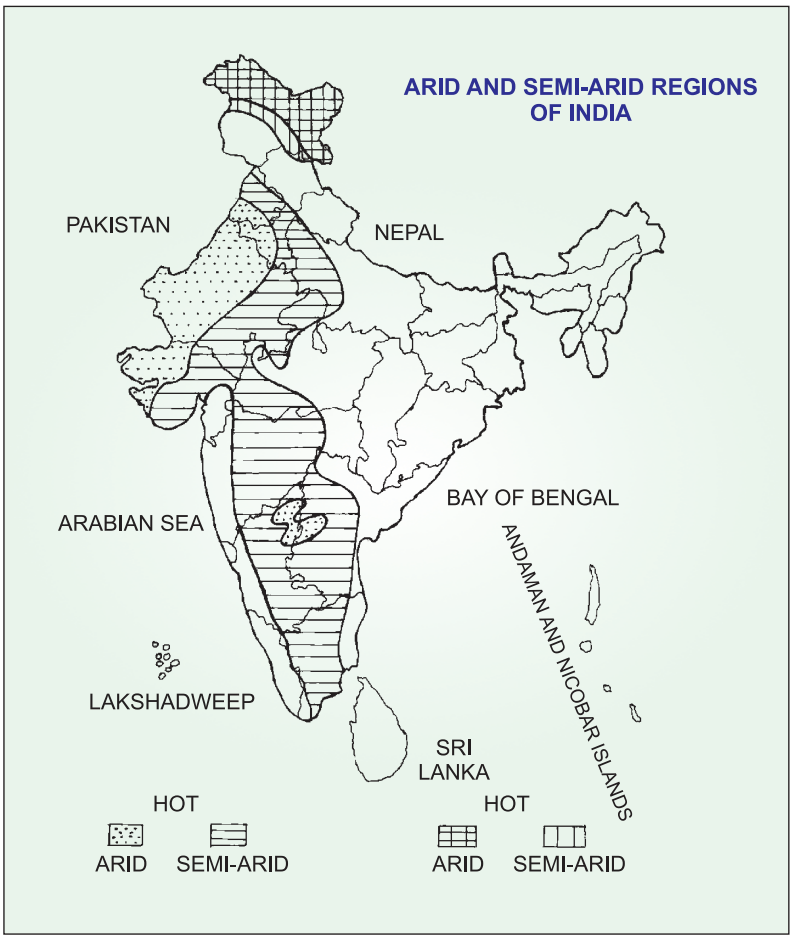
In India, Rajasthan is the largest state covering maximum area (49.61% of total arid region) under hot arid zone. Out of total geographical area of Rajasthan, 79.08% is lying in arid and semi-arid climate spread over 21 districts of the state. The twelve districts of north-western Rajasthan (Barmer, Bikaner, Churu, Sri Ganganagar, Hanumangarh, Jaisalmer, Jalore, Jhunjhunu, Jodhpur, Nagour, Pali and Sikar) accounts for 63.4% area of the hot arid realm of the country. The distribution of arid and semi-arid regions in the country is depicted in the Map.

Extent of arid region in India

Regions	Area (m. ha)	Percentage of total arid region in India	Percentage of geographical area of India	Districts
A. Hort arid region	31.71	80.20	9.64	
(a) North-west India	28.56	72.26	8.68	
Western Rajasthan	19.61	49.61	5.96	Bikaner, Barmer, Jaisalmer, Jodhpur, Sri Ganganagar, Churu, Pali, Jalore, Nagaur, Ajmer, Sikar, Jhujhunu
North-western Gujarat	6.22	15.73	1.89	Kuchchh, Amreli, Surendranagar, Junagarh, Banaskantha, Mehsana, Jamnagar
South-western Punjab	1.45	3.67	0.44	Ferozpur, Bhatinda
South-western Haryana	1.28	3.25	0.39	Hisar, Rohtak
(b) Southern India	3.15	7.94	0.96	
Andhra Pradesh	2.16	5.45	0.66	Anantpur, Cuddapah, Kurnool
Karnataka	0.86	2.17	0.26	Dharwar, Chitradurg, Bellary, Raichur
Maharashtra	0.13	0.32	0.04	Dhulia, Nasik, Sholapur, Satara
B. Cold Arid region	7.83	19.80	2.38	
Jammu & Kashmir	7.00	17.70	2.13	Leh, Kargil
Himachal Pradesh	0.83	2.10	0.25	Lahual Spiti, Chamba, Kinnaur
Total (A+B)	39.54	100.00	12.02	

Genetic resources

Indian sub-continent is an important gene centre being origin of nearly 166 cultivated plant species and rich in diversity of as many as 320 species and their wild relatives. The arid region has comparatively fewer plant species but several of them are of great horticultural value. *Ziziphus mauritiana* (ber), *Z. nummularia* (jharber), *Z. rotundifolia* (boradi), *Cordia myxa* (gonda), *Salvadora oleoides* (pilu) yield edible fruits. The seeds of *Acacia senegal* mixed with unripe pods of *Prosopis cineraria* (khejri), unripe fruits of *Capparis decidua* (ker) and ripe fruits of *Cucumis callosus*, commonly found in arid region, are used to prepare a delicious vegetable (panchkuta). Similarly, cluster bean, cowpea, amaranth



and cucurbitaceous crops are common vegetables. Fully ripe pods of khejri are very nutritious and contain nearly 56% carbohydrates and over 10% protein. *Euphorbia antisyphilitica* and *Simmondsia chinensis* have performed well in the region. The region is also rich in medicinal plants such as *Balanites aegyptica* (hingota), *Commifera wightii*, *Catharanthus roseus* (periwinkle), *Withania somnifera* (ashwangandh), *Aloe barbadensis* and *Cassia angustifolia* (senna).

The native species such as *Prosopis cineraria* (khejri), *Ziziphus nummularia* (jharber), *Z. mauritiana* var. rotundifolia (boradi), *Capparis decidua* (ker), *Citrullus lanatus* (mateera) and *Cucumis callosus* have considerable variability. Fruit species such as *Ziziphus mauritiana*, *Punica granatum*, *Emblica officinalis*, *Phoenix dactylifera* (date palm), *Psidium guajava* (guava), *Aegle marmelos* (bael), *Morus* spp. (mulberry), *Carissa carandas* (karonda) and*Cordia myxa* (gonda) have performed well.

Under the irrigated conditions, excellent quality production of fruits such as grape, sour lime, sweet oranges, kinnow, mango, vegetables such as cucurbits, beans, tomato, brinjal, chillies, okra, onion and leafy vegetables, medicinal plants such as *Ocimum sanctum, O. basilicum*, *Solanum* sp., *Opium* sp., isabgol, vetiver, liquorice, henbane and anise flower crops such as Damask rose, marigold, jasmine, etc.

Quality produce

The peculiar agro-climatic conditions of the region imparts unique quality in fruits such as ber, sweet oranges and vegetables such as chilli, cumin, fenugreek and cucurbitaceous crops. Since, the region has ample sunshine hours, low humidity coupled with fewer incidences of pests and diseases, it is most suitable for production of arid fruits and vegetables for export. Due to its peculiar climatic conditions crops like date palm can only be grown in hot arid part of the country.

Surplus family labour

Owing to long slack seasons and low intensity of cropping, there is considerable surplus family labour available in the arid zone farming communities, which can be put to use for increasing production of horticultural crops.

Research infrastructure

The Central Institute for Arid Horticulture, Bikaner along with its Regional Station (Central Horticultural Experiment Station) at Vejalpur, Godhra and the All India Coordinated Research Project Centres located in 8 State Agricultural Universities and 3 ICAR Institutes provides a strong infrastructure for research on various aspects of Arid Horticulture.

Infrastructure for surface transport

The various parts of arid and semi arid regions of the country are well connected by the network of roads and have facilities for surface transport of produce. This help in transportation of produce to the nearby markets, which brings better prices and reduce gluts in the market.

6.2 WEAKNESSES

Low productivity of horticultural crops

Considering that the small area under horticultural crops in the region is mostly under assured irrigation and fairly good care, the productivity of these crops is low (Fruit 8.04 t/ha; Vegetables 10.36 t/ha) in comparison to national average. This is mainly because of inadequate production technology related to adaptable genotypes and optimum management practices. Although, the region has great potential for quality production of fruits such as ber, aonla, date palm, sapota, custard apple, jamun, mahua, bael, lasora etc, vegetables and other horticultural crops, the suitable package of practices for these crops to achieve high productivity under its peculiar agroclimatic conditions are not available.

Poor soil conditions

The arid zone soils are very poor in fertility. The soils of the north western arid region described as ‘desert soils’ and ‘grey brown soils’ of the Order Aridisols are light textured. The solum of these soils is moderately calcareous (0.2% $CaCO_3$) and below this solum at depths of 40–120 cm, a sharply

differentiated zone rich in alkaline earth carbonates (5 45% $CaCO_3$) is present in the form of hard crystalline concretions, which may be many metres thick. Most of arid areas (about 64.6%) are duny where the soils often contain 3.2–4% clay and 1.4–1.8% silt. The brown light loam soils occupy 1.7% area, which has loamy fine sand to fine sandy loam on the surface and heavier subsoil underlain with calcium carbonate concretions. Besides this, about 5.9% area is covered by soils having hard pan, 5.6% is under hills and pediments, 6.8% area is alluvial duny and 1.6% is sierozems extending from the soils of Haryana and the Punjab. In Gujarat also, grey brown soils are widespread besides a large area having deltaic alluvium with small area in Kachchh having deep black and medium black soils. In the peninsular India, a considerable part of arid region has red sandy soil and some parts have mixed black soils.

The soils are poor in organic matter having percent organic carbon of 0.03 in bare sand dunes to 0.1 in the stabilized dunes. The soils are generally rich in total potassium (8,250–18,980 ppm) and boron (1.9–12.2 ppm) but are low in nitrogen (185–150 ppm) and phosphorus (285 ppm) and micronutrients such as copper (10–11 ppm), zinc (2.07 ppm) and iron (20 ppm). The soils often have high salinity.

Poor ground water resource

The ground water resource is not only limited owing to poor surface and sub surface drainage but is also generally highly saline. The depth of water ranges from 10 m to as high as 140 m. The other irrigation water resources in the region are seasonal rivers and rivulets in Gujarat, surface wells and some runoff water storage devices (e.g. tanka, khadins). Thus the water resources in arid region are limited and can irrigate hardy 4% of the area.

Low and erratic rainfall

The mean annual rainfall in the Indian arid region is very low and varies from 100 mm in north western sector of Jaisalmer to 450 mm in the eastern boundary of arid zone of Rajasthan. In Gujarat, it varies from 300 to 500 mm and in Haryana and Punjab from 200 to 400 mm. In peninsular region, the rainfall varies from 520 mm in Bellary (Karnataka) to 748 mm in Cuddappa (Andhra Pradesh). Most of the precipitation in northwestern arid region occurs during July–September in about 19–21 rainy days.

Resource constraint farmer

The major income source of the farmers of this region is through crop and animal husbandry which gets affected due to recurrent droughts and natural calamities, the farmers remained resource poor and majority are illiterate. This drastically affects adoption of advanced technologies developed by the organizations.

Lack of technical knowledge of the farmers: In arid region, mostly farmers are illiterate and have negligible knowledge about the cultivation of horticultural crops.

6.3 OPPORTUNITIES

Exploitation of indigenous variability

Reserve of considerable variability of a number of hardy plant species, which yield edible fruits, and products of horticultural value provide opportunity for their exploitation by genetic improvement and systematic plantation. Identification of abiotic stress tolerant genes from the available gene pool will provide patentable material for the country.

New introductions

Several fruit yielding species common in the arid region have not yet been commercially exploited mainly owing to the absence of their standard cultivars/types. Similarly, there is scope for production of plant species introduced from the isoclimatic regions of the world, e.g. cactus pear, quandong, carob, African dove plum, argan tree, marula nut, nance, oyster nut, ye eb nut, etc.

Genetic improvement

Genetic improvement in the traditional fruits such as ber, pomegranate, aonla and vegetables such as chilli, tomato and cucurbits to induce resistance against abiotic stresses with particular reference to drought and heat should further boost their production in the region. Some of the traditional horticultural plants suffer from productivity constraints owing to their susceptibility to specific disease and pest problems, e.g., powdery mildew in ber and cucurbits.

Thus by genetic improvement in the traditional as well as presently wild but potential species and introduction of suitable exotic species, the major casual factors for the slow pace of spread of area under horticultural crops and for their extremely low productivity in the arid region can be mitigated.

Production for export

Since arid zone agro-climate offers a great potential for production of high quality produce, there is great opportunity for production for export. There is a need to initiate research on priority basis on export-oriented production in arid horticultural crops. Standardization of grading and packing requirements for indigenous and foreign markets with reference to size, colour and quality parameters should be done. Survey and identification of indigenous flora for export market will find place in the export market. Standardization of parameters and techniques for export oriented horticultural crops needs priority. In this context, the potential of quality production of citrus fruits such as sweet oranges and kinnow, ber, pomegranate and vegetables such as tomatoes, chillies and spice crops such as cumin and isabgol are well known.

Value added products

There is great scope for developing high value products from the indigenous produce. In order to generate appropriate technologies for post harvest management, government interventions through policy directions are needed. Promoting establishment of processing units in production centers based on cluster village concept to process excess produce for export.

Cropping systems

The high solar radiation resource in the arid areas provides opportunity for its harvesting by optimization of cropping system models incorporating multi-layer receptor crops.

Agro-based industries

The advanced agro-techniques developed for crops suitable for arid ecosystem, the production is increasing steadily. This provides an opportunity to establish agro-based industries in the region, which will avoid gluts of produce in the markets, generate employment and income to the inhabitants.

6.4 THREATS

The arid zone ecosystem is very fragile and is prone to serious imbalances even with slightest disturbance owing to mismanagement of resources or influx of external factors.

Abiotic stresses

High temperature, high wind velocity, high solar radiation, saline soils and brackish water and low temperatures during winter adversely affect the productivity of the crops.

Poor management of water resources

Due to resource constraint, illiteracy and lack of proper water policy, the farmers are not able to use the water resource efficiently for better crop production. Moreover, farmers are not aware about the technologies for efficient water uses because of this a major part of this valuable resource goes waste and is not available for crop production.

Genetic erosion

With the growing population pressure the indigenous gene pools are getting eroded. Since this trend is continued to grow there is danger of extinction of native gene pools. Also most part of arid region is on international boarder, aggravating such a threat for the region.

Recurrent drought and high potential evapotranspiration

Arid environment poses constraints to productivity mainly because of abiotic stress owing to scanty rainfall, high summer temperature, high solar radiation and high wind velocity, low winter temperature, low soil fertility and high salinity in irrigation water and soil. The potential evapotranspiration (PET) in the arid districts of Rajasthan varies from 2,063.2 mm at Jaisalmer to 1,503 mm at Sikar with a moisture index value of 68.9 to 91. In Gujarat, the PET varies from 1,700 at Surendranagar to 2,144.6 mm at Rajkot with moisture index value of 70 to 82%. In Haryana and Punjab, the PET value ranges from 1,615 mm at Hisar to 1,362.8 mm at Ferozpur with moisture index value from 58.9 to 72.9. In the peninsular arid region, the PET value varies from 1,857.1 mm at Anantapur to 1,738.1 mm at Bellary with moisture index value of 68.6 to 70.1. This region is characterised by the extremes of temperature having dry and severe winter with temperature as low as 4°C and very hot summer with temperature as high as 48–50°C. In summer, hot winds (loo) are

common and sand storms are frequent. Wind speed can be as high as 12 to 15.8 km/hr particularly during the summer. The solar radiation both in the northern and peninsular India is intense (from 414 cal/cm^2/day in winter to 612 cal/cm^2/day in summer at Jodhpur). Owing to these conditions, the atmospheric vapour pressure deficit reaches as high as 30 mb during May June. These conditions get aggravated in the low rainfall years.

Bio-Physical Constraints

The presence of animal insect bird faunal complex particularly concentrating in the localized green belts often poses problems. The disease occurrences are comparatively fewer but are often observed to adversely affect. The recurrent drought phenomena in arid region often cause the loss in crop production.

7. PERSPECTIVE

The current annual fruit and vegetable production in India is respectively 49.52 and 77.33 million tonnes, which will have to be increased to meet the internal consumption need of about 55 and 160 million tonnes, respectively by 2025 AD. The arid regions cover nearly 12% land surface of India of which about 59% (13 million ha arable lands and 6 million ha wastelands), given technology inputs, can greatly contribute in this endeavor. At present only about 290 thousand and 160 thousand ha area is under fruit and vegetables respectively giving a production of only 1.32 and 1.9 million tonnes as against current requirement of 2.5 and 5.0 million tonnes. By 2025 AD, therefore the production of fruits need to be increased two times and that of vegetables three times.

Export requirements of horticultural produce and products are expected to grow very fast in the post GATT scenario. The peculiar dry and warm blend in the arid region agro climate offers opportunity for producing quality products of high health standard. This obviously would require R&D preparedness.

The population pressure would result in: (a) shrinking of agro resources and aggravated pace of erosion of the indigenous biodiversity and (b) increase in surplus labour particularly women. Conservation and characterization of the available gene pools and valuable gene sources for their use for the benefit of mankind would require concerted efforts. To make the horticultural production system profitable and sustainable under the competitive post GATT scenario precise technology package needs to be developed incorporating efficient use of inputs for quality production under arid environment.

At present, commercial production is restricted to a small number of fruits and vegetables. Over the world only about 26 fruit yielding species are commercially grown whereas there is a reserve of over 3,000 of which at least 200 have economic potential. Fast growing information technology and modern communication networks have already increased awareness in the world communities about the rich variability in exploitable horticultural plant species. Some less known fruits and vegetables have already attracted the palate of the people in distant corners of the globe. Fortunately the Indian sub-continent is a rich reservoir of such resources. Arid regions also abound in 24 new plant types.

Recurrent droughts and persistence of extreme aridity conditions result in crop failures so common in the region. A considerable land area is degraded. If left to it, the growing biotic pressure and abiotic stresses would further aggravate the already precarious conditions. Appropriate and satisfactory safeguards to these conditions in the production system will have to be developed to make it sustainable and profitable. Productivity enhancement through genetic manipulations and by efficient management of natural resources and inputs such as water, nutrients and soil will need greater attention. Amelioration and profitable use of the degraded lands would also assume importance.

Monoculture production system is often unprofitable owing to less efficient resources utilization and risk of climatic calamities in the arid region. Therefore, developing appropriate crop combinations droughtailing with the available agroclimatic resources would assume great significance.

Owing to their perishable nature value addition by suitable processing techniques will be essential for stabilizing income from horticultural crops. Also exploitation of income potential from the indigenous produce can be enhanced by value addition. Technologies need to be developed for horticulture enterprise such as nursery, post harvest handling of produce and processing for gainful employment to the rural people.

The relationship between the existing animal bird insect faunal complex with the horticultural plants often create problems in their intensive production particularly under the limited resources of the arid region. Therefore, integrated management systems will need to be evolved for sustainable production. Similarly, integrated management system for the relevant diseases will also need to be worked out.

As discussed earlier, to ensure nutritional security for our people, along with effective participation in world trade through export of high quality, high value and low volume produce, production and productivity of horticultural crops will have to be increased many fold. This will demand higher priority for horticulture on R&D front. However, fact remains that good land is not available due to pressure from urbanization, industrialization, and infrastructure development and production of staple food. Therefore, for expanding horticulture to arid zone is essential where still large area with enough biotic abiotic agricultural resources are available.

In order to achieve the expectations from arid ecosystems, following thrust areas needs require special attention by researchers and extension agencies:

1. **Genetic Resource management:** Globally by 2025, majority of the genes responsible for imparting tolerance to biotic and abiotic stresses, improving input use efficiency, quality production for processing, enhancing production of active ingredients etc. Since Indian arid ecosystem harbours are rich gene pool for most of the above listed parameters, therefore, the immediate demand is 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 intensify research efforts to develop improved cultivars of indigenous as well as introduced species through conventional as well as biotechnological approaches **to transfer the genes from available gene pool into standard cultivars for resistance against biotic and abiotic stresses.**

3. **Improving production and Productivity of horticultural crops:** Although commendable progress is made on research front and a number of technologies are developed, poor adoption of such technologies has always been a major handicap in increasing productivity. A wide gap exists between the yields obtained and the potential yields with improved varieties and technologies. Therefore, promotion of developed technologies through various mechanisms is key to harness the available technologies and ensuring increased productivity and profitability to farmers. By adopting the improved cultivars and technologies, the productivity can be enhanced two times. Therefore improving the productivity of the crops use of quality plating and seed material and improved production technologies are the utmost requirement. Since most of the horticultural crops are self-incompatible therefore, the productivity is low whenever the population of pollinizers becomes limiting. This calls for in-depth analysis of insect plant relationship for improving the productivity of crops as well as byproducts from insects.

4. **Exploitation of Biotechnology in arid horticultural crops:** role of biotechnology should be utilized in relation to arid horticultural crops production. Use of molecular markers for gene tagging, transfer of genes from wild taxa, development of transgenes resistant to the biotic and abiotic stresses, micro-propagation, etc. are the potential areas. Micro-propagation technique should be standardized to maintain the elite genotypes like gynoecious, dioceous, male sterile lines, asexually propagated crops, etc. in different horticultural crops. **Standardization of norms for certification of tissue culture plants, infrastructure facilities, trained manpower need to be developed so that its full potential is exploited. Biotechnological tools would be of immense help in solving the important problems of horticultural crops**.

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, hence information on basic aspects on biotic and abiotic stress tolerance mechanisms, seed and plant vigour, canopy architecture, 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.

6. **Hi-Tech crop production:** To bridge the vast gap between actual and potential productivity, there is urgent need to adopt following hi-tech efficient cultivation of horticultural crops which will not only increase productivity but also enhance quality production at low cost thereby ensuring better returns to the farmers

   (a) Hi-tech nursery raising for production of healthy seedlings

   (b) Protected cultivation around peri-urban areas

   (c) 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.

   (d) 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 availability of quality produce throughout the year, and maximize the use of natural resources growing crops out of the normal season. Off-season production of certain high value crops under low cost poly house/net house around peri-urban systems would be economic preposition.

8. **Micro-irrigation:** Micro-irrigation system has proved very successful particularly water scarcity areas and farmers are taking very good yield of different horticultural crops. Recommendations for micro-irrigation/fertigation in horticultural crops with reference to crop wise season wise requirements should be standardized.

9. **Organic farming:** Organic farming is another important aspect and there is a great demand of fruit and vegetables for export produced through organic farming. Package of practices for organic cultivation needs to be developed in the strategic crops. The need of conducting research on the efficient use of organic inputs is to be started. Standardization of norms for certification of organic products and deciding the certification agency must be addressed immediately. Prospects of establishment of organic zones exist in the region of rainfed areas of resource poor farmers traditionally practicing natural farming, tribal areas and degraded forestlands with virgin soils.

10. **Crop diversification:** Majority of the cultivable lands has reached its production potential to a plateau and will further shrink due to urbanization. In view of this the need by 2025 will be to convert wastelands of arid eco-region into cultivable lands. This can be achieved if appropriate crops are introduced in these wastelands and suitable technologies are provided for their cultivation. The past experience has shown that monoculture is risky proposition and therefore, the need of the hour will be to develop intensive cropping system taking in to consideration fruit crops, vegetables medicinal and mushrooms which can be grown in a multi tier system for harnessing natural resources, provide income and nutritional security throughout the year. This calls for research preparedness **to develop agro-techniques for sustainable cropping systems, integrated pests and disease management so that these lands can be fruitfully utilized for production fruits and vegetables for domestic and export purpose.**

11. **Resource management:** The arid eco system is bestowed with ample sunshine, vast area high wind velocity. Dedicated research 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.**

12. **Post harvest management:** With increase in area and productivity of a particular crop it is expected that the market will be full of produce during harvesting season. It has been estimated that in fresh produce the post harvest losses are to the tune of 25 to 30%. All efforts are required **to minimize these losses by developing appropriate for value addition of the produce or improve shelf life. In addition to this dehydration of produce can be undertaken since area has high solar radiation and low humidity coupled with incidence of diseases and pests. Varieties suitable for processing must ber developed. Food and agricultural**

technology parks should also be developed to promote agro and processing industries in areas where there predominant production of processable horticultural products

13. **Transfer of technologies**: Institute has developed various innovative arid horticultural technologies. The demand of the time is to translate them on farmer's field for which modern tools of transfer of technologies will be adopted and farmer's will be appraise of latest know how in horticultural production through trainings, field demonstrations, etc.
14. **Human Resource Development:** The optimum technical productivity of the human resource can be obtained provided the staff is trained on the various aspects. For this, the staff of the Institute will be encouraged to participate in national/international training programmes, seminar, symposium and workshops

8. ISSUES AND STRATEGIES

Issues	Strategies
Genetic Erosion of agro-biodiversity of different horticultural crops	Establishment of National Field Repository of mandate fruit crops through survey, collection and subsequent characterization, cataloguing and conservation of genetic resources
Genetic improvement of arid and semi-arid horticultural crops	To development of improved cultivars of indigenous as well as introduced species through conventional as well as biotechnological approaches to transfer the genes from available gene pool into standard cultivars for resistance against biotic and abiotic stresses.
Scanty and incomplete information on basic mechanism for adaptation	Information on basic aspects on biotic and abiotic stress tolerance mechanisms, seed and plant vigour, canopy architecture, biotechnological interventions for mass multiplication and gene transfer, identification and sequencing of genes will be generated
Lack of commercial exploitation of potential species	Evaluation of cultivates/lines of horticultural species and standardization of site-specific agro-techniques to obtained optimum productivity by better input use efficiency.
Optimizing input use efficiency	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.
Commercialization of horticulture through value addition	Development of technologies for post-harvest handling, storage and processing.

Issues	Strategies
Lack of planting material	Development of protocols for faster and mass multiplication of planting material through vegetative and biotechnological interventions.
Considerable losses of soil and water through runoff and erosion	Standardization of wind breaks and shelter belts, standardization of water harvesting and moisture conservation techniques
Need to ameliorate and utilize degraded lands of arid and semi arid region.	Integration of need based tree-crop-animal components for economic and ecological sustainability including watershed approach.
Considerable loss due to pest and diseases	Development of integrated pest management and integrated diseased management..
Poor adoption of improved arid horticultural technologies on farmer's field	Strategies like wide publicity of technologies, conducting farmer's training programmes and result demonstrations, development of scientific attitude of farmers, providing sufficient improved seeds and planting materials to farmers may increase of adoption technologies.

9. PROGRAMME IDENTIFICATION (R&D)

With the merger of CHES, Godhra (Gujarat), the programme identified includes both for arid and semi arid regions with the emphasis (a) conservation and utilization of biophysical resources, and (b) sustained economic benefits to the farmers of arid and semi-arid regions.

9.1 PROGRAMME

A.1 Genetic resource management and utilization

Fruit crops

Phoenix, Ziziphus, Punica, Cordia, Emblica, Capparis, Tamarindus, Annona, Ficus, Citrus, Buchanania, Syzygium, Aegle, Carissa, Feronia, Morus, Acharus, *Salvadora oleodis*

Vegetable crops

Citrullus lanatus, Cucumis callosus, C. melo var. *momordica,, Capsicum*, *Solanum melongena, Lycopersicon esculentum,* Moringa, *Prosopis,* beans and Aloe

A.2. Introduction of exotics

Fruit crops

African dove plum, Argan tree, Barbados cherry, Marula nut, Nance, Oyster nut, Quandong,Ye eb nut, Carob, white sapote, black sapote.

Vegetable crops

Muskmelon, watermelon

B. Crop improvement

Development of trait specific cultivars

Fruit crops

Ber, Aonla, *Cordia*, *Capparis*, Custard apple, Fig, Chirounji, Jamun, Tamarind

Vegetable crops

Cucurbits and Solanaceous crops, moringa, khejri and beans

Identification a rootstocks resistant/tolerant to abiotic stresses:

Aonla, ber, bael, khejri, sapota, woodapple

Incompatibility studies in horticultural crops

Ber, aonla, underutilized fruit crops

Exploitation of Biotechnology

- **Micropropagation**

  Priority wise crops- Date palm, ker, khejri, lasoda, bael, aonla, aloevera, cactus pear (vegetable type) and other under utilized crops.

- **Development of regeneration protocol for transgenic work**

  Priority wise crops- Date palm, aonla, ber and cucurbits vegetable, chilli and other species.

- **DNA finger printing of elite genotypes, landraces and improved selection/hybrids/varieties**

  Date palm, khejri, ber, aonla, bael, cucurbits vegetables.

- **Molecular markers for QTL mapping, gene tagging, marker assisted selection, gene cloning**

  Cucurbits (water melon, mateera) chilli, dateplam, ber, aonla.

- **Gene cloning for biotic resistance-** Ber, cucurbits, aonla, date palm

C. Mass multiplication of planting materials

Clonal propgation

Ber, aonla, bael, khejri

Standardization of agro-techniques for production of certified seeds and quality planting material

Ber, aonla, bael, khejri, lasora, citrus, Cucurbits, Indian beans, Cluster beans, brinjal, chilli, aloe.

D. Physiological and biochemical mechanism in relation to plant productivity

- Physiological and biochemical mechanisms for tolerance to abiotic stresses
- Seed physiology of arid horticultural crops
- Identification and characterization of allelo chemicals

E. Soil and water management/conservation

In situ water management – rain water harvesting

In situ saoil water conservation measures through mulching, soil compaction, conservation aillage, bentonite application and bunding, microcatchment etc. Ber, aonla, lasora, khejri, jamun, custard apple, cucurbitaceous and solanaceous crops

Water management and fertigation

Ber, aonla, date palm, bael, aonla, annona, sapota, cucurbitaceous and solanacious vegetable crops

Management of problematic soil/water

Aonla, date palm, ber, Sueda (Sajji), cucurbitaceous and solanaceous crops

Development of watershed on micro and macro level

F. Integrated nutrient management

Improvement of substrate dynamics- for nutrients and microbes

Aonla, ber, date palm, custard apple, sapota, legumes and cucurbits

Organic cultivation

Ber, aonla, sapota, custard apple, cucurbits and leguminous

Evaluation of critical limits of nutrients

Ber, date palm, aonla, custard apple, lasora, citrus, sapota, beans, moringa, aloe and chilies

G. Agro-techniques

Planting system

Aonla, Ber, Pomegranate, Custard apple, Sapota, Bael, Jamun, Chiraunji

Canopy management

Ber, Bael, Khejri, Aonla, Sapota, Mahua, Jamun, etc.

Crop regulation

Ber, Aonla, Custard apple, Pomegranate, Drum stick

Plant growth regulators

Aonla, date palm, pomegranate, citrus

Insect-Plant relationship in terms of pollinization efficiency

Ber, aonla, custard apple, underutilized fruit crops and vegetables

Protected cultivation for high value crops

Off-season and high value crops

Integrated approach for weed management

Aonla, sapota, custard apple, tamarind, moringa

Production technology for vegetables: Cucurbits, solaneceous and leguminous

Identification, characterization and production technology for mushrooms

Production for exports

Aonla, ber, custard apple, khejri, ker, lasora, clusterbean and moringa

H. Planting models for arid and semi-arid ecosystem

- Date palm based cropping system
- Ber based cropping system

- Aonla-based cropping system
- Tamarind based cropping system
- Khejri (*Prosopis* cineraria) based cropping system
- Jamun based cropping system
- Bael based cropping system

I. Post harvest technology and processing

Post harvest handling

Ber, date palm, aonla, custard apple, bael, sapota, jamun, tamarind, mahua, cordia, mateera, kachri, moringa, chilli, khejri and ker

Maturity standards

Date palm, aonla, custard apple, jamun, chirounji, bael, wood apple, mateera, kachri, beans

Development of processing techniques and products

Date palm, aonla, bael, ber, khejri, custard apple, ker, *Cordia*, tamarind, mahua, jamun, mateera and kachri

J. Crop protection

Plant pathology

- Integrated management of major diseases of arid and semi-arid fruits and vegetables
- Basic and strategic research on major diseases of fruits and vegetable of arid and semi-arid regions
- Exploitation of use microbes including PGPR for plant growth promotion and disease resistance/ management
- Breeding for resistance against diseases of fruits and vegetables

Integrated pest management

- Fruit flies in ber, pomegranate and cucurbits
- Management of fruit/stem borer.
- Management of other insects

Management of the diseases caused by nematodes and viruses

K. Information systems

- Development of e-data base for arid horticultural crops
- GIS for crop productivity and natural resources management
- GIS for arid horticultural development
- Developing expert system to help in transfer of technology.

L. Extension and socio-economic aspects

- Innovative extension models for transfer of technologies.
- Dissemination of innovative technologies.
- Generation of data base of ITKs
- Off- farm research and development
- Consumption and quality pattern of horticultural commodities
- Human Resource development
- Marketing intelligence
- Impact assessment of technologies and constraints analysis
- Study of behaviourable, socio-psycho-economic aspects.

Proposal of a new regional station

Presently, the CIAH Bikaner is engaged in research and development of arid horticultural crops, which can be grown in hyper arid climate of the country. The regional research station at Godhra addresses mostly the crops grown and problem faced by the farmers of tribal belt of Gujarat. However, a large number of horticultural crops grown in arid and semi-arid conditions such as fig, jamun, tamarind, custard apple and under utilized fruits, need further attention since they are cultivated in substantial area in peninsular region of the central and southern India. In order to resolve, the problem faced by farmers of this region, it is proposed to establish new regional research station at Dhule in Maharashtra. With the establishment of this regional station, the farmers will get a boost in their production of above-mentioned crops.

Extension education and training programme

As a result of research and development of arid and semi-arid horticultural crops, fund of information and technologies have been generated which needs to be transfer to the farmers and entrepreneur. To disseminate the technologies to the end user, a large set up of human resource and infrastructure is required. In view of this to upgrade the knowledge of farmers, field functionaries and developmental officers, it is proposed to organize the short and long term training programme for which infrastructures in terms of manpower (Scientific and technical), buildings, teaching aids for establishing Trainers Training Centres is proposed at the Institute.

Educational centre for graduate programme

Most of the agricultural universities are providing undergraduate programmes either in the field of agriculture or horticulture. In both the programmes, arid horticulture occupies a minor portion in their syllabus. With globalization in agriculture and more and more participation of business houses in agriculture, there is a need to develop human resource with narrow specializations catering to the needs of entrepreneurs. Arid ecosystem due to its various merits is coming up as an ideal home for entrepreneur to produce arid horticultural crops for export. This calls for development of human resource, preferable at graduate level, to cater the needs of agricultural industries. Since, CIAH Bikaner is the premier institution devoted for research and development on arid horticultural crops and has expertise on various aspects of arid horticulture, it is proposed to initiate education programme leading to award of degree in Arid Horticulture.

9.2 SETTING OBJECTIVES ON TIME SCALE

In the preceding chapters the overall research priorities have been identified. However, the specific researchable topics/programmes need identification with a time scale for their implementation. The following matrix outlines the relevant programme on a time scale from 2007–2012, 2013–2018, and 2019–2025.

Programmes	Activity milestone		
	2007–2012	2013–2018	2019–2025
Genetic Resource Management and Utilization			
Fruits	◄——►	◄——►	◄——►
Vegetables	◄——►	◄——►	◄——►
Introduction and evaluation of exotics	◄——►	◄——►	
Crop Improvement			
Fruit	◄——►	◄——►	◄——►
Vegetables	◄——►	◄——►	◄——►
Exploitation of Biotechnology	◄——►	◄——►	◄——►
Mass Multiplication of planting materials			
Quality planting material of Fruit	◄——►	◄——►	◄——►
Certified vegetable seeds	◄——►	◄——►	◄——►

Programmes	Activity milestone		
	2007–2012	2013–2018	2019–2025
Physiological and biochemical mechanism in relation to plant productivity	◄——►	◄——►	◄—►
Integrated water management			
In-situ water management	◄——►	◄——►	
Ex-situ water management	◄——►	◄——►	◄——►
Use of poor quality waters		◄——►	◄——►
Integrated nutrient management			
Nutrient indexing	◄——►	◄——►	
INM	◄——►	◄——►	
Organic cultivation	◄——►	◄——►	◄——►
Agro-techniques			
Planting system	◄——►	◄——►	◄——►
Canopy management	◄——►	◄——►	
Crop regulation	◄——►	◄——►	◄——►
Plant growth regulators	◄——►	◄——►	
Protected cultivation	◄——►	◄——►	◄——►
IWM	◄——►	◄——►	
Planting models for arid and semi-arid ecosystem			
Ber based	◄——►	◄——►	
Aonla based	◄——►	◄——►	◄——►
Khejri based	◄——►	◄——►	◄——►
Bael based	◄—►	◄——►	◄——►
Jamun based		◄——►	◄——►
Date palm based		◄——►	◄——►
Tamarind based		◄——►	◄——►
Post harvest technology and processing			
Post harvest handling	◄——►	◄——►	
Maturity standards	◄——►	◄——►	
Processing and products	◄——►	◄——►	◄——►

Programmes	Activity milestone		
	2007–2012	2013–2018	2019–2025
Plant protection			
IPM	← →	← →	← →
IDM	← →	← →	← →
Information systems	← →	← →	← →
Extension & socio-economic aspects			
Innovative estension models for TOT	← →	← →	← →
Dissemination of innovative technologies	← →	← →	
Generation of data base of ITKs	← →	← →	← →
Off-farm research and development	← →	← →	← →
Human resource development through extension	← →	← →	← →
Marketing intelligence for horticultural products			
Impact assessment and constraints analysis			
Study of socio-psycho-economic aspects			

9.3 FUNDING NEEDS OF THE PROGRAMME

	Programme	Rs in lakhs
A.	Introduction, collection, characterization, conservation and evaluation of horticultural biodiversity	1,000
B.	Genetic improvement in horticultural crops	750
C.	Mass multiplication of planting materials	1,000
D.	Growth and development of horticultural crops under abiotic stresses	750
E.	Water management in horticultural crops.	750
F.	Integrated nutrient management in horticultural crops	750
G.	Agro-techniques for improving productivity of horticultural crops	2,000
H.	Development of planting models in horticultural crops for arid and semi-arid ecosystem	1,000
I.	Post harvest handling and processing studies in arid and semi-arid horticultural crops	1,500
J.	Integrated pest and disease management in arid and semi-arid horticultural crops	1,000
K.	Information system	500
L.	Social sciences and TOT	1,000

9.4 AICRP ON ARID ZONE FRUITS

Research on fruits like ber, date palm, pomegranate, fig, custard apple, etc. was initiated on adhoc basis since 1976 under AP Cess Fund Scheme entitled "Research on some selected fruits in the semi-arid areas in India" at 10 centres. During the Sixth Five Year Plan, this ad-hoc scheme was merged as such and was named as the Cell III of the AICFIP. At present, there are 12 centres functioning under the Project.

The technologies generated by the CIAH will be tested on all India basis at the centres of the AICRP on Arid Zone Fruits so as to arrive at usefulness and applicability of results at different locations in the country. The AICRP on Arid Zone fruits will also continue to conduct multilocation testing of the technologies generated by different institution/organizations in the country, which are conducting research on the fruits relevant to these areas. In the biennial meeting held at NDUAT, Faizabad (March 2004), CISH, Lucknow was identified as new centre of AICRP-AZF.

Proposal of new centres AICRP on Arid Zone Fruits in SAUs

At present, The All India Coordinated Project on Arid Zone Frits is function at 13 centres located in SAUs and ICAR institutes. Over the years, a large number of technologies have been generated for arid and semi-arid fruit crops which requires multi-location testing even no- traditional areas, Accordingly it is proposed to open following centers of AICRP on AZF to conduct the trials on crops identified for each as detailed below:

S. No.	Name of University	Location of Centre	Mandate crops
1.	Sher-E-Kashmir University of Agriculture & Technology, Sri Nagar	Leh	Nuts and Fruits of cold desert
2.	Jwahar Lal Nehru Krishi Viswa Vidhyala, Jabalpur	Sagar	Arid and semi-arid Fruits
3.	IGKVV, Raipur	Jagdalpur	Semi-arid fruits
4.	Central Agricultural University, Manipur	Paighat	Aonla, Jamun,

10. LINKAGES, COORDINATION AND EXECUTION ARRANGEMENTS

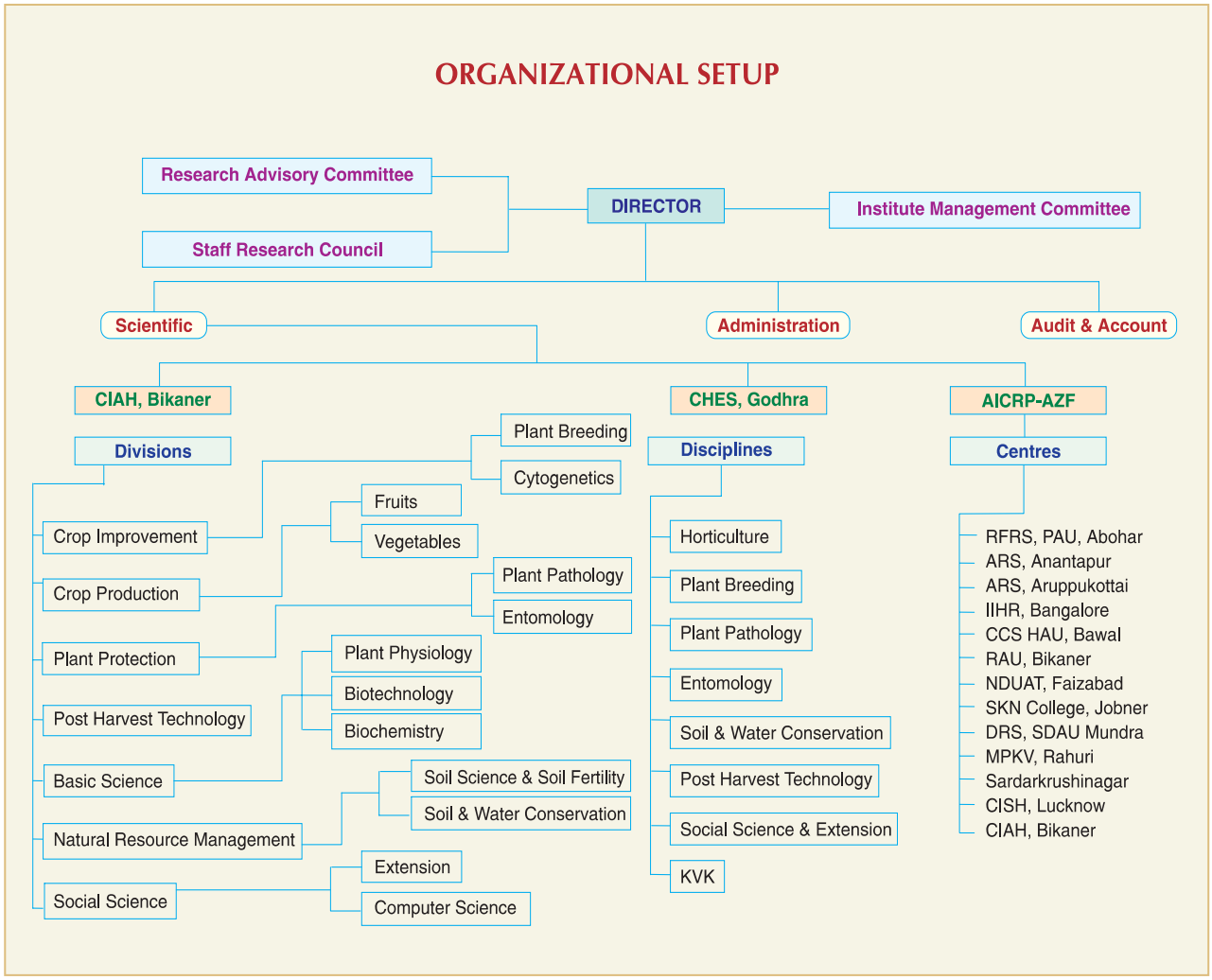
10.1 LINKAGES

Institution	Area of Collaboration
National	
(a) National Bureau of Plant Genetic Resources, New Delhi	Germplasm survey, collection, cataloguing and evaluation
(b) Central Arid Zone Research Institute, Jodhpur	Collaboration in soil and water conservation, cropping system research and fabrication/ evaluation of solar driers.
(c) Indian Institute for Horticultural Research, Bangalore	Collaboration will be established for assessment of genotypes of commercial horticultural crops for endurance to arid zone conditions.
(d) Indian Institute for Vegetable Research, Varanasi	Collaboration will be established for assessment of genotypes of commercial vegetable crops for endurance to arid zone conditions.
(e) Central Institute for Sub-Tropical Horticulture, Lucknow	Collaboration will be established for assessment of genotypes of commercial mango, guava, bael, aonla for endurance to arid zone conditions.
(f) Central Soil Salinity Research Institute, Karnal	Collaboration will be established for assessment of genotypes of fruits and vegetables against salinity.
(g) Indian Agriculture Research Institute, New Delhi	Collaboration in crop improvement through biotechnological approach.
(h) MPKV, Rahuri (Maharashtra)	Collaboration in collection, conservation and evaluation of pomegranate genotypes.
(i) PAU, Ludhiana (Punjab)	
(j) NDUAT, Faizabad (UP)	Collaboration in collection, conservation and evaluation of aonla and bael genotypes.
(k) GB Pant University of Agriculture and Technology, Pantnagar (Uttarnchal)	Survey, collection of frost resistant germplasm of aonla and ber.

Institution	Area of Collaboration
(l) CCS HAU, Hisar (Haryana)	Survey, collection and evaluation of ber genotypes.
(m) Rajasthan Agricultural University, Bikaner (Rajasthan)	Development of farming system for arid and semi-arid regions.
(n) SDAU, S.K. Nagar, Gujarat AAU, Anand, Gujarat	Germplasm, survey, collection of date palm.
(o) TNAU, Coimbatore, (TN)	Integrated pest management.
(p) ANGRAU, Hyderabad (AP)	Collaboration in exploration and research on tamarind, custard apple etc.
International	
(a) The Hebrew University of Jerusalem, Israel Ben-Gurion University of the Negev	Pressurize irrigation. Protected cultivation
(b) Govt. of Egypt	Micropropagation of date palm
(c) Govt. of Iraq	Production technology of date palm
(d) Govt. of Iran	Production technology of date palm, pomegranate and melons
(e) Republic of Uzbekistan	Production and post harvest technology
(f) UAE	Introduction of date palm
NGO's and other organization SAUs such as RAU, Bikaner, SDAU, SK Nagar, AAU, Anand, CCS HAU, Hisar, MPUAT, Udaipur, IGKVV, Chattisgarh, JNKVV, Jabalpur including N.E. Regions.	Research and Education
Farmers, NGO's and Industries	For feedback for technology adoption and technology refinement

10.2 COORDINATION AND EXECUTION

The Director, Central Institute will effect the execution and coordination of the programme for Arid Horticulture as per its mandate and priorities fixed from time to time by the Division of Horticulture, ICAR and the relevant Committees of the ICAR through the instruments of the Management Committee and Staff Research Council. The programme will be implemented by the different research laboratories supported by technical and other units as illustrated below:



Organizational Setup

11. CRITICAL INPUTS

11.1 FUNDING (PLAN+NON PLAN)

X Plan (2002–2007 AD) 1,727 lakhs

Total (2007–2025 AD) 12,000 lakhs

11.2 MANPOWER

The manpower requirement is given below:

Cadre	Existing	Sanctioned	Beyond X Five Year Plan
Scientific	25	36	100
Technical	42	42	150
Administrative	25	25	50
Supporting	37	37	150

12. RISK ANALYSIS

The research strategy of CIAH will be directed towards solving problems in horticultural productivity in backward areas of the arid and semi-arid region, which is well known to have uncertainties in productivity of largely rainfed crops. Even in irrigated micro pockets, the potential productivity diminishes under the extreme conditions, which are of recurrent occurrence. The drought epidemics are common. Therefore, germplasm conservation will have to take care of these risks besides the biotic interferences by wild life and owing to proximity to international border. The problems related to drought, erratic rains and extreme radiation would have to be considered in experimental procedures to be adopted.

13. PROJECT REVIEW, REPORTING AND EVALUATION ARRANGEMENTS

The CIAH is part of the Division of Horticulture headed by Deputy Director General (Horticulture) in Indian Council of Agricultural Research under the Department of Agricultural Research and Education, Government of India, New Delhi. A Management Committee will oversee and catalyze the Institute's activities and a Research Advisory Committee and Staff Research Council will advise on its research needs, priorities and approaches through periodic meetings. The Division of Horticulture

of the ICAR will constantly monitor the research programmes and other activities of the Institute.

The results of the work done will be published every year in an Annual Report besides through other publications. A Quinquennial Review Team constituted by the ICAR will review programmes and approaches every five years.

14. RESOURCE GENERATION

Consultancy could be provided to development functionaries of Government and Non-Governmental organizations as well interested growers/entrepreneurs for field application of the technologies through organizing various training programmes. In due course consultancy could also provided for establishment of seeds and plant multiplication units intensive field production units for field productions as well as post harvest utilization infrastructure and research and technological education organizations.

The Institute will be able to generate the sufficient revenue from the sale of quality planting and seed material of the developed varieties, sale of the products, patenting of the technologies, providing consultancy to the big cooperative farming and sale of Institute's publications.

15. OUTPUT AND EXPECTED SITUATIONS

It is hoped that up to end of 2025, the Institute would generate enough competent technologies for horticultural crops production in arid and semi-arid region which will leads to production of sufficient fruits and vegetables to meet the requirements of increasing population of the country and revenue generation from international markets by exporting quality products of arid horticultural crops. It is also expected that the horticultural development in arid regions will helpful in maintaining the agro-ecological balance and biodiversity in arid regions.

16. OUTCOME

All the technologies developed by the Institute and significant achievements having outcome values will be categorized into public and private domain. All the technologies under public domain will be transferred to the farmers and other stake holders with the participation of development agencies. The technologies under private domain would be taken up for further commercialization to corporate houses, trade organization and private industries at cost either on exclusive/ non-exclusive transfer of rights or on profit sharing basis. The technologies developed on value addition of produce will provide an opportunity to small scale entrepreneur to develop cottage industry. This will lead to development of horticulture scenario in arid region, improve the economic status of the farmers and provide employment to the youth and farm women.

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