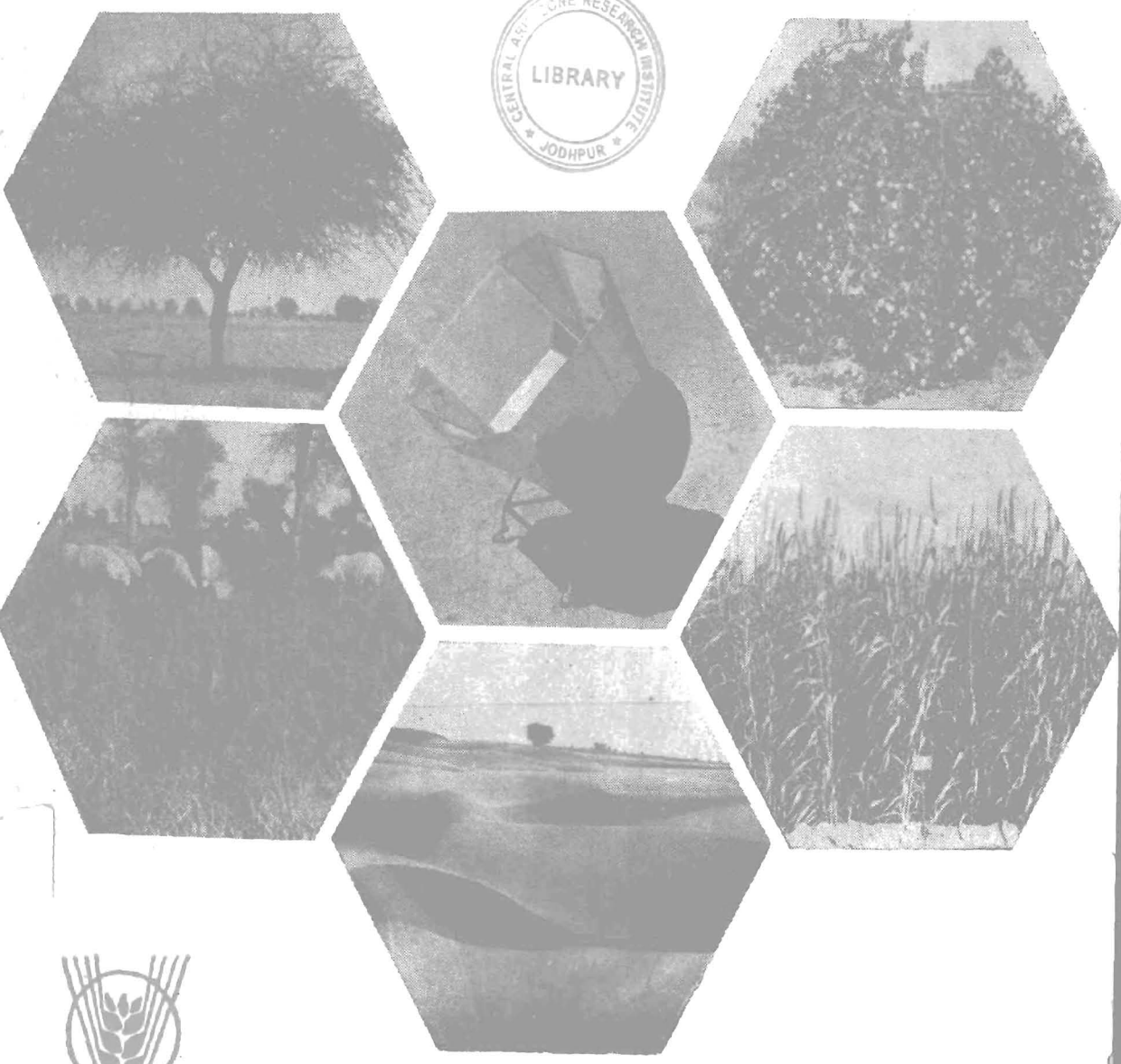
25 YEARS OF ARID ZONE RESEARCH 1952-77



ICAR

Central Arid Zone Research Institute Jodhpur

CAZRI

25 Years of Arid Zone Research
1952-77

ICAR

CENTRAL ARID ZONE
RESEARCH INSTITUTE
JODHPUR-342 003

October, 1979

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PREFACE

The importance of the problems of the Indian desert and its vital role in the development of national economy was realised soon after India attained independence. The statement made by the Planning Commission that the Indian desert was spreading outwards in a great convex arc, at the rate of half a mile per year, and the resolutions of the Symposium" The Rajputana Desert" organised by the Indian National Science Academy (INSA) in 1952 aroused consciousness in the nation about its development. Consequently, the Government of India based on the recommendation of an UNESCO Advisory Committee for Arid Zone Research, established a Desert Afforestation Research Station at Jodhpur in 1952, expanded it as the Desert Afforestation and Soil Conservation Station in 1957. It was further reorganised and redesignated as the Central Arid Zone Research Institute, (CAZRI), in 1959.

During the last 25 years, the Institute has kept pace with the progress and development in the country and has grown into full-fledged research organization of national as well as international importance. It conducts researches in the general field of arid zone ecology which includes climatology, geomorphology, geology, hydrology, pedology, soil conservation, systematic botany, agrostology, range management, silviculture, horticulture, plant breeding, plant ecology and plant physiology, agronomy, dry farming, agricultural chemistry, agricultural engineering, agricultural economics, statistics, animal ecology, animal physiology and nutrition, rodent pest management, toxicology and plant protection, solar and wind power utilization and sociology.

During the last two and a half decades, the Institute has developed technologies to control and reclaim the arid areas and to improve the productivity of both land and livestock. The Institute, in collaboration with the State Development Departments, is engaged in the task of transferring technologies to the farmers through Operational Research Project and Lab to Land Programme. In short, as a result of the continuing efforts of the CAZRI, the Thar desert can claim to be one of the best studied deserts of the world and CAZRI the largest data-base on arid lands.

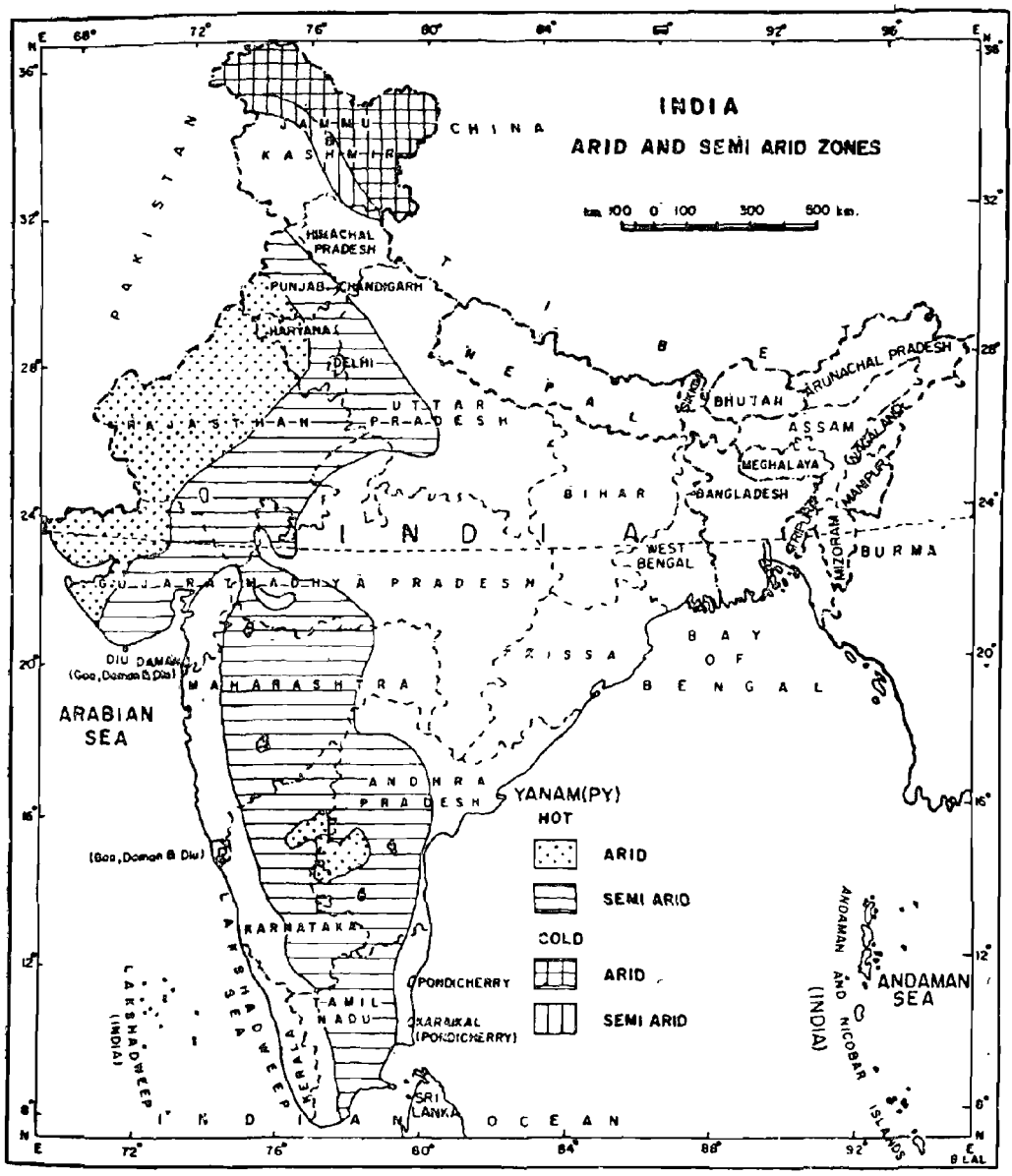
The CAZRI has been conducting Training and Education Programmes and has organised several International Symposia, Training Courses, Workshops, Summer Institutes and Winter Schools for the benefit of the Afro-Asian countries. A number of scientists are on the advisory panel of UN and other International and National Organisations.

The results of research conducted by CAZRI have been published in national and international scientific journals besides the Annual Reports of the Institute. Popular and semi-technical articles have also been published. In order to meet the ever increasing demand from various agencies for the research results and other details of the CAZRI, a resume of the major activities and achievements is presented in this bulletin.

I am grateful to the scientists of the CAZRI for their contribution for inclusion in this publication. Shri Gian Chand, Technical Officer, CAZRI has compiled and edited this bulletin. His work to bring this bulletin in its present form deserves appreciation. Comments and suggestions for improvement for incorporation in the subsequent issues of this bulletin will be welcome.

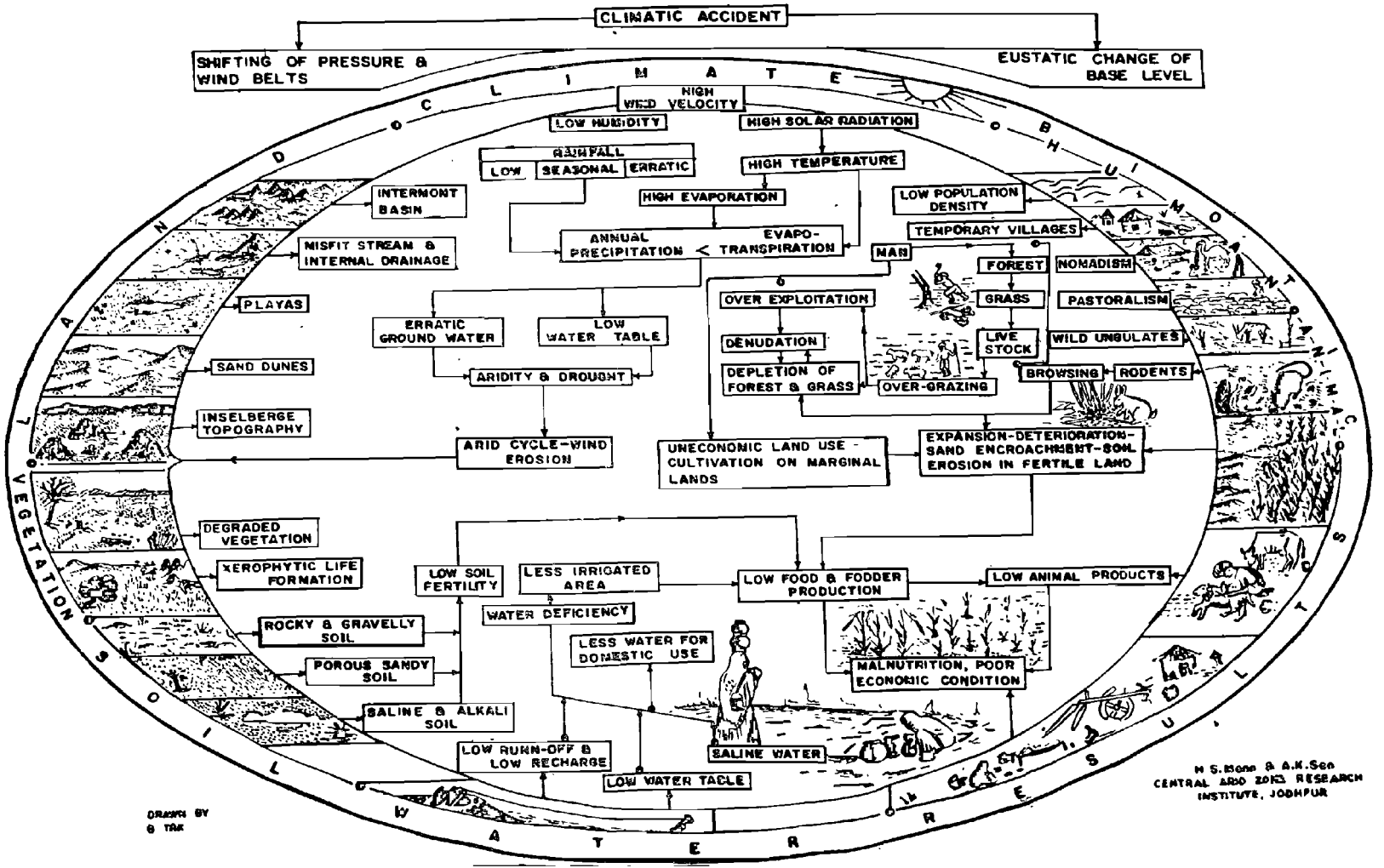
H. S. MANN
Director
Central Arid Zone Research Institute
Jodhpur

Jodhpur
August, 1979



Based on Survey of India Map with the permission of Surveyor General of India.
The boundary of Meghalaya shown on this map is as interpreted from the North-Eastern Area (Reorganisation) Act, 1971, but has yet to be verified.
The teritorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line.

DESERTIFICATION



25 YEARS OF ARID ZONE RESEARCH

INTRODUCTION

Man's struggle against aridity started in antiquity. Until recently most of the success in obtaining higher productivity in arid regions came through the trial and error method and through learning from successful experience. Age-old practices like *khadin* cultivation in western Rajasthan and the use of stone catchments and cisterns in Negev (Israel) are quite well known, besides being testimonies to human ingenuity. History is a good guide to tell us the relationship of man to his land, his domesticated animals and to the vegetation in the arid regions. Great civilizations are known to have flourished in these regions. However, the quality of life has remained generally poor. Therefore, to attain a reasonably good standard of living for the desert people, scientific knowledge and developmental technology for optimum use of the available resources become increasingly important.

The Arid Zone of India occupies about 12 percent of the country's geographical area with a human population of over 20 millions, a part of which is nomadic, maintaining a livestock population of about 23 millions. The human and livestock population in our desert are rather high, considering the scarce and delicately balanced resources of the region.

The general problem of arid and semi-arid areas with large populations is essentially one of human ecology. In the absence of adequate scientific knowledge and prevailing attitudes, the local population has over-exploited the natural resources resulting in an ecological imbalance. Where large scale water resources from outside the arid regions cannot be tapped, the inherently meagre and fluctuating water resources within the region set the ultimate limit to production of plant material which sustain both human and animal population. Erratic rainfall results in fluctuating production.

This, in turn, leads to frequent scarcities. As the population increases the stress becomes greater. Eventually, there is an increasing rate of imbalance between the human and animal populations on the one hand, and plant, water and land resources on the other. As the human demands persist and intensify, the resources tend to become further depleted. Thus, there is set into operation, a process of progressive desertification. If continued unchecked, it leads to permanent damage to vegetation through excessive grazing or cutting for fuel leading to their replacement by bare land, or, at best, by less useful plant communities, to the loss of surface soil by water or wind erosion, to lower soil fertility and ultimately to the production of large areas of waste land or of barren sand dunes which are not only unproductive but may involve considerable public expenditure where they encroach on community services.

As a result of the cumulative effect of all these processes, changes are brought about in both the hydrology of the region and its micro-climate, which tend to create a more-arid and less-productive environment. Nevertheless, such vast areas with abundant natural assets like plenty of sunshine, soil responding to management, round the year possibility of plant production and a healthy climate have definite potentiality for development.

Realising the importance of the problems and the potential of the area, the Government of India established a Desert Afforestation Research Station at Jodhpur in 1952 to carry out afforestation research work and forestry extension including the erection of shelter belts and afforestation of sand dunes and wastelands unfit for cultivation of crops. In 1957, the scope of the station was enlarged by inclusion of soil conservation programmes, and it was named as the Desert Afforestation and Soil Conservation Station for conducting researches for development of crop husbandry and grasslands.

Subsequently, it was felt necessary to establish a full fledged research institute at Jodhpur for undertaking basic and applied research for the development of the arid areas of the country. On the recommendations of Mr. C.S. Christian of the CSIRO, Australia, the Desert Afforestation & Soil Conservation Station was reorganised in 1959 as the Central Arid Zone Research Institute. In April, 1966 the administrative and technical control of the Institute was transferred from the Ministry of Food and Agriculture to the Indian Council of Agricultural Research. The UNESCO and the Government of Australia have taken very keen interest in the development of this Institute by providing funds, equipments, books and journals and the facilities for training of the scientists abroad.

Objectives of the Institute

The Institute has the following major objectives :

1 Identification of the problem through integrated survey involving geomorphic, geohydrological, pedological, biological, climatic and sociological aspects over a cartographic overlay and to suggest measures for the overall development of the arid and semi-arid regions of India.

2 Evolving silvicultural, grassland and pasture management technologies under different soil, rainfall, biotic conditions and to achieve the optimum use of the natural resources.

3 To explore the underlying principles of soil-water-plant-environment relationships for their gainful utilization through newer technologies to augment plan production in arid and semi-arid areas.

4 Development of technologies for harnessing wind power, solar and bio-energy for human benefit with special reference to prevailing agro-climatic conditions of desert biome and its modulation over time.

5 To make an inventory of the animal, insect, vertebrate pests, wildlife and livestock resources and to devise suitable measures for their management for enhancing the productivity of the arid lands.

6 To study the available human resources in the arid and semi-arid areas and to suggest ways and means for their optimum utilization.

7 To expose the rural population to recent technologies and their economic benefits, to monitor gains of the newly evolved plant and animal husbandary methods through extension programmes, to impart short term trainings for quicker impact on the management of desert and to study constraints in the transfer of technology.

Organisation*

The CAZRI comprises of the following eight Divisions with three experimental Research Farms, twelve Range Management and Soil Conservation centres situated in different bioclimatic zones and a few forestry areas and nurseries.

1 Division of Basic Resources Studies
2 Division of Plant Studies
3 Division of Animal Studies
4 Division of Wind Power and Solar Energy Utilization Studies

* Organisational chart is enclosed.

5 Division of Soil-Water-Plant Relationship Studies
6 Division of Economics and Sociology
7 Division of Extension and Training
8 Division of Agricultural Economics (Proposed for the Sixth Five year Plan)

Besides, the main centres of the following All India Co-ordinated Projects of the Indian Council of Agricultural Research are also located at the Institute :

1 All India Co-ordinated Research Project for Dryland Agriculture
2 All India Co-ordinated Millets Improvement Project (AICMIP)
3 Integrated Project for Research on Water Management and Soil Salinity
4 Co-ordinating centre of the All India Co-ordinated Research Project on Rodent Control
5 Operational Research Project on "Drip and Sprinkler Irrigation" and Arid Land Management.

The Research Projects are organised, planned and executed on a multi-disciplinary basis with problem-oriented approach.

The Division of Basic Resources Studies is mainly engaged in integrated surveys of natural resources, including climate, soil, landscape, water, vegetation, livestock and human resources to identify the problems limiting production and to assess the potentials and suggest optimum utilization of the resources, beside monitoring of desertification processes.

Division of Plant Studies conduct research on problems of reclamation, utilization, management, improvement and maintenance vegetation, crop and livestock resources with a view to evolve packages of practices for increasing the productivity of crops, grasses, pastures, livestock, horticultural and forestry plants.

Division of Animal Studies is engaged in studies on physiological adaptive mechanism and nutritional requirements of desert breeds of sheep and goat and conduct ecological studies on wildlife and vertebrate pests, particularly rodents with a view to develop suitable control measures.

Division of Wind Power and Solar Energy Utilization Studies in collaboration with other disciplines is engaged in designing, fabricating and testing of prototype devices for utilizing the wind power and solar energy. Investigations on water and energy balance of plants under different agro-climatic and soil conditions and

dynamics of soil moisture in stabilized and shifting sand dunes, preparation of agro-climatic reports and wind erosion studies are also being undertaken.

Division of Soil-water-plant Relationship Studies undertake researches on physiology of the plants adapted to arid environment, plant nutrient availability, erosion hazards and crop production, maintenance and build-up of soil fertility, physical conditions of the soil and their moisture retention, micro-organism population, efficient use of limited water under arid conditions for producing the crops economically, varietal trials and cultural practices, optimum fertilizer use, weed control and cropping patterns etc. to evole suitable technology for the management of arid lands consistent with maintenance of soil productivity and ecological balance.

Division of Economics and Sociology undertakes Socio-economic surveys of the settled and nomadic human resources of the arid areas. The scope and economics of different farm and livestock enterprises, and evaluation of the improved agricultural practices developed at the Institute on the basis of input-output relationships is worked out before testing at the farmers field.

Division of Extension and Training carries out demonstrations on farmers fields and prepares literature for the benefit of extension workers and other agencies engaged in the development of arid zone. Liaison with the development agencies, organising and participation in the training programme is an important activity of this Division. It is primarily engaged in transferring the tested technologies from research farms to the farmer's fields. For this the division is imparting training and education to various levels of workers engaged in development works. Demonstrations of different technologies on 'entire farming system approach', are being effectively carried out through Operational Research Projects on "Arid Land Management" and "Drip and Sprinkler methods of Irrigation".

Co-ordinated Projects

Under the Co-ordinated Research Project on Dryland Agriculture, studies are being conducted for developing an integrated technology to maximise and stabilise broad base crop production under varying rainfall patterns (below normal, normal and above normal) through i) identification and breeding of suitable varieties of crops, ii) identification of new alternative crops, iii) developing agronomic practices and methods of soil fertility improvement, iv) designing appropriate implements and

machinery for various methods of soil tillage, and v) evolving suitable water harvesting and moisture management technology.

Co-ordinated Millet Improvement Project is engaged in the evaluation and breeding of new composites and hybrids of Bajra suitable for the arid tract and also in giving suitable agronomic recommendations. Also included are studies to assess the suitability and yield potentials of different minor millets for the arid zone and the release of high yielding varieties.

Integrated Project for Research on Water Management and Soil Salinity conducts investigations on the optimum use of irrigation water for intensive cropping in arid regions with special reference to soil salinity.

Under the All India Co-ordinated Research Project on Rodent Control, studies on behaviour of rodents, bait shyness and sex attractants are in progress at four centres in India (Jodhpur, P.A.U. Ludhiana, U.A.S. Bangalore and C.P.C.R.I. Kasargod. CAZRI is also the Co-ordinating and Monitoring Centre for Rodent Research and Training under the National Programme for Rodent Pest Management. The Centre publishes a quarterly Rodent Newsletter.

FACILITIES

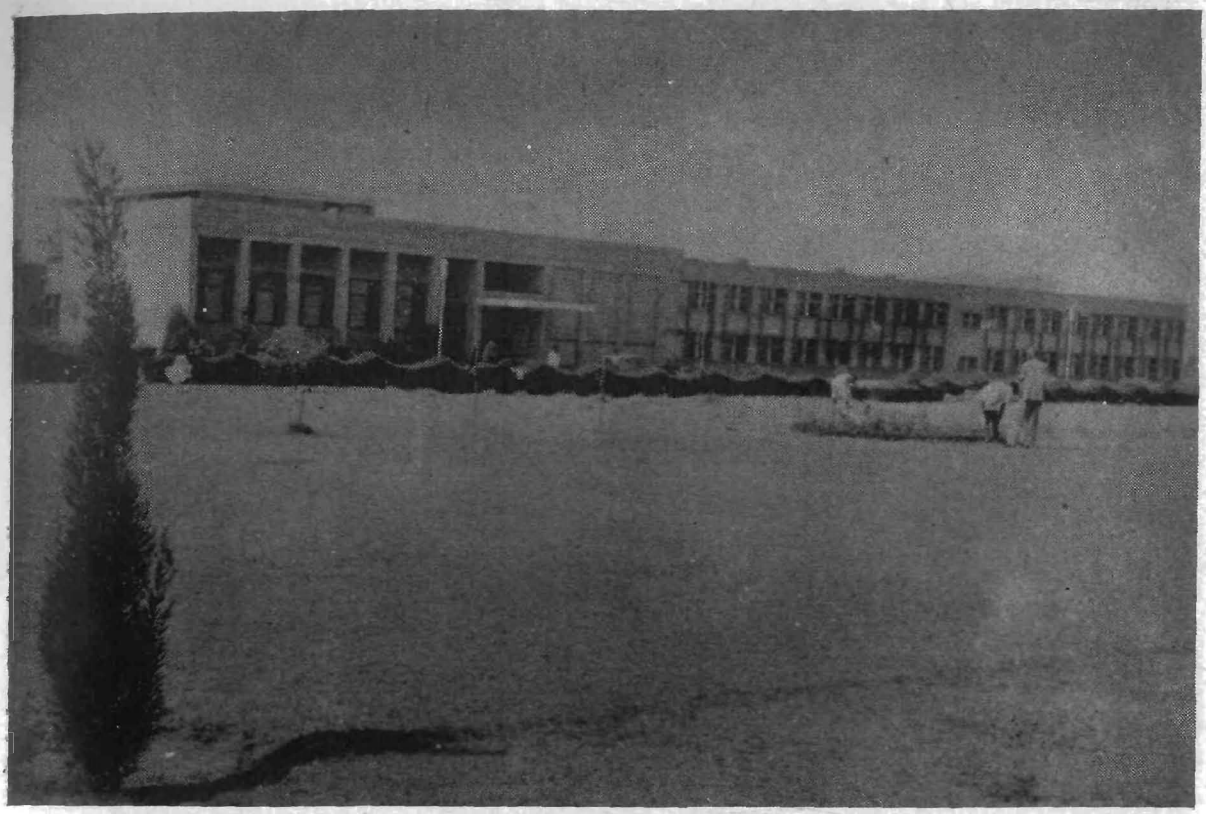
Experimental Farms, Sand dune afforestation and Range Management Centres

For field investigations, the Institute has the following stations located at different bioclimatic zones in western Rajasthan :

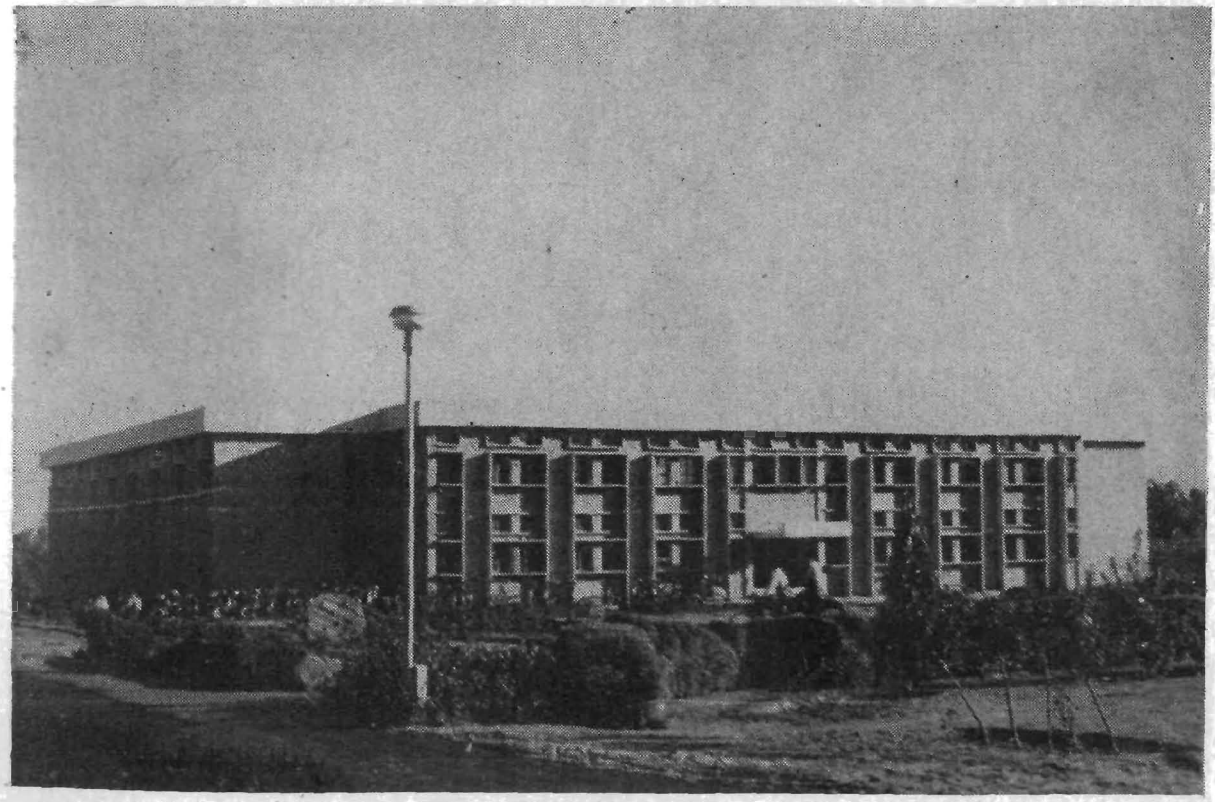
Research Farm	Area in hectares
1 Jodhpur	283.48
2 Pali	380.40
3 Bikaner	192.00

Range Management and Soil Conservation Centres

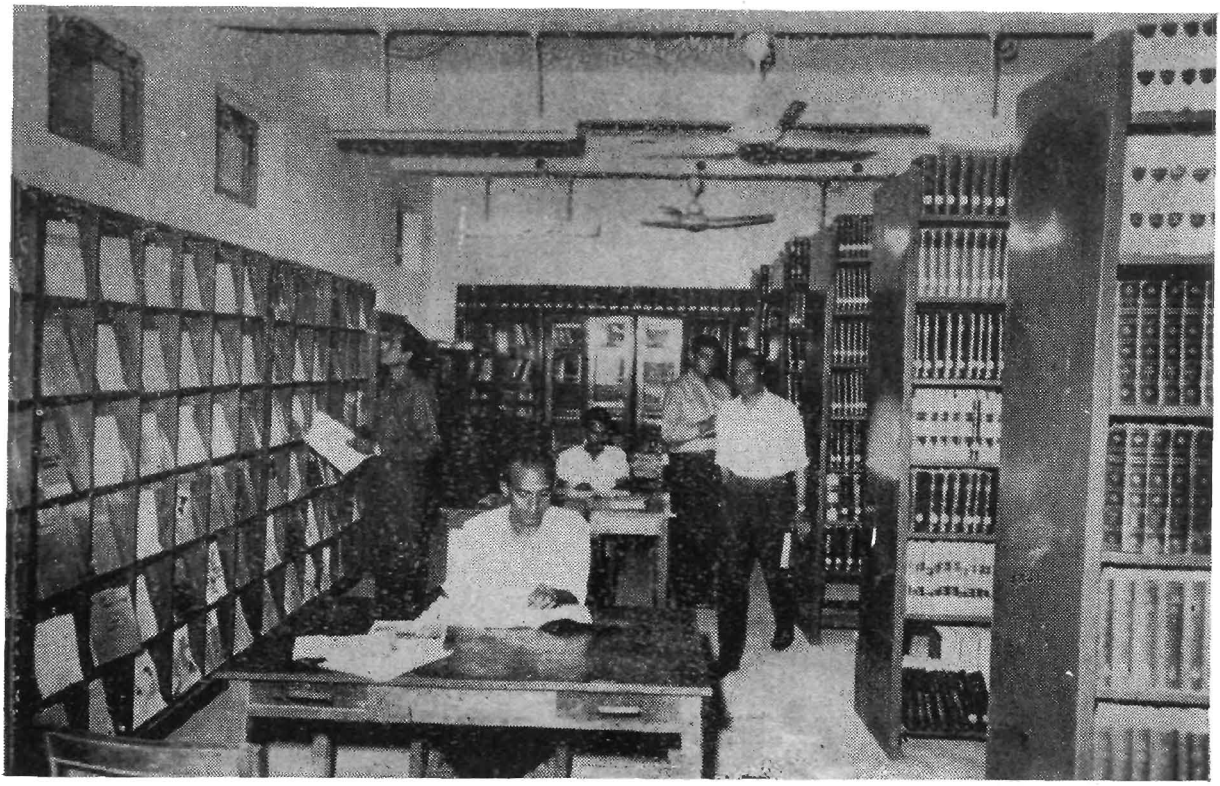
1 Jaisalmer	133.94
2 Chandan	95.10
3 Khetolai	70.94
4 Lawan	168.34
5 Beechwal	71.22
6 Bhopalgarh	51.39



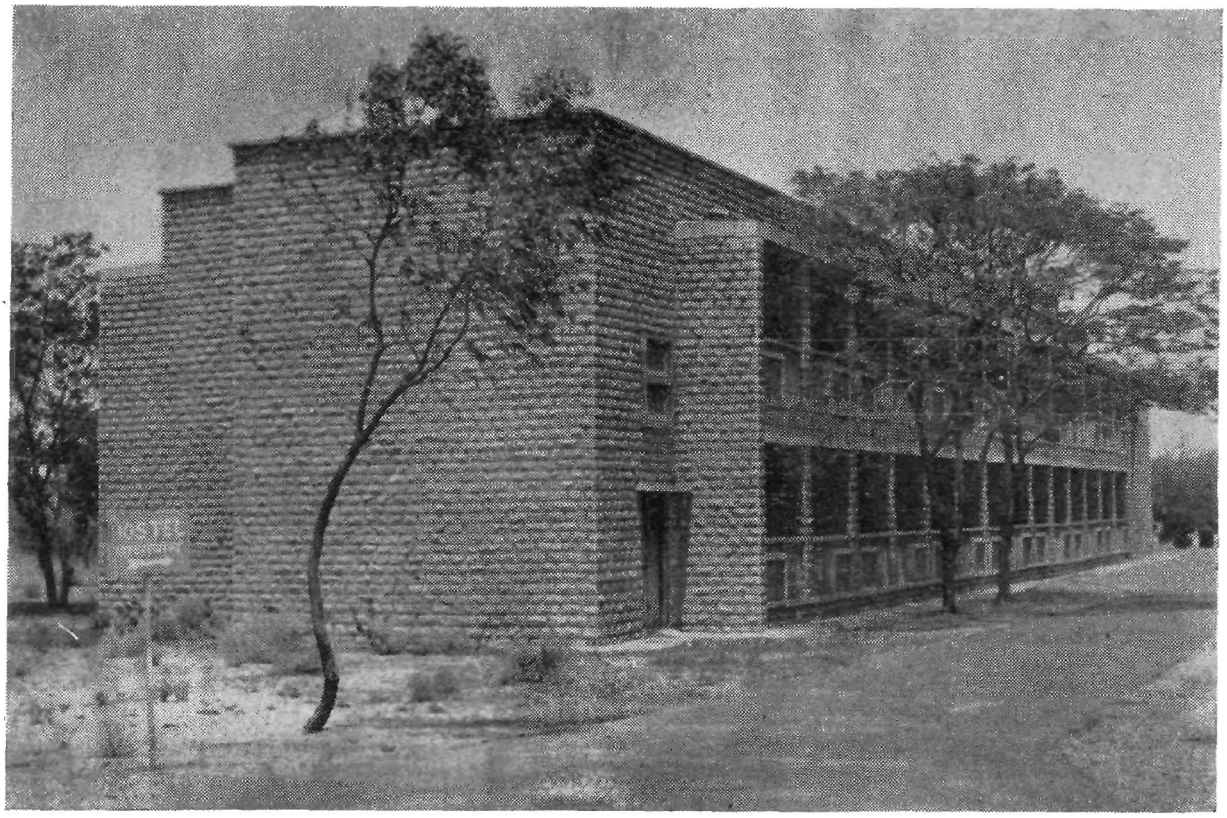
Main Laboratory building, CAZRI



Soil-water-plant relationship Laboratories, CAZRI



A view of CAZRI Library



A view of CAZRI Hostel for trainees

7	Borunda	67.58
8	Bisalpur	63.13
9	Jadan	76.89
10	Samdari	81.12
11	Jaswantgarh	76.48
12	Palsana	73.65

Afforestation and Sand dune fixation sites

1	Udramasar	177.65
2	Shivbari	10.11
3	Shri Kolayatji	12.14
4	Kailana	311.85
5	Beriganga	262.68

To support afforestation and extension works forest nurseries are conjointly working with the above areas.

Laboratories

The Institute has three spacious Laboratory and office buildings and a Solar EnergyYard, situated at the Research Farm at Jodhpur. The laboratories are well equipped with modern scientific equipments procured from both within the country, as well as abroad through the generous assistance of UNESCO under its UNDP programme and by the Government of Australia under Colombo Aid Programme.

Library

The Institute has a very good Library with a collection of 10634 books, 150 Indian and 150 foreign Journals and a considerable number of scientific reports, bulletins, pamphlets and reprints etc. on arid zone research and development. The Library serves the need of scientists as well as research workers, trainees and scientists from other sister organizations. CAZRI publications are being requested by an ever expanding circles of readers in various countries engaged in arid zone research.

Audio Visual Equipments : The Institute is having all sorts of sophisticated Audio Visual Aids like slide and 16 mm film and sound projector, over head projectors, public address systems and a complete set of automatic conference system with 25 microphones.

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Museum

The Institute has a museum where the various problems, constraints and technologies evolved by the Institute to tackle these problems have been depicted with the help of photographs, charts, models and specimens.

Herbarium

The Institute has an ecological herbarium mostly representing the flora of Western Rajasthan. So far over 6000 sheets belonging to 73 families, 326 genera and 850 species have been intercalated.

Auditorium and Conference Hall

The Institute has a spacious Auditorium with a capacity to seat 114 persons and a Conference Hall to accommodate over 90 persons. The Auditorium and Conference Hall are fully furnished with screens, projectors, public address equipment and conference microphone system with other allied facilities for conducting symposia, seminars, meetings, workshops etc.

Hostel

There is a hostel building which has 50 fully furnished single bed rooms and a spacious dining hall with attached Kitchen. This is being used by visitors, trainees and research students besides staff members.

Accommodation

At present there are 82 residential quarters of different types constructed at the Central Research farm, Jodhpur.

Guest House

There is a guest house for the use of visiting Scientists.

Others

Besides the above the Instiitute has a Photo-laboratory, Instrument Repairs Cell, Field Laboratory, Botanic Garden and Automobile Workshop at the Central Research Farm, Jodhpur.

Extension, Training and Education

The Institute actively participate in the publicity and extension work so as

to create awareness about the desertification problems, and to achieve public participation in the development programmes of the region.

To achieve this objective the seeds and seedlings of promising desert species are supplied to progressive farmers and state development agencies including forest departments.

An Operational Research Project to try and demonstrate the package of practices evolved by the Institute at farmers field has been initiated in a group of five villages near Jodhpur.

The important research achievements of the Institute are also highlighted through models, charts and display boards in the National and local exhibitions and in the farmers fairs.

The Institute also imparts training to the State Development Officers, Army Officers of the Desert School and other trainees from various sister organizations and Agricultural Universities in the field of aerial photo interpretation and applied geomorphology, resource survey and land use planning, arid zone forestry, rodent control and desert development etc.

Research Collaboration Overseas and with other Institutions

A close liaison is being maintained with the State Development Departments, Agricultural Universities, DPAP and other ICAR Institutes with a mission similar to that of CAZRI for mutual benefit.

The value and relevance of the research carried out at this Institute is well reflected in the formation of the development plans in the states viz., Rajasthan, Haryana and Gujarat.

The CAZRI has been actively collaborating with the international agencies engaged in the arid zone research. It has attained international recognition to its contribution to the science in arid zone technology. In recognition for this, the CAZRI was entrusted a case study on Desertification by the UNESCO. In addition to the above, the technology developed by the Institute and other agencies was compiled by the Indian Council of Agricultural Research in its publication "Desertification and its control" and presented to the United Nations Conference on Desertification held at Nairobi (Kenya) from August 29-September 9, 1977, which was highly appreciated.

Recently the International Symposium on Arid Zone Research and Development, held at Jodhpur, has recommended that the scientific competence and skill available at CAZRI may be utilized for training the scientists and technicians in desert technology by the countries in Asia and Africa. Presently it is collaborating in the following three international projects :

(a) UNESCO's "Man and Biosphere" project No. 3 'Productivity of Grazingland Ecosystem'

(b) Monitoring of Desertification Processes and related Natural Resources in Arid and Semi-Arid areas of South-West Asia".

(c) "Social Aspect of Desertification Processes."

Research Association

To promote active researches on various aspects of the arid zone, an Arid Zone Research Association was established by the research staff of the Institute in 1962. A large number of scientists interested in arid zone research and belonging to different countries throughout the world are now members of the Association. A quarterly scientific journal, viz., *Annals of Arid Zone*, is being published by the Association and so far 16 volumes have been published.

Extent and Distribution of Indian Arid Zone

Based on detailed studies on aridity index the boundaries of the arid and semi-arid zones in India have been demarcated and the percentage area and population inhabiting these areas are presented in Table 1.

Table 1 : *Area and Population in Arid and Semi-arid zones of India*

	Population (1971) in lakhs			Density of Population/sq Km		
	State	Arid zone	Semi-arid zone	State	Arid zone	Semi-arid zone
Rajasthan	257	86	150	75	44	120
Gujarat	267	30	162	136	45	174
Punjab	135	27	16	268	189	300
Haryana	100	20	67	255	152	255
Maharashtra	417	2	267	164	158	142
Andhra Pradesh	434	22	182	157	108	147
Karnataka	293	9	222	153	112	159

	Population (1971) in lakhs			Density of Population/sq Km		
	State	Arid zone	Semi-arid zone	State	Arid zone	Semi-arid zone
Jammu and Kashmir	46	0.7	0.2	**	**	—
Uttar Pradesh	884	—	250	300	—	391
Madhya Pradesh	417	—	62	94	—	105
Tamil Nadu	411	—	249	316	—	292
Total	3661	196	1697	162++	61+	182

*Includes area under illegal occupation of Pakistan and China.

**Could not be worked out because no census was possible in the areas which continue to be under illegal occupation of Pakistan and China.

+(1) Excludes area of NEFA (2) Total may not tally because of rounding.

++ Excluding Jammu and Kashmir and North-East Frontier Agency.

	Percent area		Percent Population	
	Arid zone	Semi-Arid zone	Arid zone	Semi-Arid zone
Rajasthan	57.42	36.67	33.47	58.37
Gujarat	33.72	47.50	11.18	60.56
Punjab	28.60	75.40	20.11	64.02
Haryana	29.32	59.77	19.70	67.36
Maharashtra	0.42	61.17	0.49	64.69
Andhra Pradesh	7.18	44.66	4.99	41.89
Karnataka	4.27	72.60	3.14	75.72
Jammu and Kashmir	31.13*	6.22	1.64	0.33
Uttar Pradesh	—	21.73	—	28.26
Madhya Pradesh	—	13.38	—	14.19
Tamil Nadu	—	65.54	—	60.48
Total	12.13	29.17	3.6	31.00

Aridity explained

In view of the strong monsoon circulation peculiar to the Indian subcontinent, the weather conditions during monsoon in the Indian arid zone are different

from those of other deserts. Though actual rainfall is low here, the humidity of the air is high and is almost similar to places with higher rainfall in the semi-arid and sub-humid zones-Table 2.

Table 2 : *Mean vapour pressure, relative humidity and rainfall at selected stations in India* (1931–1960)

		Barmer (Arid)	Jodhpur (Arid)	Kota (Semi-arid)	Indore (Sub-humid)	Bhopal (Sub-humid)
Mean vapour	July	28.7	27.9	28.7	26.6	27.1
Pressure (mb)	August	28.1	28.0	28.7	25.9	27.0
Mean relative	July	65.0	65.0	69.0	80.0	79.0
humidity %	August	70.0	71.0	75.0	83.0	82.0
Mean annual rainfall (mm)		310	380	841	1053	1209

In the upper atmospheric levels also the humidity is high. For instance, the mean precipitable water vapour during July over Jodhpur is 5.6 gm/cm^2 while the corresponding values for Delhi, Nagpur, Bombay and Trivandrum are 6.1, 5.5, 6.2 and 4.6 gm/cm^2 respectively. Inspite of these comparable humidity conditions, the clouds over the arid region do not grow vertically and tend to dissipate due to divergence in the atmosphere and associated descendance of air at the higher levels. During those years when no monsoon depressions move across Rajasthan or they recurve in Madhya Pradesh, the desert regions experience drought as happened in 1968 and 1969 in Jaisalmer, Barmer and Bikaner districts.

Preliminary scientific evidence suggest that the presence of atmospheric dust due to wind erosion may be one of the important causes for the divergence in the upper levels of the atmosphere and for the absence of rain in the arid region. Provision of vegetative cover, improved rangelands and pastures, controlled grazing, afforestation, establishment of shelter-belts and wind breaks and stabilisation of shifting sand dunes would considerably reduce the dust. Suitable techniques for these practices have been evolved. Further research on these aspects is in progress. The suggested practices if adpoted on a larger scale over the arid region, would help in bringing more condensation of dew and more rainfall over the region, thereby enhancing the productivity of the region.

Analysis of rainfall pattern and distribution

A study of the rainfall distribution during *Kharif* season in the arid and semi-arid zones indicates that there is an intrinsic difference between the two regions. While the distribution of rainfall in the semi-arid zone attains normality when accumulated rainfall for periods of one month or more from the date of commencement are considered, the arid zone is characterised by lack of symmetry and absence of normality for each of such periods including the entire rainy season. The latter follows an asymmetrical distribution (Gamma distribution). Using appropriate theoretical distribution values, rainfall probability charts have been prepared. Knowing the optimum water requirements of a particular crop in a particular area, these charts can be used to predict the percentage chances of success of that crop at that location.

Maps of western Rajasthan showing (a) means and parameters of variability and skewness, etc. of the annual rainfall, (b) the amounts of excess and deficient rainfall patterns expected once in 5 years and 10 years periods and (c) the frequency percentages of highly deficient or highly surplus rainfall years have been prepared. Further, major rainfall types which are typical of various districts of western Rajasthan have been classified. While there is a significant association between the relative earliness criterion of the growing season and the total quantum of rainfall in Jodhpur, Jhunjhunu and Pali districts, the same has not been noticed in the case of other districts in western Rajasthan.

Detailed agro-climatic reports incorporating information on the distribution of rainfall, temperature, humidity, conservation of run-off water, general climate, crop relationships, available crop/pasture growing season and its variability, and incidence of droughts etc. have been prepared for the central Luni basin, a number of development blocks and a few range management areas of the Institute. Detailed reports have also been prepared for the districts of Bikaner, Jodhpur and Nagaur.

Rainfall trends from 1890 in the arid zone of North-west India have been studied and it has been brought out that a deficit rainfall spell of large magnitude occurred in the region during 1962-71 comparable to that of 1895-1905.

Study of the decadewise analysis of aridity index line of 80 in westen Rajasthan indicates an eastward shift of this line implying that the deterioration of

desertic conditions was more marked in recent decades in Churu district in the north and Jalore district in the south.

In the year subsequent to a drought year, there is a sharp rise in the occurrence of dust storms. Thus it can be concluded that the drought years have a multiplier effect in the desertification process.

Evaporation

Mean summer evaporation in arid zone during summer exceeds 12 mm per day. The least evaporation of 5.4 mm/day occurs during winter. The mean values of potential evapotranspiration by Penman's method varies from 7-9 mm/day during summer. It has been found that the Penman's method underestimates the potential values because of insufficient weightage given to the aerodynamic term. In arid zone, evaporation is governed mainly by saturation deficit during the afternoon and wind speed. These were found to explain 83% of variance while addition of radiation parameter explains only 5% more.

Field energy balance studies

Field energy balance studies have been conducted over bajra, mung, wheat and important arid zone grasses like *Lasiurus sindicus* and *Cenchrus ciliaris*. The radiation profiles within the crops and albedo have been studied. The diurnal and seasonal variation of net and total radiation on horizontal surface and spectral distribution of total radiation at normal incidence have been determined.

An analysis of the photosynthetic efficiency of the *Cenchrus ciliaris* grass cover at Palsana (mean annual rainfall 567 mm) a semi-arid region, a mixed grass cover of *Lasiurus sindicus, Cenchrus ciliaris, Cymbopogan schoenanthus* etc. at Bikaner (mean annual rainfall 291 mm) and a predominently *Lasiurus sindicus* grass cover at Chandan (mean annual rainfall 189 mm) revealed that the photosynthetic efficiency of the grassland at Palsana was 0.48% while it was 0.76% and 1.62% at Bikaner and Chandan, respectively. *Lasiurus sindicus* grass cover was thus photosynthetically more efficient at Chandan than at the other two regions.

An analysis of the water use efficiencies of these three grasslands revealed that the water use efficiency of the grass cover at Palsana was 1.10 gm/m^2/mm of water, while it was 0.96 and 1.86 gm/m^2/mm of water at Bikaner and Chandan respectively.

Soil Thermal Regime

An analysis of the soil temperature data from soil surface to 120 cm depth recorded from 1967 to 1976 indicated two types of thermal regimes for the sandy soils of Jodhpur.

Summer pattern : The soil temperature decreases from the surface to deeper depths during the afternoon hours, while during the morning hours, it increases from surface to 30 cm depth and thereafter it decreases.

Winter pattern : The soil temperature decreases up to 30 cm and thereafter increases during the afternoon hours. In the morning hours, however, the temperature increases continuously all the way from the surface.

The summer patterns of temperature lasts from mid-March to mid-October with breaks during peak monsoon periods. Variations in temperatures are observed only upto the depth of 30 cm throughout the year.

Conditions are favourable for upward movement of water in vapour phase during morning hours and for downward flow during the afternoon hours throughout the year.

The intensive study of summer and winter patterns of soil thermal regimes in Jodhpur and their harmonic representations was completed.

A new method for determining hydraulic conductivity of sandy soils was evolved. In this method, simultaneous estimation of bare soil evaporation is also possible.

Wind erosion studies

Dust collection under different land use conditions at Jodhpur as well as from field areas in Jaisalmer, Chandan, Bikaner and Pali were made. Analysis of dust samples indicate the presence of large quantities of silt at 2-3 metre levels above ground indicating movement of fertile fraction of eroded soil.

Rational Utilization of Basic Resources

Inherent in the desert problems is the necessity to recognise that the arid areas are supporting a substantial population and that methods of reclamation or utilization must be applied while the population continues to subsist on land. Arid and

semi-arid regions have definite limitations imposed on their potential productivity. In certain areas the existing population has already exceeded the limit of permanent supporting capacity. One of the objects of arid zone research, therefore, is to assess the eventual resource potential of different areas. For the purpose of obtaining comprehensive knowledge and understanding of resources, reconnaissance integrated surveys have been completed in 43917 sq km (in the states of Rajasthan, Haryana and Mysore); semi-detailed surveys in 52,736 sq km (in Rajasthan and Gujarat) and detailed surveys in about 288 sq km mostly in western Rajasthan. These surveys provide comprehensive information with regard to (a) land use capability classes based on land use data, erosion hazards (wind and water), soil types and type and intensity of dunes, (b) Pasture types, (c) tree communities (d) water resources (surface and ground-water) water quality, water potential zones and their capabilities to supply ground water, and village tanks and their water potentials, (e) Socio-economic correlations of various caste groups household structure, rural working force, class of farmers and holding size, animal–vegetation-human relationships, forms of settlement etc. On the basis of these surveys, methods of utilising these resources rationally to upgrade production are suggested.

In the State of Rajasthan reconnaissance survey of 19 percent of the arid land comprising the Central Luni basin and Bikaner district has been conducted. In addition 17.3 percent of the area comprising the Siwana, Saila, Ahore, Jalore. Luni and Chohtan Panchayat Samitis and Jodhpur has been surveyed at the semi-detailed level. In Haryana State, 23 percent of arid area in Mahendragarh district, in Gujarat State 22 percent of arid areas in Santalpur block and in Mysore State 24 percent of arid areas in Challakere taluk have been surveyed. Amelioration measures have been suggested to make these areas more productive. Possibilities of exploitation of surface water and ground water in each block have been indicated. The quality of water in block was assessed and recommendations made regarding its suitability for irrigation.

Biophysical mapping of each surveyed area, giving an integrated picture of land forms, soils, vegetation, water resources and land use, has been done. Assessment of basic resources of each biophysical unit to upgrade production to suggest rational approaches to the development of its resource has been made. For example, Bikaner district has been divided into 10 biophysical land types for the purposes of assessment and development of resources. Flat aggraded alluvial plains, flat interdunal plains with moderately deep to very deep fine sand to loamy sand soil and

Kharif cropped land with 40-80 per cent intensity of cropping form the principal biophysical units of the district which need immediate attention to introduce modern techniques of dry farming practices to increase production. Recent alluvial plains with deep stratified fine loam to silty clay soils in the north-west is a biophysical unit which needs special attention under irrigation which is proposed in the area under the Rajasthan Canal Project. Soil salinity at lower depths needs special attention for amelioration if good production are to be expected under irrigation. Large areas of active sand dunes in the district without vegetation form focii of sand movement creating hazards for surrounding cultivated areas, village sites, railway embankments and roads. These need immediate attention for stabilisation. With favourable moisture status in these un-stabilised dunes at a depth of about one metre, it should not be difficult to establish trees on such dunes.

Water Resources in Arid Areas

The surveys have indentified locations where new *Nadis* or reservoirs could be constructed for storage of monsoon runoff. In the absence of suitable groundwater aquifers these are the only sources of water for domestic and live stock. In many areas in western Rajasthan since the soil infiltration rate is very high, the runoff is hardly 5 per cent of the rainfall. Detailed work on suitable treatments and prevention of loss of water through evaporation and seepage is in progress. For example it has been shown that lining with *Janta* emulsion at 2.5 litres with 2.5 litres of kerosene oil per 100 sq ft of wetted surface has been found to reduce the seepage loss from the sandy soils of Jodhpur to 3.2 per cent from the usual 40 per cent or so occurring from unlined channels. Plastering of the channel surface upto about 5 mm depth with a mixture of Janta emulsion and soil was found more effective and durable.

Detailed surveys for underground water in different areas are being carried out using modern geophysical equipments to predict the depth of aquifer, the water cushion, approximate rate of discharge, source and rate of recharge and the quality of water.

Recent surveys conducted at Jodhpur district have shown a number of favourable sites for surface water storage. There is a possibility of additional storage capacity of 27 million cubic metres of water (the present water storage capacity is 156 million cubic metres). Jodhpur district has a potential of nearly 40,000 million cubic metres of ground water of salinity upto 2000 mmhos E.C. The occurrence of these waters is uniformly distributed in various tehsils of the district. The surface water potential

of the district has been estimated at 689 million cubic metres, a large portion is lost by evaporation from the soil surface.

Water resource survey of Nagaur district (17, 643 sq km) indicated high potential catchments which could yield maximum surface runoff of 70-80 mcm during good rainfall years. These high potential catchments are mainly located in East, NE and SE of the district. The catchments are rocky and gravelly. There is a great scope for the development of this region in the district. This is evident from already existing storage reservoirs. Few ideal sites for development have been suggested in the village areas of Punlotha, Maroth, Pachranda and Bhojawas.

Evaluation of surface water yield from high potential catchments of Luni Basin was done. There are 11 major catchments. Individual catchment has been evaluated for surface water yield. The total surface water potential of the basin is roughly 12, 213 mcm.

This estimation is based on the basis of Hydrologic-soil-cover complex. This is the only basin which is the major surface water resource of Rajasthan. In order to assess accurately the water yield from catchments in the desert region, small experiments on rocky catchments have been carried out at Kailana. During good rainfall years, catchments with grass vegetation yield as much as 20% and all vegetation including trees yield as much as 58%.

Surface water yield from small water sheds can be increased by treating the catchments with water proof cover. Studies carried at CAZRI indicated that Jantha emulsion treatment increased the surface runoff by over 40%. Sodium carbonate treatment yielded runoff as high as 91.75% during 1972 monsoon.

About 85 percent well waters of Barmer, Jalore and Jodhpur districts are classified as C_3, C_4 and C_5 which are normally used for irrigation of salt tolerant crop varieties. About 10 per cent water having T.S.S. of over 10,000 ppm are unsuitable for any use. Only 5 per cent waters are potable. Boron content of the ground water goes upto 7.5 ppm but the majority of the samples have values of 2.5 ppm or less and are suitable for irrigation.

The ground water of the *Lathi* tube well complex near Jaisalmer is moderately saline except for the *Jetha* tubewells. These waters have high sodium and residual sodium carbonate concentration. Boron concentration is generally low. The soils have coarse texture, low fertility with isolated saline patches. The ground water in

this region is mostly suitable for irrigation. In the case of high salinity waters some degree of leaching is needed.

The ground water of *Borunda* tube well complex near Jodhpur is relatively more saline as compared to that of the *Lathi* area. High salinity waters are found in a central belt comprising *Jhak*, *Kalauna*, *Rampuria* and *Bhagasni* villages. Salinity and alkalinity problems in the soils have been observed in *Beejasni*, *Bilara*, *Unchera*, *Borunda*, *Hariadhana* and *Ransigaon* villages.

Water quality in Pali district is of very high salinity in the well and tube well irrigation water. Sodium and boron hazards of the irrigation water are rather high, while the residual sodium carbonate concentration is relatively low. Soils are coarse to medium in texture. Salinity and alkalinity problems are very severe in the irrigated soils. 80% of the soils are saline alkali in nature.

Some Special Attributes of Arid Land-Scapes

Studies using aerial photo interpretation revealed that salt basins, saline soils and subsurface salinity zones are located at the confluence points of the buried drainage systems. The natural salt is found at the lower reaches and at the confluence points and gypsum at the upper reaches of the same segments of the streams. Sometimes this salinity is not manifested on the surface, but it may move upwards in course of time, particularly with irrigation and poor drainage.

Investigations have shown the existence of prior drainage system in arid Rajasthan. It has been possible to identify and map this with the help of vertical aerial photographs. The study is expected to help in the location of the potential water sites.

Though surface and subsurface salinity tends to accumulate in arid environment in lower reaches of drainage system, particularly at the point of their confluence, it has been found that the soils in the dominant upland position have sufficient internal drainage to prevent salinisation. The salts added through use of saline water for irrigation are amenable to leaching and there is no manifestation of progressive build-up of salinity.

Despite the fact that dominant arid zone soils are light textured, these are fairly well provided with most of the essential nutrient elements. It has been seen that potassium and various trace-elements are generally more than adequate, which

is also reflected in fairly high concentration of these elements, particularly iron, copper and zinc in foliage of top-feed plants. Concerning phosphorus, picture is variable whereas nitrogen or organic matter content is low in these soils.

The extent of Indian desert and its geographic limit has been defined. The creep of the desert has been studied in relation to the increase and decrease of desert sand and the extent of sand dunes. The study indicates that the desert is not expanding towards the east. But fresh deposition within the desert is still going on leading to intensification of desertic hazards.

The present land use survey in the arid region indicates that although 60 to 70% of the land is mapped under cultivation but in practice only about 50% of the land is cultivated in a year as it includes short and long fallows and marginal lands too. Intensity of cultivation has been related with geomorphic, soil and climate factor. It has also been seen that the middle and lower flanks of the stabilised sand dunes are cultivated while the upper flank and the crest constitutes open grazing lands.

Ecology of Grass Species

Autecological studies of important grasses like *Lasiurus sindicus*, *Cenchrus ciliaris* and *C. setigerus* have shown that the productivity in these grasses is directly related to the soil moisture conditions. Considering germination and growth characteristics and crude protein content, *C. ciliaris* is a better species than *C. setigerus*. Dry matter production of *C. ciliaris* under competition with the surrounding herbage is reduced by about 52 per cent as compared to production without competition during the growth period. Above-ground productivity studies in natural pastures on the older alluvial soils at Jodhpûr under different intensities of grazing, viz., protected, partially utilised, and overgrazed under natural conditions of grazing have shown that dry matter production (above-ground biomass) was 0.264, 0.174 and 0.067 g/day/m^2 in 1968-69 against 0.26, 0.14 and 0.13 g/day/m^2 in 1969-70

A number of high yielding and promising strains/cultivars of desert grass species as well as annual fodder legumes under dryland and partially irrigated conditions have been identified. The important strains/cultivars are as follows : CAZRI Nos. 277, 392, 214, 357, 358, 362, 541, 588, IGFRI 3108 and Molapo of *Cenchrus ciliaris*, 417, 418, 1, 76 and 413 of *C. setigerus*, 318, 319, 321, 352, and 353 of *Lasiurus sindicus*, 331, 333 and 379 of *Panicum antidotale*, 490 and 491 of

Dichanthium annulatum, T 3, T 18, T 16 and T 24 of *Phaseolus aconitifolius* (Moth), B 19-1-55, Durgapura safed, FS 277 and HFG 182 of *Cyamopsis tetragonoloba* (Guar) HFC 42-1 and FOSI of *vigna unguiculata* (Cowpea) and No. 144 of *Dolichos lablab*.

About 1500 kg seeds of the above mentioned improved strains/cultivars of grass and legume species have so far been distributed to various agencies throughout the country for research and development purposes.

Introduction of Perennial Fodder Legumes

Two promising perennial legumes viz. *Dolichos lablab var lignosus*(strain No. 144) and *Clitoria ternatea* have been found to be suitable for arid zone pastures. Combination of *Clitoria ternatea* and *L. sindicus* gave better yield performance even up to third year of testing, whereas *Dolichos lablab* could yield more only in the first year and later got eliminated in subsequent year of testing. *Clitoria ternatea* also proved to be a good combiner with other grasses like *Cenchrus ciliaris* and *C. setigerus*.

Intercropping grass species e.g. *(Lasiurus sindicus, Cenchrus ciliaris, C. setigerus* and *Dichanthium annulatum)* with some of the commonly cultivated legumes e.g. *Phaseolus aconitifolius* and *P. radiatus)* has resulted in 29-30 per cent increase in forage yield as compared to pure culture of the grasses. In addition, the practice also gives some relief to the farmer when the crops fail during droughts.

Cactii as Forage

Among the spineless cactii collection, *Opuntia ficus-indica* appeared to be the most promising. Green forage yield to the tune of 7.34 t/ha was obtained in the establishment year whereas a 3 year old plant produced 30 t/ha green forage. Establishment techniques for its large scale plantation has been evaluated and plant to plant and row to row distance of 3 m is recommended. The green forage from this cactus contains 6.8% crude protein. The spineless cactus is suitable for growing in the hot desert and the drought prone areas.

Pasture Reseeding

A good nucleus of high-yielding and palatable perennial grasses such as *Cenchrus ciliaris*, *C. setigerus* and *Lasiurus sindicus* is available in the north western Rajasthan and *Dichanthium annulatum, Sehima nervosum* and *Chrysopogon fulvus*

in the south western Rajasthan. These provide a good potential for grassland development in this arid tract.

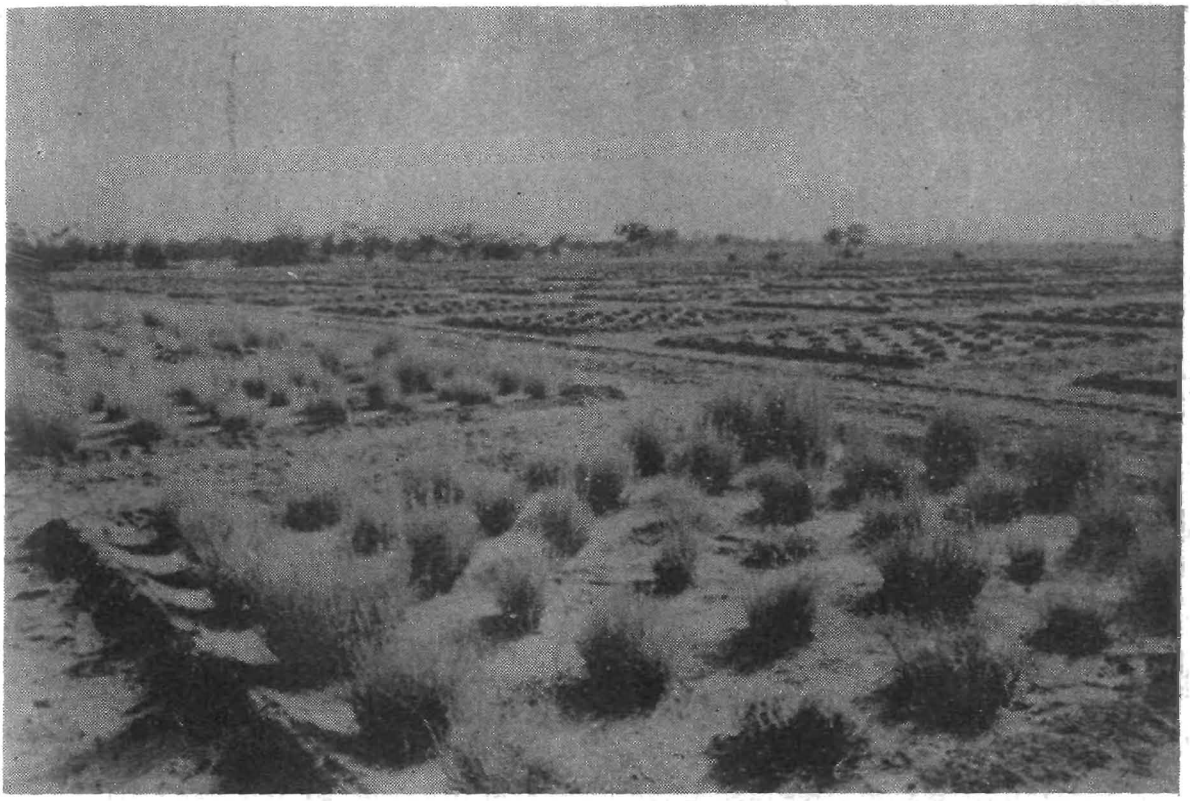
Establishment of improved pastures from the above species can be effected by direct sowing and transplanting of seedlings. The average seed rate recommended is 2 kg per hectare for *Dichanthium annulatum* and *Panicum antidotale*, 2 to 3 kg per hectare for *Cenchrus ciliaris* and *C. setigerus* and 5 kg per hectare for *Lasiurus sindicus*. Seeding during the monsoon season (July-August) usually results in maximum germination as compared to pre or post-monsoon sowings. It is not the depth of seed placement but that of soil cover on the seed that is important. Studies carried out at Jodhpur have indicated that the seed should be covered with soil to a depth of 1 to 2 cm only. The grass seed may be sown by drills or by bullock driven implements. In order to make the seed heavy some quantity of soil may be mixed with it. Line sowing has the advantage over broadcasting of seed as in the former case it is easy to operate the tractor or bullock-driven implements between the lines for purposes of interculture, fertilization and harvesting of forage and seeds. The recommended spacing between the lines is 50 cm for grasses and 100 cm for grass-legume mixtures where an annual legume crop may be grown between the grass rows for combined forage and grain production. Complete soil working, grubbing out of shrubby weed and seeding of perennial grasses in lines 50-75 cm apart at a depth of 1-2 cm have resulted in satisfactory pasture establishment and has given 67 per cent increase in forage production. The perennial grasses remain productive for over ten years or even more under proper care and management.

Pasture utilization and animal production

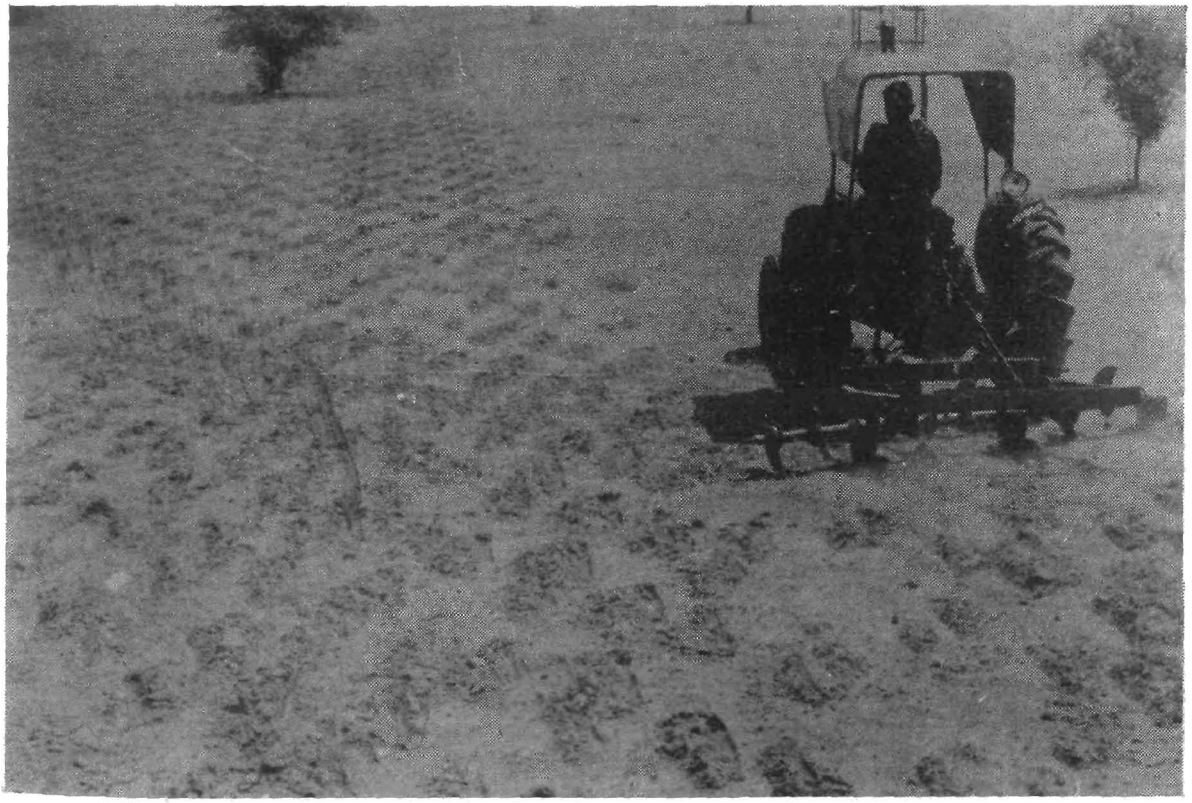
1 Six wethers (Marwari sheep) per hectare has been assessed as the carrying capacity of 'fair' type of natural grasslands on sandy loam soils.

2 The relative carrying capacities of reseeded grasslands on sandy soils for sheep are 4.46 for *C. ciliaris*, 2.53 for *C. setigerus* 4.06 for *P. antidotale* and 6.92 for *L. sindicus* per hectare while on sandy loam soils the sheep carrying capacities have been assessed as 7.53 for *C. ciliaris*, 6.04 for *C. setigerus*, 4.90 for *Panicum antidotale* and 6.86 for *D. annulatum* per hectare.

3 On a long term basis, sheep production on a variety of cultivated pastures represented by (1) *C. ciliaris* with *L. sindicus* (2) *C. sciliaris* with *C. setigerus* and (3) *C. ciliaris* + *C. setigerus* + *L. sindicus* has been more than 200 per cent higher per unit of land as compared to production on natural pasture.

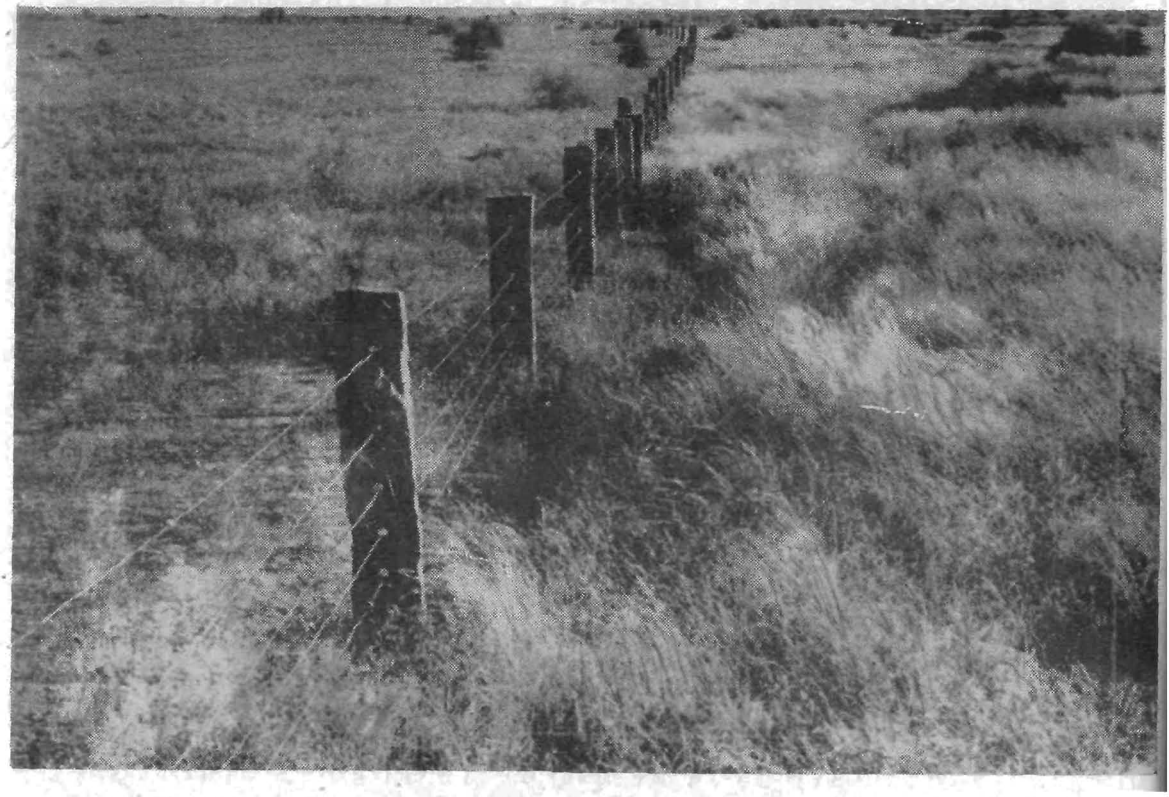


Experiments on promising desert grasses at CAZRI



CAZRI Pitting Disker—a device for micro pits for water conservation

Lest the hollowing winds blow away the top soil—a soil conservation measure in practice



Fencing protects and improves the range

Productivity studies on three desert grasses, viz., *Cenchrus setigerus* (Moda Dhaman), *C. ciliaris* (Anjan, Dhaman) and *Lasiurus sindicus* (Sewan) have shown that the above ground biomass production in these species reaches a peak during September-November. The rates of production of these three grasses have been found to be from 0.95-9.94, 0.66-9.73 and 0.26-7.68 g/m^2/ day for *C. setigerus, C. ciliaris* and *L. sindicus* respectively. Net primary productivity values ranged from 647-837 g/m^2 in *C. setigerus* 662-977 g/m^2 in *C. ciliaris* and 630-952 g/m^2 in *L. sindicus.* These studies have also indicated the tremendous plasticity and adaptability of these three grass species to adjust themselves to the environmental conditions prevailing during the growing period. They have great potentialities for rehabilitation of the over-exploited desert grass lands.

A device for water harvesting developed at the CAZRI, Jodhpur, called "Pitting Disker" has been found to be very suitable for conservation of rain water. The advantage of pitting disker is more distinct in case of natural pasture as compared to sown pasture having perennial grasses with well established root system. The per cent increase in dry matter yield over control in protected natural and reseeded pastures was 83.04 and 52.00 respectively.

Range Management and Soil Conservation

With a view to establish scientific methods for the upgrading and utilisation of the denuded rangelands in the arid and semi-arid regions of western Rajasthan, studies were initiated on 53 Range Management and Soil Conservation areas (each of about 80 hectares) located in different rainfall and soil conditions (land forms) in eleven districts. From 1969 onwards the research work has been intensified at 12 such sites located in seven districts of western Rajasthan. Some of the important observations made during these studies are as follows :

1 With adequate protection and proper grazing management on native rangelands according to its carrying capacity, the forage yield could be practically doubled in 3 to 5 years time. Fertilization with 22.5 kg N/ha further increases the forage yield by 15 to 69 per cent.

2 Amongst the different types of fencings tried, the one having angle iron posts with 4-5 strands of barbed wire proved to be most effective and economical in the long run although initially costly. Its present cost works out to Rs. 12.00 per running metre.

3 Reseeding rangelands with appropriate high yielding gerennial grass species suiting the agroclimatic conditions has given encouraging foarge yields. In well established strips of high perennial grass species the maximum air dried forage yields of 5.8, 3.4 and 3.0 m tonnes per hectare have been obtained from areas under *Dichanthium annulatum, Cenchrus* species and *Lasiurus sindicus* respectively. In saline soils, where reseeding has not succeeded, salt tolerant species like *Sporobolus* species has given forage yields of 2.0 tonnes per hectare.

4 Soil and water conservation measures like contour furrows, trenches and bunds on rangelands with shallow soils and rolling topography increased the forage yield by 95.7 per cent (from 683 kg/ha to 1337 kg/ha) within a year.

5 For soil and water conservation on rangelands with shallow soils and rolling topography, contour furrows of 929 sq cm cross section, 61 cm width, and 22.6 cm depth and spaced 8-10 m apart have proved superior to contour bunds and trenches. The increase in forage yield has been of the order of 638 per cent over control (average of 10 years).

6 Studies conducted on the performance of selected strains of different grass species viz. *Cenchrus ciliaris, Cenchrus setigerus, Dichanthium annulatum* and *L. sindicus* revealed that different strains perform differently in different habitats. However, strain No. CAZRI 357, 358, 214 and 303 of *C. ciliaris.* CAZRI, 175 and 296 of *C. Setigerus,* CAZRI 491 of *Dichanthium annulatum* and CAZRI 318, 319 and 565 of *L. sindicus* have shown stability for production at various habitats of arid and semi-arid zones.

7 In reseeded rangelands dominanted by *Cenchrus ciliaris* the forage yield increased by 17.2 and 50.0 per cent by soil working and application of 20 kg N/ha and 40 kg N/ha respectively.

8 Studies on the contribution of the under story (grass component) in areas afforested with *Prosopis cineraria, Albizzia lebbek, Tecomella undulata* and *Acacia senegal* have revealed that the production of forage under different tree species varied yearly with the rainfall. The overall production was observed to be the least under *Acacia senegal* and the differences in forage yield under the rest of the species were non-significant.

9 Heavy intensity of grazing during the monsoonic season, utilising pasture upto 97 per cent does not destroy the weeds, while the palatable species are overgrazed.

10 Studies on seasonal grazing of rangelands have revealed that the growth of animals remained highest during the period August-October, followed by November-January. The least gains were obtained during the period May-July. The availability of fodder to the animals during the hot weather (May-July) is about 33 per cent of the estimated production value.

11 The forage yields on rangelands, specially in desertic areas has been found to be affected by different intensities of grazing, viz., light (2.4 ha/heifer), medium (0.80 ha/heifer) and heavy (0.48 ha/heifer), (average of 5 years). Light intensity of grazing (grazing based on carrying capacity) has proved to be superior.

12 With the highest intensity of grazing stress on rangelands, the animals harvested more nutrients per unit area. But with supplemental feeding of concentrates the harvest of nutrients declined.

13 Body weight gains of yearling heifers in 'Good', 'Fair' and 'Poor' condition classes of rangelands have been 1892, 1656 and 1055 kg respectively per unit area of 100 hectares of rangeland. The body weight gains in sheep (ram lambs) in 'Poor' and 'Fair' condition class rangelands have been 554 and 889 kg respectively per year. Continuous controlled grazing has given the highest livestock production, while deferment of grazing for 16 weeks from 1st July has been found to reduce the live weight gains by 50 per cent.

14 The growth rate of heifers was observed to be the highest in treatment where animals grazed on the basis of carrying capacity (light intensity) of the range land as compared to medium and heavy intensities of grazing. Feeding of concentrates from January-July, to meet the Digestible Crude Protein (DCP) and the Total Digestible Nutrients (TDN) requirements, has practically doubled the growth rate in comparison to grazing based on carrying capacity. It is helpful for early maturity also.

15 Continuous controlled grazing and deferred rotational grazing (at an interval of 2 weeks to 8 weeks) appeared to be equally effective in the rangelands as far as the livestock production is concerned. On an average, per day production of 230-270 gm/day/heifer and 35-40 gm/day/ramlamb was recorded on well managed rangelands.

16 Comparative growth of heifers and lambs (Sheep) under mixed grazing in rangeland of *Lasiurus-Cymbopogon-Aristida* cover revealed that the growth of

heifers per unit was highest when cattle grazed alone, followed by alternate grazing at six month interval by cattle followed by sheep and the least gain was recorded when sheep grazed alone.

17 Regression equations to estimate body weight of different classes of cattle with the help of girth measurements have been evolved to assist in the estimation of feed requirements of cattle.

18 Drinking water requirements of different classes of farm animals of the range have been studied. The requirement in adult cows increase from 19.3 litres in January to 41.1 litres in June and from 2.1 litres in January to 4.5 litres in June in case of adult sheep. In the case of young stock (heifers) the water consumption in December is 9.0 litres and it increases to 17.0 litres in June. In case of ramlambs, 1.6 and 4.0 litres water per lamb is required in December and June, respectively.

19 Grazing behaviour of experimental animals with preference to palatability of different species revealed that annual grasses like *Aristida* species and *Cenchrus biflorus* are not consumed after August till November. These species are grazed only when their awns and seed fall on the ground.

20 Comparative performance of animals reared on villagers level and in the range management areas have revealed that the animals of same age and body weight group are capable of producing 50 to 300 per cent more weight on rangelands during July-December as compared to animals maintained by the local villagers.

Afforestation

Of the different exotic tree and shrub species that have been tried *Acacia tortilis, Acacia aneura, Acacia raddiana, Acacia salicina, Acacia farnasiana, Eucalyptus camaldulensis, E. terminalis, E. melanophloia, E. tessellaris, E. coolabah, E. oleosa, E. siderophlola, E. pachyphylla, E. brewifolia, Pittosporum phillaraeoides, Schnius molle, Brasilettia mollis, Colophospermum mopane, Dichrostachys glomerata, Moringa aptera, Prosopis juliflora* (Israel, Chile and Peru varieties) and *Euphorbia antisyphilitica* have been found very promising for planting in the arid and semi-arid areas. Of these, *E. camaldulensis, E. terminalis, E. pachyphylla, Brasilettia mollis, Colophospermum mopane* and *Dichrostachys glomerata* flowered and fruited profusely.

Natural regeneration from wind dispersed seeds of one fodder tree species *Colophospermum mopane* of South Rhodesian origin observed to be encouraging. This is the only tree species which exhibited natural regeneration under arid conditions. Another fodder tree species namely *Dychrostachys glomerata* from Israel produced suckers from the roots and its seedlings were found at 8 to 10 m away from the mother trees. Further studies on the growth attributes and economics of these two species and their performance on sand dunes are being studied.

Studies on *Bursera dupectiana* a Linole oil yielding plant and *Euphorbia antisyphilitica a* candelilla wax plant are in progress. These species have adapted well to the local environment.

Acacia tortilis and *Prosopis juliflora* were found to be very well adapted tree species to the arid environment. Their fast growth, resistance to drought, capacity to grow under different habitat conditions, high yield of fruits having fodder value and good charcoal yielding properties have made these species ideal for afforestation in low rainfall areas. The other important fuel cum fodder tree species recommended for the arid zone are : *Prosopis cineraria* (Khejri) , *Albizzia lebbek* (Siris), *Azadirachta indica* (Neem), *Colophospermum mopane*, *Dichrostachys glomerata*, *Leucaena leucocephala* (Koobabool), *Tecomella undulata* (Rohida), *Dalbergia sissoo* (Shishum), *Cassia siamea* (Kala siris) and *Calligonum polygonoides* (Phog).

Species performance trials in four different habitats have revealed that the following tree species planted at 5 x 5 m are suitable for afforesting largely on frost free sites.

i) *Deep sandy soils : Acacia tortilis* (Israeli babool), *Prosopis juliflora* (Vilayathi babool), *Prosopis cineraria* (Khejri), *Azadirachta indica* (Neem), *Albizzia lebbek* (Siris), *Acacia senegal* (Kumat), *Dichrostachys glomerata, Cassia siamea* (Kala siris), *Tamarix articulata* (Farash), *Holoptelia integrifolia* (Churel), *Colophospermum mopane.*

ii) *Shallow sandy loam soils overlying hard calcareous pan : Acacia tortilis, Prosopis juliflora, Azadirachta indica, Albizzia lebbek, Zizyphus nummularia* (Bordi), *Dichrostachys glomerata, Holoptelia integrifolia, Dalbergia sissoo* (Shishum).

iii) *Sand stone rocky and semi-rocky sites : Acacia tortilis, Prosopis juliflora, Acacia senegal, Butea monosperma* (dhak), *Azadirachta indica, Albizzia lebbek, Cassia siamea.*

Studies to determine the performance and suitability of tree species in saline soils (Jadan) with pH 8-9 and salinity ranging from 12,000 to 28,000 mmhos at 25°C has shown that *Eucalyptus camaldulensis* gave the best performance (299.3 cm height) followed by *Prosopis juliflora* (Israel) and *Acacia tortilis*.

Farm Forestry

Prosopis juliflora and *Acacia tortilis* have also been found to be most suited for farm forestry and shelter belt plantation. The only precaution needed is to dig out a deep (60-75 cm) trench along the plantation to check the effect from their roots on the adjoining cropped fields.

Further studies on soil chemical aspects have indicated that the fertility of the soil under *P. juliflora* is particularly low in nitrogen and phosphorus. Available nitrogen phosphorus and potassium concentrations of 200, 10 and 25 kg/ha respectively and available DTPA-extractable micronutrients like zinc, manganese, copper and iron concentrations of 0.48, 7.5, 0.5 and 2.6 ppm respectively have been found in the soil surrounding *P. juliflora* communities. Similar investigations on the soils beneath other tree species like *Prosopis cineraria*, *Tecomella undulata*, etc. have indicated that the general soil fertility under *P. juliflora* is markedly lower as compared to the other species. The soil moisture status is also significantly low beneath the *P. juliflora* trees as compared to the other prominent tree species. The moisture status has been found to be particularly favourable under *P. cineraria*.

Silvical Studies

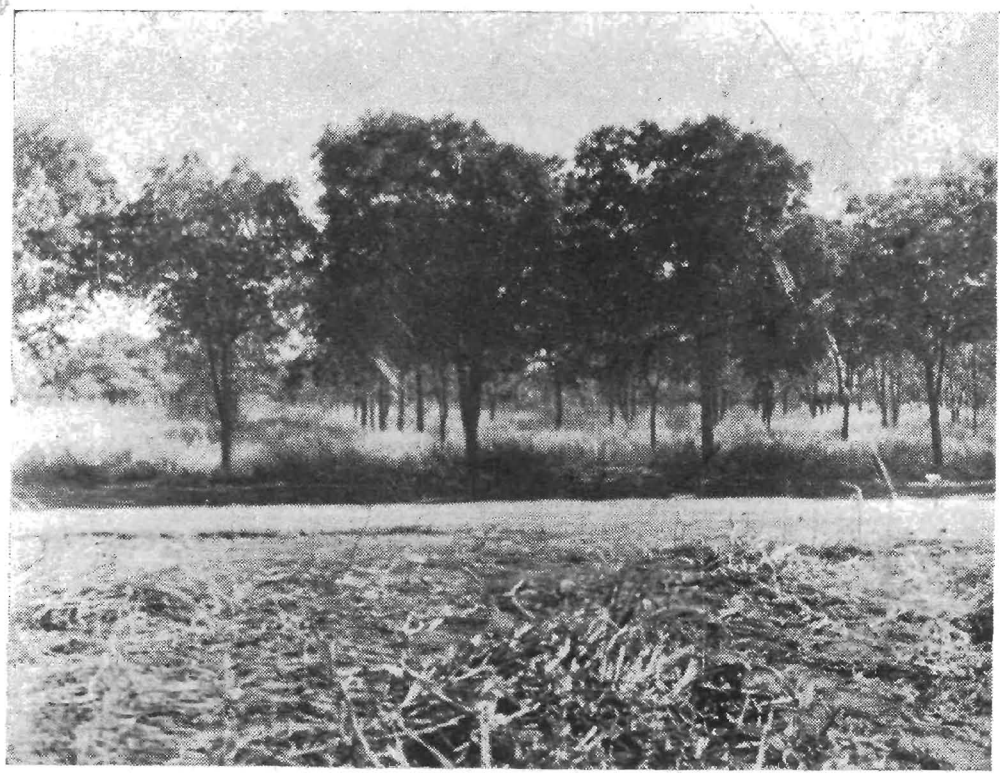
Prosopis cineraria exhibit comparatively higher establishment and growth when planted in the first half of August as compared to any other time of planting.

Six month and nine month old tree seedlings of *Albizzia lebbek* and *Acacia senegal* have been found to establish better than seedlings of higher age groups, namely one year and two years old.

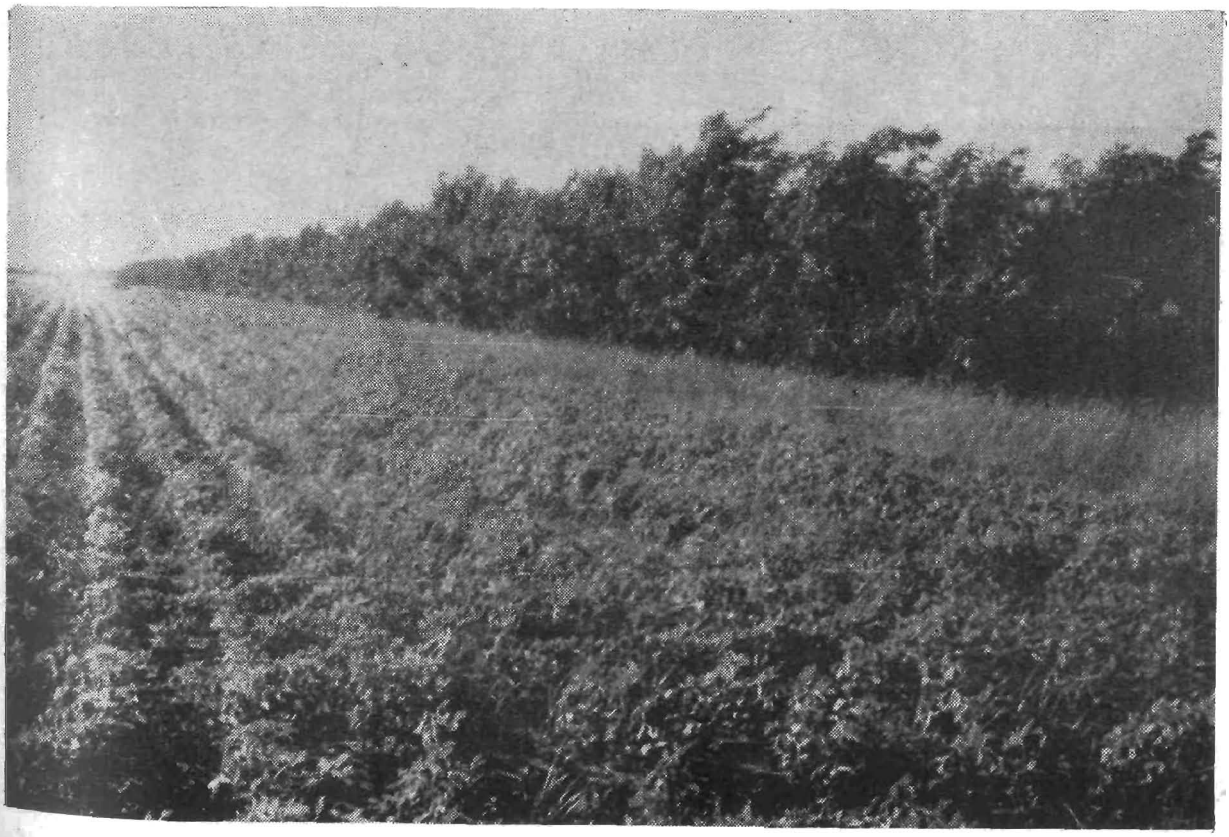
Two weedings a year for the first three growing seasons and 5 x 5 m spacings are the ideal treatments for raising tree plantations in this tract.

A well balanced potting mixture consisting of 1/3 sand, 1/3 clay and 1/3 farm yard manure is essential for the proper growth of seedlings.

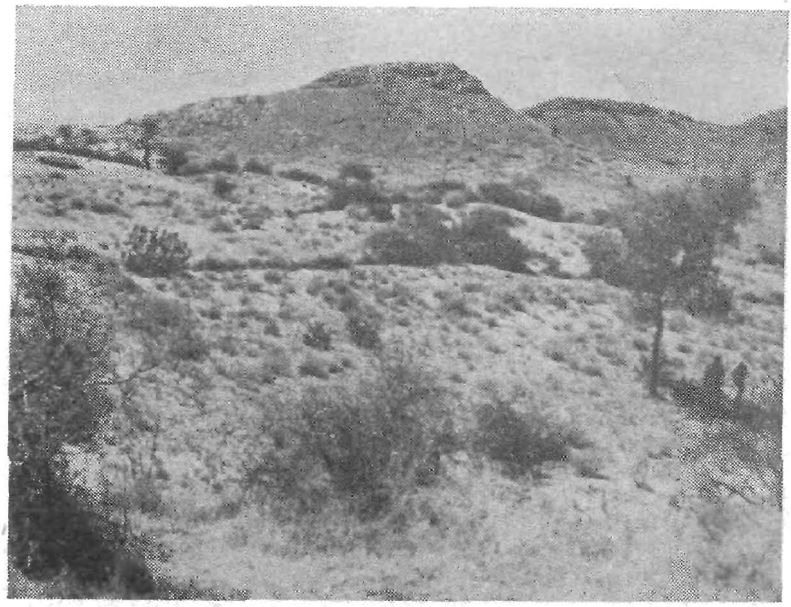
Raising of nursery stock in galvanised iron tubes kept in partially shaded cemented sunken beds with watering at the rate of 9 litres/set of 50 tubes at a time has been found to be the most suitable and economic technique.



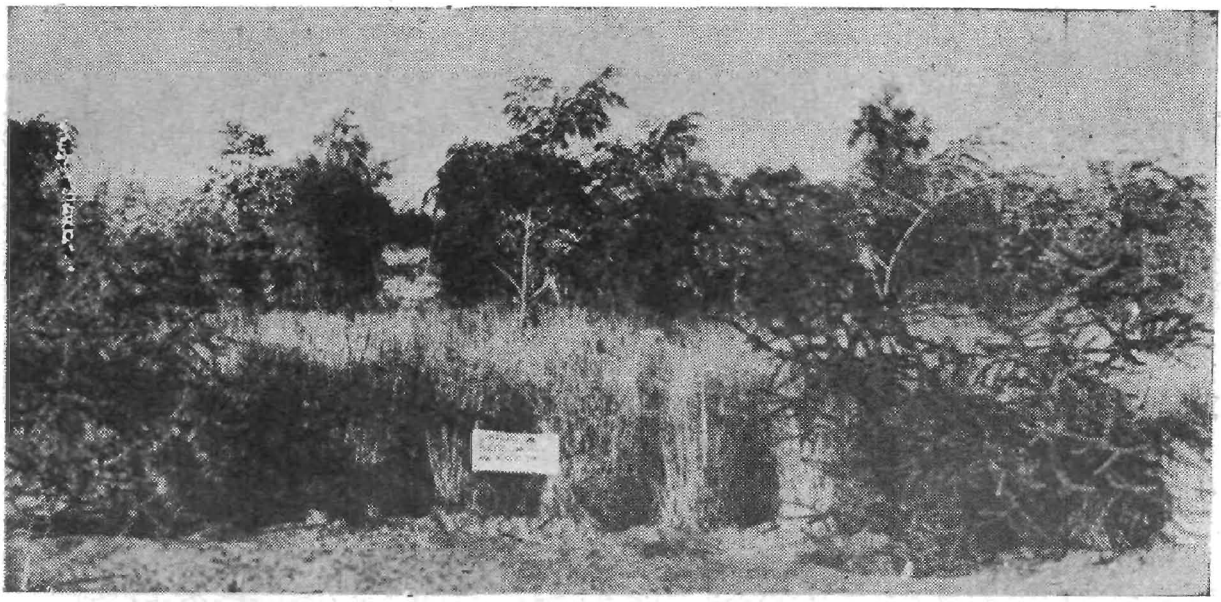
Azadirachta indica and Cenchrus ciliaris



Shelter belt for erosion control and enhancing the crop production



A view of stabilised sand dune



Chrysopogon fulvus (Mhow) intercropped with Acacia tortilis in foreground, Albizzia lebbek in back-ground

Studies on fuel yield revealed that closer spacing (3 x 3 m) of *Acacia tortilis* yielded 536.0 q/ha (dry fuel) whereas wider spacing of 4.5 x 4.5 and 6 x 6 m yielded 444.5 and 392.5 q/ha respectively. However, dry fuel yield from single tree of the above spacing gave 48.2, 89.8 and 140.0 kg/tree respectively. From this it is evident that for fuel plantation closer spacing will be advantageous, whereas for silvi-pastoral studies wider spacing would obviously be desirable.

Performance of Grasses in Silvi-Pastoral System

The studies on the performance of five range grasses namely *Cenchrus ciliaris* (Molopo), *C. ciliaris* (IGFRI 3108), *C. setigerus* (yellow anjan), *Chrysopogon fulvus* (Mhow) and *Sehima nervosum* (Jhansi) were initiated in 1975 in a tree plantation of *Acacia tortilis*, *Albizzia lebbek* and *Lucaena glauca*. Results of third year showed that in *Chrysopogon fulvus* (Mhow) the application of combination of 40 kg N and 20 kg P_2O_5 /ha gave maximum yield of 5.2 t/ha compared with 4.2 t/ha in control. Forage yield in *Sehima nervosum* increased significantly under three treatments viz., 20 kg P_2O_5/ha (2.46/ha), 20 kg P_2O_5 + 20 kg N/ha (2.0 t/ha), 20 kg P_2O_5 + 40 kg N/ha (2.0 t/ha) compared with control yield of 1.2 t/ha. *C. ciliaris* (Molopo), *C. ciliaris* (IGFRI 3108) and *C. setigerus* did not give significantly increased yield over control.

At Pali in the Silvi-pastoral system, the forage yield (dry matter) of the order of 22.4, 22.2, 21.5 and 19.6 q/ha was obtained under *Albizzia lebbek*, *Holoptelia integrifolia*, *Azadirachta indica* and *Acacia tortilis* respectively.

Stabilisation of Shifting Sand Dunes

The morphology of sand dunes in western Rajasthan has been studied and dune systems have been classified as old and new. The distribution, occurrence and orientation of different types of dunes of the two systems have been mapped in various areas. Parabolic dunes occur most frequently in this region, followed by longitudinal, transverse and barchan dunes. The cultivated dunes of the old system prove hazardous to the surrounding areas during the summer (March to June) when the wind velocity is higher. The shifting dunes of the new system are mostly barchans and shrub coppice dunes. These dunes need stabilisation on a priority basis in order to remove the hazard of sand blowing in the area. The dunes of the old system, which are generally stabilised, need suitable management system to protect them from biotic activities.

Techniques have been evolved for the stabilisation of shifting sand dunes by fixing barriers and by growing suitable plants and grasses, taking advantage of the existing subsurface moisture.

The sand dune stabilisation techniques comprises three distinct processess : (1) Protection against biotic influences through fencing, preferably with angle iron posts and barbed wire which costs Rs. 12/- per running metre; (2) Treatment of shifting sand dunes by mulching which involves fixing of barriers from the crest down to the heel of the dune. This is done by collecting locally available brushwood and burrying it vertically, crown downwards, in lines 2 to 5 metres apart, across the wind direction. These mulches reduce the wind velocity at the dune surface by creating obstructions. Mulching should be completed before the onset of monsoon. The cost works out to Rs. 150/- per hectare; (3) Establishment of vegetation. To stabilise the sand in the interspace between mulch barriers, it is essential to vegetate them properly. This requires establishment of tree and grass cover. For successful plantation of tree species on the dune a "Brick planting" technique has been evolved. By using seedlings raised in 'Bricks' prepared from a mixture of clay, sand and manure and then sundried, the plantation does not need any watering. For successful planting on the sand dunes, 0.8 to 1.2 m high well developed seedlings should be planted 50–80 cm deep and about 0.40 m above the ground so that the root zone comes in direct contact with the moist sand. The cost of plantation is about Rs. 500/- per hectare. Several tree species adaptable to different agroclimatic regions which can be used for the stabilization of dunes, have been selected, viz., *Acacia tortilis, Prosopis juliflora* and *Caligonum polygonoides.* It is essential to grow drought hardy and quick growing grass species in the interspace between the rows of trees, *Saccharum bengalense,* a deep rooted grass, is a good soil binder. The cost of planting *Saccharum bengalense* and grass seeds is about Rs. 250/- per hectare.

Sowing seeds of drought hardy grass species like *Panicum turgidum, Panicum antidotale* and *Cenchrus ciliaris* have given encouraging results. Castor, which is a fast growing tall plant and acts as a wind break, has proved successful and it has been recommended that seeds of this plant should be sown along the mulches.

Management of dunes

Plantations as stated above, should be closed to grazing, cropping and other biotic influences for at least 15 years. Grasses should not be harvested during the first two years. From the tenth year onwards, the trees should be lopped

for top feeds and a felling rotation may be carried out. The approximate annual cost of management of such dunes, involving watch and ward replacement of casualties, general upkeep of the areas, etc., is about Rs. 150/- to 175/- per hectare, based on a block of 200 hectares.

The Institute has demonstrated sand dune stabilisation techniques over 1000 hectares of shifting sands which were threatening the towns of Bikaner, Jhunjhunu, Sardar Shahar, Sikar, Barmer etc. The moving sand masses have been stabilised and their movement arrested.

A preliminary study on the dynamics of soil moisture in sand dunes at Osian, 72 km WNW of Jodhpur has indicated high moisture content exceeding field capacity throughout the year at depths below 1.5 metre in the shifting sand dunes. The moisture content in the stabilised sand dunes were very low up to a depth of 7 metres. This evidently points to better afforestation possibilities on the shifting dunes.

Shelter-belts

As a result of experimental work extended over about 207 km of road sides, tree species have been selected and techniques developed for raising avenue plantations along highways in the arid regions of Rajasthan.

A technique of establishing shelter-belts with a number of species was developed after successfully raising 103 km long shelter-belts at the Central Mechanised Farm, Suratgarh. Amongst the various tree species tried, *Acacia nilotica* (Babool) and *Dalbergia sissoo* (Shishum) were found most suitable for making good shelter belts when grown with irrigation. Following this technique the raising of further shelter belts in the Central Mechanised Farm is in progress.

Genetic Improvement

Germ plasm collections of important arid zone grasses like *Lasiurus sindicus* and *C. ciliaris*, legumes like *Dolichos lablab, guar (Cyamopsis tetragonoloba)* and perennial legumes like *Siratro (Macroptilium atropurpureum), Clitoria ternatea, Atylosia Scara baeoides, Leucaena leucocephala* and *Sesbania grandiflora* are being evaluated for their yield and quality attributes.

Breeding work in *guar* has resulted into selection of some determinate mutants having regular bearing and good yield potential. Breeding trials on *guar* are being coordinated at different places of testing in Haryana, Rajasthan and Gujarat.

Under the All India Coordinated Millets Improvement Project, some high yielding inbreds of pearl millet with early maturity, drought and disease tolerance have been developed. Most of them, having attained homozygosity, have been categorised into maturity and height groups. The superior inbreds have been utilized in the hybrid development programme. Some promising experimental hybrids for arid areas are 5054A x 76-K-2, 5071A x CR23, 5071A x 76-F-38 and $18D_2$ A x 76-E-9. In view of the difficulties experienced in arid areas for hybrids production, emphasis is also being laid on the population improvement programme. Variety No. 2 developed by mass recurrent selection from local varieties possessed reasonable tolerance to diseases and a high yield (20-25 q/ha). Some complexes developed from intra varietal crosses between local and promising types are being tested against better varieties.

Two minor millet crops *Setaria italica* (Foxtail millet) and *Panicum miliaceum* (Common millet) have been found suitable for arid region. The breeding programme on minor millet improvement was initiated with the collection and testing of their suitability of cultivation in arid zones. Variety Un-15 of *P. miliaceum* developed at CAZRI with a record early maturity of 37 days only is being improved for combining higher yield and other desirable attributes.

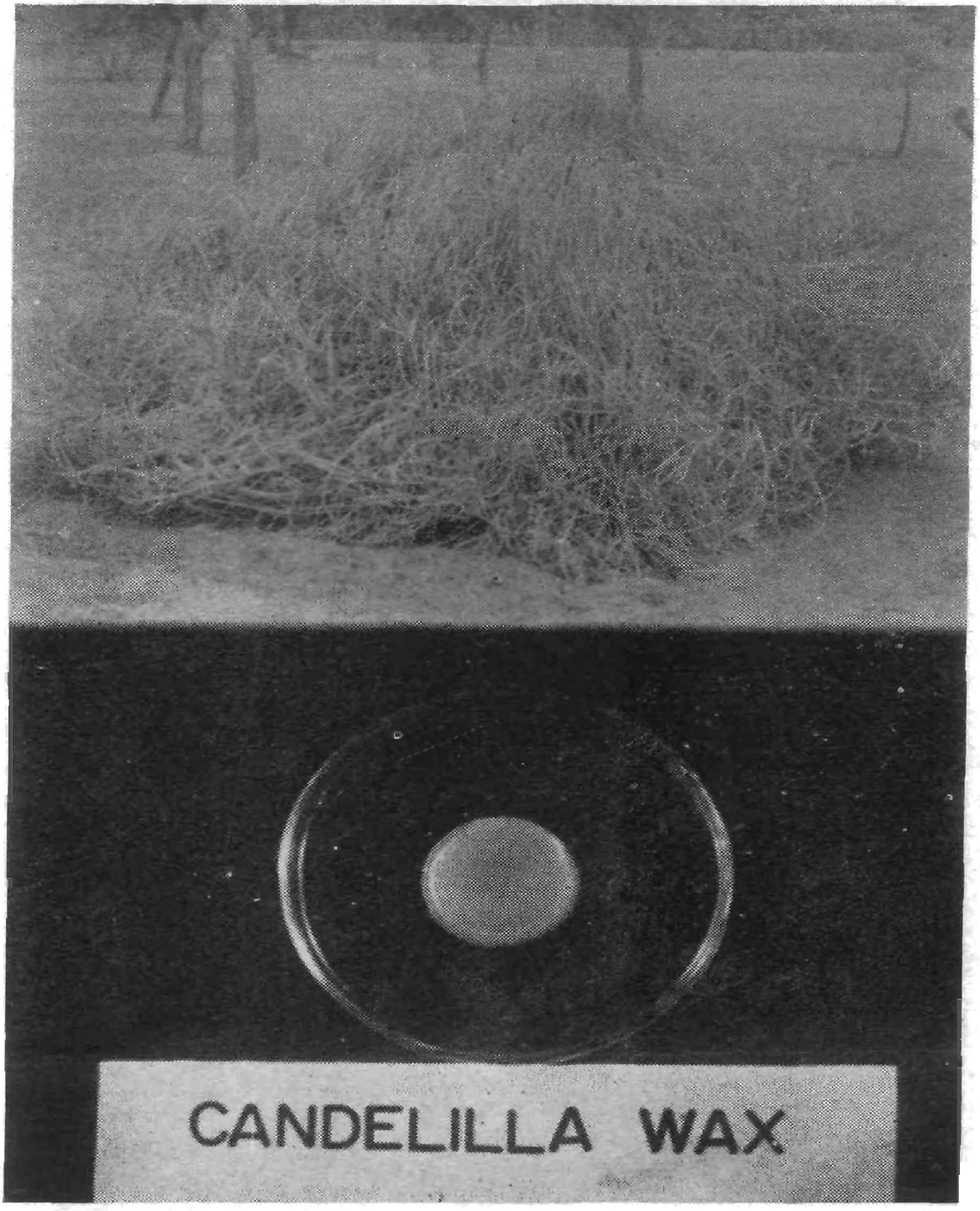
Several early maturing strains of *Setaria italica* and *Panicum miliaceum* have been developed. Variety Se-21-1, S. No. 1, S. No. 9 of *Setaria italica* (grain yield 15–18 q/ha, maturity 50–55 days) and PM 31, PM 21 and PM 29 of *Panicum miliaceum* (grain yield range 12–16 q/ha) are quite promising. Variety Se-21-1 has shown multiple disease resistance in All India multi-location trials. These strains of minor millets have been found responsive to fertilizer application also.

Work on tree genetics is in progress on species like *Prosopis cineraria* and *Simmondsia chinensis*. Progenies of promising trees of *P. cineraria* identified from various places have been established with a view to study intra-plant variance and to make a grove for collection of genetically superior seed material.

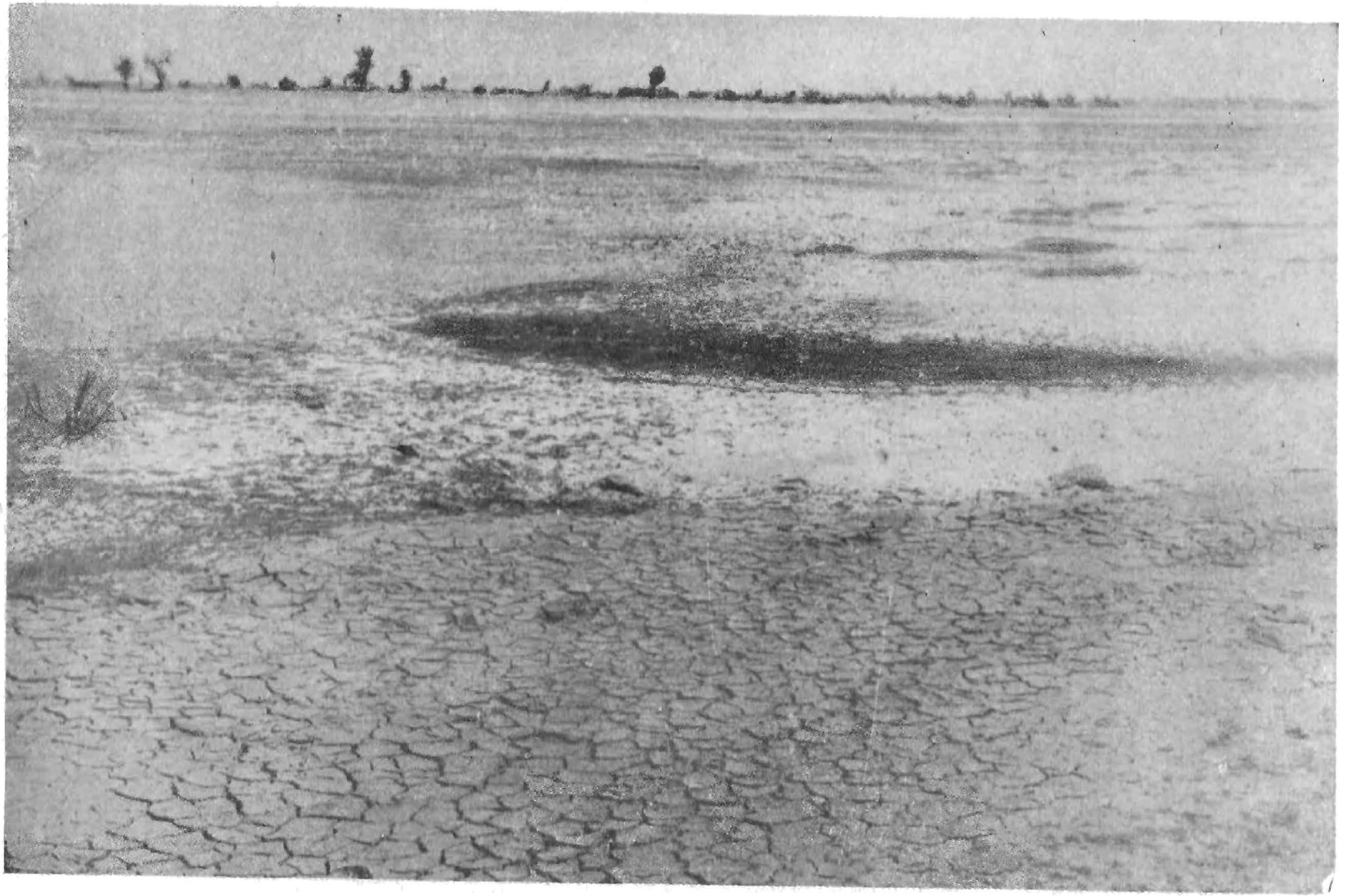
Genetic studies on *Calotropis procera* have been initiated to study the extent of variability for fibre content in progenies of different strains collected from various places of western Rajasthan.

Natural Products

A technique for the exploitation of indigenous *Acacia senegal* trees for tapping gum arabic has been developed.



Euphorbia antisyphilitica — a desert plant
yielding candelilla wax



Saline flat—a typical feature of the desert landscape

Acacia senegal trees growing in sandy and semi-rocky land types only have been recommended for tapping for gum arabic. Tapping of branches of this tree has to be restricted to the months of May and June.

Studies to identify and explore the possibilities of exploitation of plants of economic importance, revealed that Candelilla wax, Diosgenin and Hyoscine, isolated from desert plants, hold promise as a raw material for cordite and pharmaceutical industry.

Candelilla wax which has great industrial potential has been isolated from *Euphorbia antisyphilitica*, a desert plant of Mexican origin which has adapted well in the arid conditions of western Rajasthan.

Using solvent extraction technique, Candelilla wax has been obtained in 2.5 per cent yield (dry weight basis) which falls well within the limit at which economic exploitation is feasible. At present the wax is imported. The wax has been found suitable for use in the manufacture of explosives by cordite factory, Nilgiris.

Diosgenin, an important intermediate for steroid harmones and oral contraceptives, has been isolated from the root of *Balanites roxburghii* in 0.81 to 1.47 per cent yield.

Total alkaloid content in the leaves of *Datura innoxia* (E. C. 34404), raised at Jodhpur was 0.3 per cent. When raised at Bikaner, Kolayat and IARI, Delhi, the yield of active principle in the leaves was found to be 0.09, 0.2 and 01.2-0.14 per cent respectively.

Rotenone which is the most effective insecticide among rotenoids has been isolated from *Tephrosia villosa.*

Several medicinal oil bearing *Eucalyptus* species namely *E. sideroxylon, E. viridis* (Victoria, Aust.) and *E. viridis* (S. Aust.) have been analysed for their essential oil contents. *Eucalyptus viridis* (S. Aust.) is rich both in oil (1.08-2%) and cineole (93 per cent) contents. This makes the essential oil from this species more suitable for use in medicine compared to that from *E. globulus* which is at present the chief source of medicinal oil in the country and in which the reported cineole content is only 60%.

Arid Horticulture

The fruit crops suitable for the arid zone environment have been identified. Under dryland conditions, with suitable water harvesting techniques, *ber* (*Zizyphus*

mauritiana Lam.), pomegranate *(Punica granatum)*, guava *(Psidium guajava)*, custard apple *(Annona squamosa)*, and *gonda* or *lasora (Cordia myxa)* can be successfully grown. With supplementary irrigation, sour lime *(Citrus-aurantifolia)* and *amla (Emblica officinalis)* may be grown. Under the conditions of assured irrigation facility, fruits like mulberry, *phalsa (Grewia subinequalis)*, grape, date palm, sweet oranges and papaya can be grown profitably. Detailed cultivar evaluation with particular reference to *ber* and date palm is in progress. Results show that Gola and Seb cultivars of *ber* and Halawy and Shamran cultivars of date palm have performed well. In both cases early ripening cultivars have done better. Due to early maturation (January-February) these *ber* cultivars, under dryland conditions, made the best use or rain water from the monsoon. Halwy and Shamran date cultivars produced full ripe *doka* (Khalaal) fruits between 25th June and 10th July, well before the peak monsoon period. Good quality *Chhoharas* (dehydrated boiled dates) have been made from such fruits.

An improved technique for establishing *ber* orchards has been developed which takes only 5 months in the process. Rootstock seedlings are raised in 300 gauge polythene tubes (25 cm long, 10 cm dia.) filled with sand-clay-manure (1:1:1) mixture and kept in sunken bed by sowing seeds during first fortnight of April. Ninety day old seedlings are budded during first fortnight of July while they are in the tubes in the nursery. The budded plants become ready during middle of August. Plants raised by the technique have straight uncoiled roots and make good growth under the adverse conditions of arid regions. Such plants can be transported to long distances without much damage and at low cost.

Studies on the effect of runoff concentration from micro-catchments of 31 m^2 to 144m^2 per plant (besides the canopy area of 36m^2) and catchment slopes of 0.5, 5 and 10 per cent on the performance of *ber (Zizyphus mauritiana* Lam.*)* Cv. Seb indicated that maximum runoff was obtained at 5% slope and 14.5m length of run followed by 10% slope at the same length of run. This also resulted in increased moisture storage over the conventional (flat) planting, revealing that the storage increased with decrease in the length of run up to a point irrespective of decrease in the catchment area to planted area ratio. Catchment area of 54m^2 per plant with a slope of 5 per cent was optimum with respect to growth and production per tree.

Studies were conducted on watermelon (Cv. Mateera) and long melon *baris* (fields) around Bikaner (rainfall 255 mm) on unstabilized dunes under rainfed condi-

tions. Lack of capillary moisture flow (due to coarse texture) and negligible vapour phase flow (due to sub-soil temperature below 31°C) and weeding operation before monsoon helps in the conservation of moisture upto near field capacity (4-6%). The melon seeds are sown in March and about one litre of water per hill is applied to facilitate germination. The plants grow on conserved moisture. After the monsoon starts in July, fast growth rate, flowering and fruiting follow. The crop matures in September-October. The watermelon Cv. Mateera has an extremely drought hardy characteristic but it has a great variability in quality attributes. Some promising lines have been isolated.

Chillies *(Capsicum annum)* is an important cash crop in the Indian arid zone wherever irrigation facilities are available. A local cultivar named *Mathania* is popular. It, however, has great variability in quantitative and qualitative characters. Improvement work to develop a high yielding and quality variety has resulted in the isolation of a few promising types.

CROP PRODUCTION TECHNOLOGY FOR ARID ZONE

About 40 per cent of the total area in arid zone of Rajasthan is under crops mostly under dry farming conditions. The region contributes considerably to the food production, particularly pulses produced in the country. The recent statistics have shown that the arid zone of Rajasthan produces about 69 per cent of total (other) pulses produced in Rajasthan, or about 5 per cent of the total pulses produced in the country. Over 50 per cent of the total *bajra* produce in Rajasthan comes from arid districts, which inhabit a little over one-third of the total population of Rajasthan. The arid region contributes nearly one-tenth of the total wheat produced in Rajasthan, besides substantial contribution to the production of other major crops grown in the State.

Wheat yield per unit area is higher in the arid zone than the average for the country. Therefore, with increasing availability of irrigation, research results, and successive changes being brought about by the developmental plans there is a good scope of significant improvements in agriculture in arid areas. Adaptive researches on various aspects of soil, water, crops and soil-water-crop relationship have been conducted by desciplines e. g. agronomy, dry farming, soil physics, soil fertility, plant physiology and others. The practices for combating drought, improving the prospects of crop harvest and squeezing the best from the limited water supplies have been evolved.

Wind Erosion

Sand Movement : Movement of sand under different land use conditions such as bare sandy plain, sandy plain with grass cover, sandy plain with bajra stubble cover have been studied at Beechwal (Bikaner), and under unstabilised and stabilised sand dune conditions at Udairamsar (Bikaner district). Results have indicated that in a period of 75 days, from April through June, about 9 cm of sand was removed from a bare Sandy plain. The removal of sand from stubble cover was only 0.2 cm, whereas an actual deposition of 0.1 cm of sand took place under grass cover. A high cumulative depletion of sand of the order of 37 cm was observed from an unstabilised sand dune. Against this there was an actual entrapment of 1 cm of sand on dunes stabilised by grass and tree covers. Sand size distribution of eroded field indicated an increase in coarser fractions (0. 3 mm) and a decrease in finer fractions possibly because of their removal by high winds. A high amount of organic matter, total nitrogen, phosphorus and potassium was removed from bare sandy plain and unstabilised sand dunes, while there was some addition of these nutrients on stabilised sand dunes because of sand deposition.

Strip Cropping : Winds cause considerable damage to crops in the area. A system of strip cropping consisting of permanent grass studied in a crop land to grassland ratio of 6: 1 has been studied over a period of 8 years. Strip cropping has been found to reduce wind erosion, and increase yield of *bajra* by 6 and of *moong* by 17 per cent, over unprotected control.

Crop Residue Management : Crop residue management known popularly as stubble mulch farming has been investigated. The conclusion drawn from 9 years of field trial reveals that 30 cm anchored stubbles of *bajra* maintained at harvest, conserve the soil and increase, over non-stubble plots, the yield of a subsequent *bajra* crop by 11 per cent. Stubbles when ploughed in at the time of sowing of the next crop allow adequate incorporation of decayable residues in the soil.

Water Conservation

Field Bunding : The success of dryland farming hinges on storage, conservation and efficient use of rain water. A five year study has revealed that in the heavier soils at Pali, field bunding alone resulted in about 36 per cent more conservation of moisture, thereby increasing *bajra* and *jowar* yields, over non-bunded plots, by 10 to 12 per cent in the wet, and over 200 per cent in extremely dry season.

Water Harvesting

Microcatchment farming : A technique evolved for catching rain water and for cropping in the runoff concentrated in a level plot below the sealed catchment mechanically made in a cultivated field has proved useful in rainfed agriculture. The data presented in Table 3 show that runoff farming has potentials to increase and stabilise yields, lower the risk of crop failure, save inputs of production, and make the best of every rain drop that falls on the farm.

The transfer of a part of the area to the catchment does not reduce the total production. Studies indicate that the total prodction by cropping only two-thirds of a unit area (one-third of the area going into the catchment) by runoff farming is the same as obtained from conventional cropping on a flat surface control. Microcatchment farming also saves inputs in proportion to the area gone into catchment.

Table 3 : *Production potential (kg grain/cm of growing season effective rainfall)*

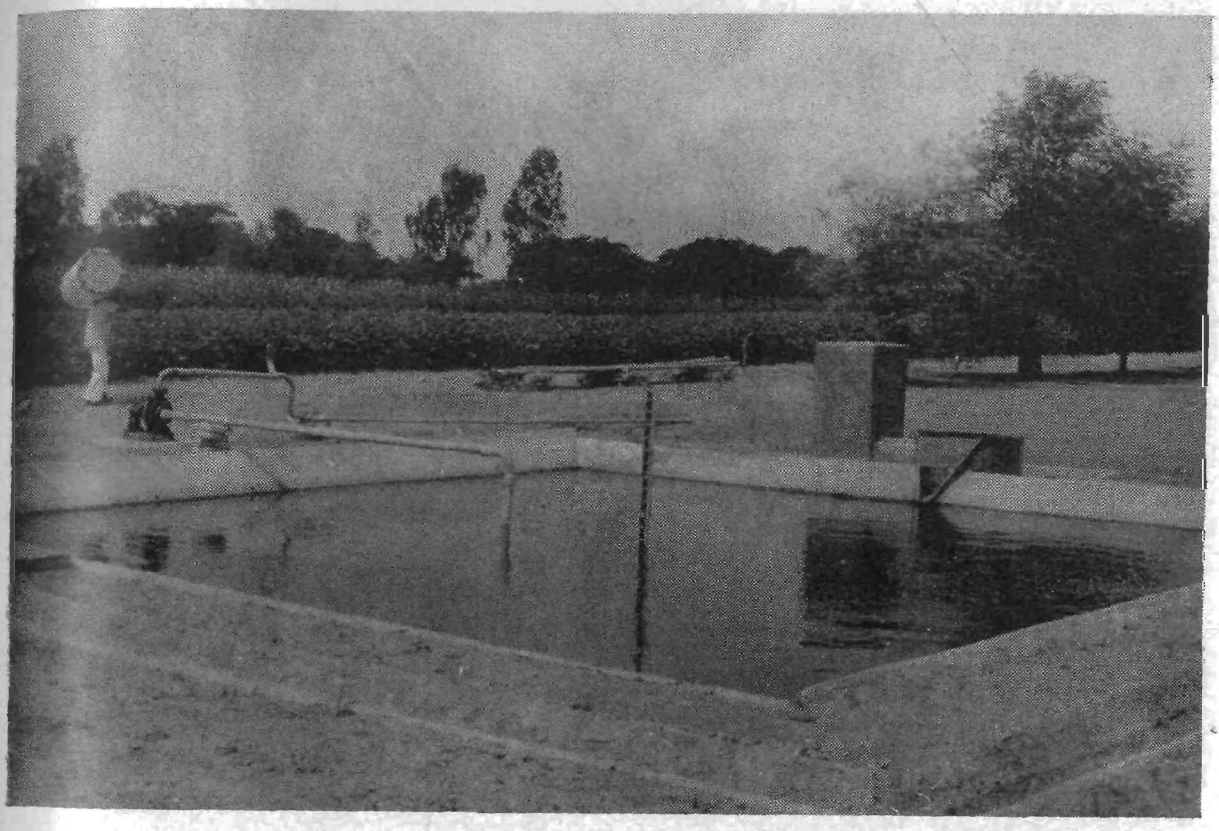
Year	Bajra	Sorghum	Moong	Cowpea	Guar	Til	Sunflower
			Flat surface control				
1970	35						
1971	57						
1972	0	0	14	10	15	9	—
1973	84	105	31	36	0	20	21
1974	0	0	0	0	0	0	0
1975	80	83	0	11	0	13	18
Mean	43	47	11	14	4	11	13
			0.5 catchment to cultivated area ratio				
1970	118						
1971	93						
1972	36	25	23	22	21	22	—
1973	101	136	43	51	0	39	34
1974	12	0	24	0	13	3	0
1975	117	138	63	39	41	12	35
Mean	80	75	38	28	19	19	23

Results showed that catchment to cultivated area ratio of 0. 5 was the optimum. Under this system the cultivated area received 140 to 636 mm of water, although rainfall received varied from 117 to 528 mm in different years. As more water became available, the need to integrate into the system all possible management practices became increasingly important. Studies showed that by integration of hybrid bajra, fertilizer use, and better crop husbandry (one shallow tillage, one weeding, double row planting geometry and rotative cropping, into the system of micro-catchment farming) brought the yield level of bajra crop from 3.2 q/ha for the local practices to 27.6 q/ha. Integration of practices into the system gave synergetic effect. For example, the efficiency of better husbandry was one and half times higher in the presence than in the absence of hybrid bajra, fertilizer and water harvesting. Likewise, the production efficiency of hybrid bajra, fertilizer and water harvesting together was greater with than without better husbandry.

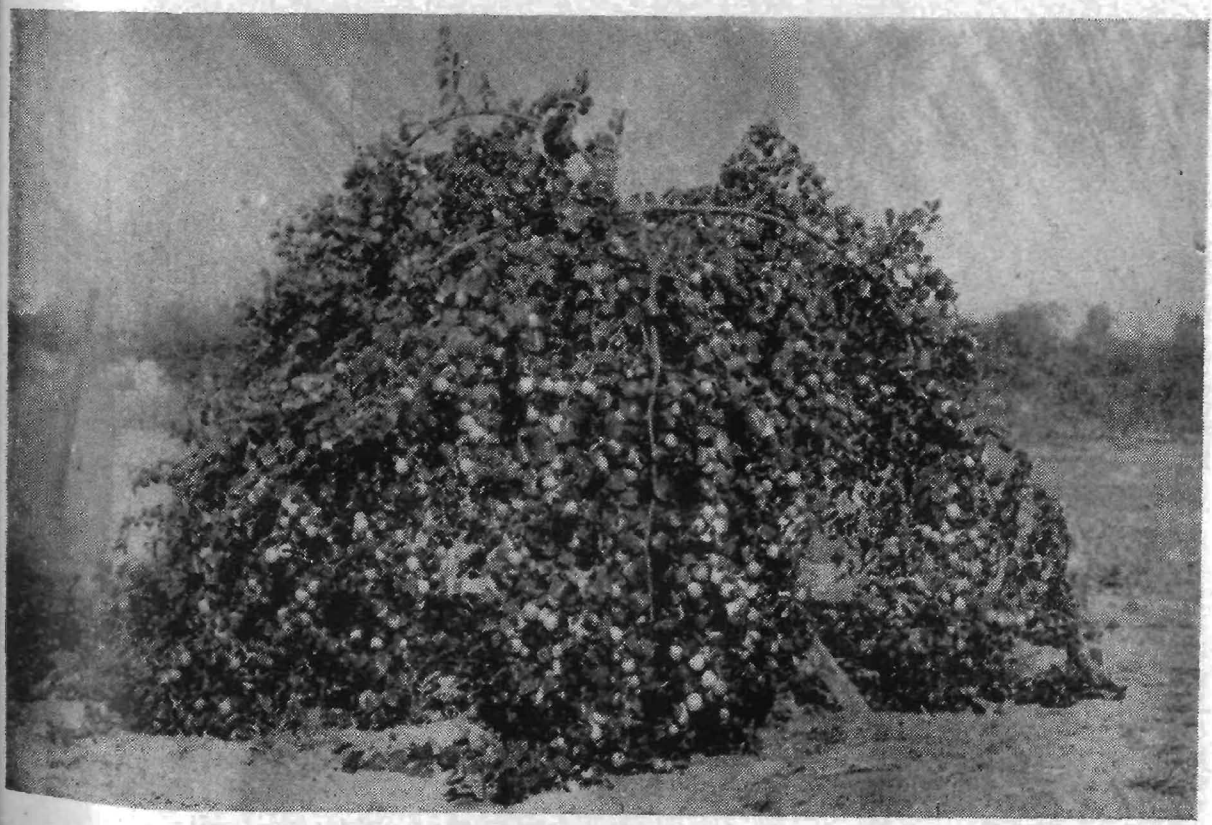
b) *Runoff Collection, Storage and less Recycling* : Studies on runoff collection from a bare catchment revealed that of the total rainfall received during the monsoon seasons of 1976 and 1977, the quantity of runoff obtained was of the order of 103 and 48 mm, being 27 and 16% of the total rainfall respectively. The studies have further revealed the possibilities of recycling the stored runoff for giving (a) a life saving irrigation to bajra during prolonged droughts in the season, (b) a supplemental irrigation to long duration crops like castor and guar beans at the later stages of growth on receding the soil moisture and (c) a presowing irrigation for crop(s) to be taken during the subsequent winter season. A supplemental irrigation of 3-5 cm given from the stored water increased the yield of castor by 10 per cent.

Use of Sub-surface Borriers for Water and Nutrient Conservation

It has been estimated that about 40% of the total rainfall is lost as deep percolation. Field trials with three subsurface barriers viz., asphalt, bentonite clay and pond silt, each placed at 60 cm in 5 mm thickness (asphalt in 2 mm thickness), on bajra indicated that these barriers allowed for 80-85%, 60-70%, and 50-60% retention of the total rainfall in the root zone respectively. Higher yields and water use efficiency by bajra have been observed under modified soil conditions with barriers compared with the condition without barriers. Asphalt barrier showed increased moisture status in soil throughout the cropping season. It also reduced leaching losses of nitrogen. Nitrogen thus conserved was reflected in higher status of



A water-harvesting system—runoff collection and its recycling



Ber (Zizyphus mauritiana)—a fruit plant for the desert

Sprinkler irrigation system — conserves water and maximises crop production

Drip irrigation — maximises production per unit of application of water and inputs

mineral nitrogen in soil and increased nitrogen oontent in the plant and its uptake by bajra.

Bentonite as Subsurface Moisture Barrier

Bentonite clay is a natural resource of western Rajasthan. As subsurface moisture barrier, it has been found to reduce deep percolation of moisture from root zone. Partial (localised) incorporation of bentonite in pits or trenches when integrated into runoff concentration technology has made possible the production of vegetable crops like *tinda* and *bhindi* under dryland conditions. Soil moisture storage by 40% and its manifestation in significantly higher yields of these vegetable crops bears this fact out. In pits, bentonite can be placed laterally too. In this way it creates a buried pot-like structure. which in particular is suitable for initial establishment of tree plantations.

Field Moisture Balance

The concept that land capability based on moisture balance as one of the parameters would be reliable for determing proper land use and choice of crops and cropping patterns has been developed for soil-climatic situations of this region. It was observed that field moisture regime could be characterized more precisely by following soil–climatic approach rather than climatic approach alone.

An approach stressing the importance of moisture retention properties of *murrum* substratum for characterizing moisture balance has been developed. Further, it was found that soil moisture moves upward in winters and downward in summers, along the soil temperature gradient. The soils underlain by *murrum* having good moisture storage capacity can therefore supply enough moisture in vapour phase to deep-rooted crop like castor and drought hardy plantation crop like ber in winter season.

Mulches for Moisture Conservation

Use of polyethylene films as mulch has shown higher moisture conservation and consequent higher yields and water use efficiency by *bajra* than no mulch treatment. This needs further verification by comprehensive studies on different kinds of mulches. However, since the soil in this desert area are self-mulching, use of organic mulches for moisture conservation have been found of limited usefulness. If drought sets in following sowing, organic mulch, however, delays the drying of soil surface and helps in emergence and establishment of seedlings. Organic mulch has also been found to keep soil temperature 3 to 4°C lower than unmulched treatment

while polyethylene mulch raised soil temperature by 2 to 4° C. All these effects for and against various kinds of mulch and their reflections in crop yields are being studied.

Soil Management

Conservation Tillage

The soils of this area, by and large, are coarse textured. Looking to the soil characteristics, the "minimum tillage" ought to find a place in dry farming practices. The results of an experiment carried out over 5 years revealed that "plough to sow" operation with a 6-row tractor seed drill yielded *bajra* in about the same quantity as obtained from a crop sown after 2 ploughings (Table 4) and thus save about Rs. 39 to 83 per hectare.

The "plough to sow" operation also conserved the soil, because of minimal tillage. However, it did create weed problem in subsequent years. To overcome this problem, pre-emergence herbicidal treatment becomes essential part and partial of "plough to sow" method of tillage.

Table 4 : *Yield of Bajra from different tillage methods*

Operation	Yield, kg/ha
'Plough to sow'	590
1-Ploughing by country plough	570
2-Ploughing by country plough	650
1-harrowing	600
1-harrowing + 1-ploughing	640
F-test	(not sig.)

In continuing quest for tillage practices suitable for sandy soils, a bullock drawn seed drill with bukhhar attachment has been developed. This drill has a draft requirement of about 45-50 kg and is capable of land preparation, fertiliser placement and seeding in a single operation. This can also be used for interculturing in widely spaced row crops.

Crust Formation and Seedling Emergence

Rainfall received after sowing of crops results in break down of soil structure which on drying forms crust and affects adversely the emergence of seedlings. Field trials to simulate rainfall at three intensities under three methods of sowing (ridge, furrow, and flat) indicated that seedling emergence of the order of 69-80% in mustard and 60-65% in sunflower occurred on seed bed with no rain after sowing, hence no crust formation. Under high rainfall intensity conditions resulting in high crust strength the percentage emergence ranged from 38-54% in mustard and 21-40% in sunflower. Shallow cultivating and sprinkling water after crust formation tended to lower the crust strength and improved seedling emergence.

Post-sowing Compaction and Seedling Emergence

Soil moisture is one of the most important factors limiting germination, emergence of seedlings and crop growth. Compaction of sand to a relatively small range has been found to increase capillary porosity and water availability. Post-sowing compaction of seeded rows with narrow iron wheel (20 cm x 5 cm) of 9.2 kg weight resulted in maximum seedling emergence of 70-80% under about 7% moisture condition, and 50-60% under about 6% soil moisture. This resulted in an early completion and high rate of emergence.

Use of Soil Amendments

Laboratory and field studies indicated that addition of pond sediment increased field capacity, decreased hydraulic conductivity and bulk density, but increased microporosity and wind stable aggregates. Increase in mineralization of nitrogen was also obtained after addition of pond sediments 150 tonnes/ha. As a result, yield of pearl millet increased by 50 per cent over control.

Sand Dunes Characteristics

Moisture Relations

Unstabilised sand dunes in Bikaner region were found to contain 50-70 mm of moisture in 180 cm profile, as against 12-23 mm in stabilised dunes. With coarse fractions at the surface, unstabilised dunes had more recharge of water and less evaporative losses, hence seemed to have better potential sites for undertaking agriculture or sand dune stabilisation programme.

Nutrient Relations

Unstabilised dunes were found to contain higher nitrate nitrogen and lower available phosphorus and potassium than stabilised dunes. Higher status of available nitrogen can be helpful to support the vegetation planted in sand dune stabilisation programme.

Crop Management

Rate, Spacing and Depth of Seeding

Success of dry farming depends on plant population in relation to the conserved moisture. Seeding of *bajra* in rows 50 cm apart (linear density 15 cm) , *moong* and *guar* at 9 kg/ha seed rate, castor at 50 x 50 cm spacing, and grain sorghum at 9 kg/ha seed in 50 cm rows was found to yield good production.

Sown at the above rates and spacings, the yield of *bajra* was about 8 per cent more than in 30 cm rows, of grain sorghum about 7 per cent more than that sown at 13.4 kg/ha seed in 45 cm rows, of *moong* 13 per cent more than that at 13.4 kg/ha seed, and of castor 38 per cent more than that obtained from 100 cm x 100 cm sown crops. The depth of sowing is important in *bajra*. Sowing 7.5 cm deep has proved better.

Crop Stand Establishment

(a) Seed Bed Preparation : Sweep cultivator and mould board plough have proved suitable over disc implements, for preparatory tillage for *bajra* in sandy desert soils resulting in greater intake of water and less weed infestation.

(b) Seeding Techniques for Bajra : Bullock drawn CAZRI drill proved superior to other drills for sowing *bajra* in sandy soils. Packing attachments with seeding devices gave better seedling emergence due to better seed-soil contact and increased stability of furrows against the impact of rain drops in the event of pre-or post-emergence rain.

(c) Plant Density/Population : In *moong*, the optimum plant population was 5-7 lakhs (18 cm row to row spacing).and 1.9 lakhs (52 cm row to row spacing) for normal and late sown conditions, respectively. In *bajra* the optimum plant population was 1.9 lakhs (52 cm row to row spacing) for normal sown crops and 2.9 lakhs (35 cm row spacing) for the crop transplanted late in the season. For

guar, row spacing of 30 cm was optimum for a single stemmed variety, and 45 cm for a branched type.

(d) Seed Soaking and Seeding Depth : Seeding of castor 10 to 15 cm deep after 24 hours of seed soaking in water ensured faster and better emergence of seedlings.

(e) Weed Control in Grain Legumes : Herbicides such as Treflan, Lasso and Tok E 25 in *guar,* and Treflan and Amiben in *moong* proved effective for control of weeds.

(f) Cropping Strategies for Aberrant Weather Situations : In the event of late onset of monsoon towards the end of July or mid-August, planting of pulses like *moong, guar, moth* and cowpeas and oilseeds like *til* is preferable over *bajra.* However, if *bajra* has to be grown late in the season, transplanting 3 weeks old seedlings proved successful giving as much yield as normal sown crop. However, high labour cost may be a factor limiting this practice.

(g) *Crop Production on Stored Moisture in the Rabi Season :* Mustard *(Brassica juncea)* can be grown on pre-season stored soil moisture, provided profile storage to 1 m depth is about 100 mm.

Crop Varieties

The varieties of crops found adapted to this tract are 'HB 3' of *bajra* (now BJ 104); 'Durgapura Safed' and 'FS 277' of *guar*; 'Aruna', 'R 63' and 'Gujarat Hyb 3' of castor; 'Sojat Bavani' of forage sorghum; 'Pratap' and 'T3' of til., 'RS 4', 'PS 16' and 'S8' of *moong*; 'T 18' and 'Jadia' of *moth* bean and 'FS 68' of cowpeas. For irrigated pockets wheat 'S 307' and 'Kalyansona' have shown promise.

Crop Rotation

A study conducted over 15 years on four rotations of *bajra-bajra, bajra-moong, bajra-guar* and *bajra-moth* has shown that the *bajra-moong* system of cropping takes advantage of rainfall distribution. If *bajra* crop is damaged by prolonged drought early in the season (as happened during the 1972 growing season), or if monsoon is so delayed that *bajra* cannot be grown successfully, *moong* serves as an alternative crop. The efficiency (i.e. per cent contribution by legume to *bajra* yield over continuous cropping) of this rotation has been the highest. As a component crop *moong* has contributed about 20 per cent to the yield of *bajra* over that of continuous cropping (Table 5).

Table 5 : *Efficiency of rotation expressed in terms of per cent increase/decrease in bajra yield due to legume in rotation over continuous cropping*

Bajra after	*Bajra* yield (kg/ha)	Per cent increase/decrease in *bajra* yield over monoculture system
Bajra	2471	100
Guar	2510	102
Moong	2963	120
Moth	2207	89

Mixed cropping

Besides being advantageous and more efficient in rotation, *bajra* and *moong* when grown together in the ratio of 3 lines to 2 have proved economical under all the fluctuating conditions of weather, product value and input prices over 3 years.

In a 4-year study on the heavier soils of Pali, the dry matter yield of sorghum grown alone and cut at the silage stage was higher than when it was grown mixed with cowpeas, *guar*, or *moong*. From the standpoint of nutrition, sorghum+cowpeas mixture is the best, because of its larger protein yield. Besides that, cowpeas reduce the nitrogen requirement of sorghum by almost 50 per cent.

Intercroppings of *guar* and *moong* beans in *C. ciliaris*, cowpeas and *moong* in sunflowers, cowpeas (fodder) in castor, and *bajra* in paired rows of *guar* as well as *moong* have been found economical in poor to normal and good rainfall years, respectively. Land and other inputs are better utilized, as revealed by higher values of land equivalent ratio.

Fodder and Forages

Fodder cowpeas (HFC 42-1) exhibited greater yield potential than other fodder legumes-cluster beans and dew gram tried, both at short and long cutting intervals. Response to phosphorus application (20 kg/ha) was also highest in cowpeas. In the case of early cutting intervals (35 to 45 days) cropping intensity can be increased from 100 to 200% by taking another fodder crop of *jowar* (locally known as *Cheepta*) in succession.

Mixed cropping of cowpeas (HFC 42-1) and *jowar* or *bajra* for fodder proved remunerative with regard to fodder quality and tonnage.

Planting Geometry

For the efficient use of conserved rainwater, sowing of *bajra* 'HB3' in 40 cm close rows alternated with 80 cm spacing, and of sorghum 'CSH_1' in 25 cm close rows alternated with 75 cm have proved satisfactory as these have resulted in an increase in the yield of *bajra* on sandy soils at Jodhpur by 94 per cent and of sorghum by 98.6 per cent on heavier soils at Pali.

Soil Fertility and Fertilizer Use

Soil Fertility Evaluation

(a) Organic Nitrogen Fractions in Soil : Hydrolyzable organic nitrogen fractions as per cent of total nitrogen, in different soil series of Jodhpur, were in the order of aminoacid N > unidentified N > ammonium N > hexosamine N. Their respective contents ranged from 18.8 to 40.0, 14.1 to 50.0, 3.1 to 9.4 and 0.8 to 3.1 per cent of total N in surface soils. Thus, these soils contain high aminoacid N, but are deficient in hexosamine N and hydrolyzed ammoniacal nitrogen. The latter two fractions are important native sources for the uptake of N by crops; therefore, there is a need to build up these fractions in soil through incorporation of legumes into the cropping sequence.

(b) Saline-Sodic Water Use and Soil Nitrogen Fractions : Effects of irrigation from saline-sodic waters on mineralization of soil nitrogen were studied. The results showed a significant increase in hydrolyzable N, aminoacid N and hexosamine N but a decrease in unidentified N and non-hydrolyzable N fractions as a result of irrigation with saline-sodic water in comparison to the soils receiving no irrigation. The favourable effect of saline-sodic water was found to be more due to the presence of Na^+ and SO_4 ions.

(c) Volatilization Losses of Urea Nitrogen : The studies indicated that loss of urea nitrogen broadcast and mixed with soil was 20% as volatilization in 14 days of application. Out of this loss, 65% occurred during first three days of its application. On the contrary, the losses were negligible when the urea was placed to plow depth. The method, which uses 2% boric acid is simple for determining volatilization losses of N direct in the field.

(d) Nutrients through Rain : Chemical analysis of rain water, collected at Bikaner, Jodhpur, Pali, Palsana and Jaisalmer, showed that on an average each mm of rainfall added 28 g N/ha and 0.14 g PO_4 –P/ha annually. In normal rainfall year,

nitrogen so added can meet the nitrogen requirement of the grass species, provided leaching losses do not counterbalance the additions.

(e) Soil Fertility Changes Associated with the Growth of Desert Tree Species : *Prosopis cineraria* (Khejri) and *Tecomella undulata* are found to enrich the soil underneath in organic matter, total N and P, available N, P, Mn and Cu contents. On the contrary the soils under *P. juliflora* were low in these nutrients.

Use of Fertilisers

The rate, source, time and method of fertilizer application have been investigated. Fertilizer nitrogen has been 30 per cent more efficient in *bajra* crop than farm yard manure on equal nitrogen basis. Under dry farming conditions the optimum level in kg/ha of nitrogen is 17.5 for Rajasthan State selections of *bajra,* 53.7 for forage sorghum in heavier soils at Pali, and 30 for castor. For irrigated crops it is 145 for '*Kalyansona*' wheat and 159 for hybrid sorghum 'CSH$_1$'. Nitrogen applied in two equal splits recognizes rainfall distributions. In 'RSJ' *bajra* one half of 22.4 kg nitrogen applied at sowing and one-half top dressed have given about 18 per cent more yield compared to a single application of the whole amount at sowing.

Application of 5.6 kg/ha of zinc in the heavier soils at Pali increased the yield of grain sorghum by 14 per cent. On the loamy sands at Jodhpur zinc at 11.2 kg/ha increased *bajra* yield by 22 per cent.

Recent studies have shown a positive effect of zinc application on the intensity of infection of downy mildew disease to hybrid *bajra* (HB3). The effective level of zinc was found to be 15 and 30 kg zinc sulphate per ha in drought and normal seasons respectively. Its application also had a favourable effect on increasing the nitrogen content and its uptake by *bajra* crop.

Application of FYM @ 40 metric tons/ha once in two years gave higher yield of *bajra* than that from 40 kg/ha of fertilizer nitrogen applied every year. Organic manure increased the availability of soil phosphorus considerably and resulted in a build up (19-35%) in soil organic matter level after 4 years of cropping.

A saving in fertiliser N to the extent of 20 kg/ha could be effected by growing *bajra* in rotation with *moong* instead of continuous cropping of *bajra.* Evaluation of different varieties of moong beans for their N fixing abilities revealed varietal differences discussed later.

Fertilizer Economy Under Constrained Supply

Four approaches have been studied. They are :—

Through Time and Method of Application : The results of a study conducted over 3 years have shown that in hybrid *bajra* var. 'HB3, nitrogen 30 kg/ha can be added at the time of sowing, and 15 kg later as top dressing in normal years, or as a spray in below normal years. If spray facilities are not available, 15 kg nitrogen cannot be applied as a top dressing during the dry seasons. In that case, only 30 kg basal nitrogen is recommended in below normal rainfall years.

(b) *Through crop management* : Fertilizer economy can be affected by growing a crop having high fertilizer use efficiency followed by one having high soil nutrient use efficiency. Investigations over 7 years have shown that in a *bajra–moong* rotation followed under rainfed conditions, application of 60 kg/ha phosphorus to *moong* crop once in 2 years and *bajra* grown on the residual fertility was most economical. In another rotation of rainfed *bajra*–wheat (wheat raised with 25 cm seasonal water), the results suggested the use of 15 tonnes/ha of farm yard manure only in *bajra* during the *kharif* season and wheat can be grown during the following *rabi* season on the residual fertility

(c) *Through better use of fertilizer carryover* : The information on how much of the fertilizer added to the previous season's crop is remaining unused is useful for determing fertiliser application to the next crop. The carryover, after one season, of 160 kg/ha of nitrogen applied to irrigated wheat was found to be 30 to 43 per cent or 48 and 68.8 kg urea nitrogen. At the present rate, this much saving in nitrogen will reduce the fertilizer requirement of subsequent crop substantially.

(d) Through biological means : The rhizobia incoulation costing only Rs 8/ha was found to be the cheapest way of boosting yield of rainfed moong. The incoculated plants nodulated profusely and gave 51 per cent higer yield than uninoculated control. Yield gain of this magnitude has not been obtained either from the application of 20 kg/ha of nitrogen or 30 kg/ha of phosphorus, or the two applied together.

However, an application of 60 kg P_2O_5/ha was found to be effective in increasing the nitrogen fixation capacities of uninoculated *moong* (S/8), *guar* (FS/227) and *moth* (local). This was due to an increase in number of nodules, per cent

nitrogen in nodules and increase in cation exchange capacity of roots. In the case of *moong* there were varietal differences with regard to the amount of nitrogen fixed and its effect on succeeding forage sorghum and barley crops. Cultivars Madira and M-10 were capable of adding nitrogen to the soil in one season equivalent to more than 20 kg/ha of fertilizer nitrogen applied.

Squeezing The Best Out Of Water

Through rainfall supplement

The basic problem of desert agriculture stems from improper land-water relationship. To ease this imbalance on a micro-scale a sprinkler irrigation of 25 cm of water over 4 ha of *bajra* 'HB3', and 27.5 cm of water over 2.5 ha of grain sorghum 'CSH_1' resulted in a total production of 10,332 kg of *bajra* and 6,385 kg of sorghum (without sprinkler irrigation these crops succumbed to drought).

Through extensive irrigation

Extensive irrigation concept seeks to apply a small quantity of water over a large area rather than a large quantity over a small area. For example, when 82.5, 50 and 25 cm of water was applied, respectively, over 1 ha each of wheat, sunflower and mustard, the respective production was 5,458, 1,607 and 1,102 kg. The corresponding production from the same quantities of water applied over 3, 2 and 1.5 ha of these crops was 9,104, 2,712 and 1,935 kg. Use of water in the latter way will, therefore, decrease the return per unit of land, but will increase it per unit amount of water.

Through use of modern systems of irrigation

Check basins are conventionally used for irrigation purposes in the area. On sandy soils with uneven surface, this method is very inefficient. Sprinkler irrigation of wheat crop has resulted in a yield of 4,301 kg/ha. This yield was about 33 and 37 per cent higher than from the conventional check basin and the border strip method of irrigation respectively.

Sometimes high wind speed limits the use of sprinkler. Drip irrigation is not affected by winds. The system of drip irrigation enables the best use of every drop of the available water. This system resulted in a saving of 50 per cent of water (in potato crop) required under conventional furrow irrigation, and displayed a high potential for the use of saline water, which is widely prevalent in the area.

As the yields under drip irrigation have been far in excess of what at one time was thought possible by conventional irrigation, the former method may be considered as an "instant transfer technology", more suited to high value, widely spaced vegetable crops. In the first stage, the utility of the technology is being demonstrated through an operational research programme undertaken on village level. The only factor seems to limit its large scale adoption is its high cost. Recent studies of stand geometry, simulated to minimum installation cost and water use by drip irrigation, have shown that double row planting resulting from 25 cm square or equilateral plant geometry reduces installation cost and water use by 50 per cent.

Through better knowledge of soil-water plant relationship : From the yield-water relationships, in wheat the concepts of the optimum yield per unit of land when land is the limiting factor, the optimum yield per unit of water when water supply is limiting and the "lowest acceptable" yield concept for assuring the greatest number of farmers to benefit from available water supply have been developed.

An optimal irrigation programme to attain the maximum yield of wheat variety 'Kalyansona' with the least number and depth of irrigation has been worked out. In the optimized programme, the dates and depths of seasonal irrigations have been defined, and alternative irrigation plans to suit different water supplies have been formulated. To illustrate three selected plans applicable to adequate (Imax), medium (Imed) and low (Ilow) water availability situations are given in table 6.

Table 6 : *Optimal (yield maximising) plan of irrigation (I) for 'Kalyansona' wheat for three levels of seasonal irrigation*

Total seasonal irrigation (cm)	*Irrigation (cm) on days after*							Yield from irrig. (kg/ha)	Total yield* (kg/ha)
	21	40	54	68	78	90	100		
84.1 (Imax)	7.2	10.4	11.8	13.2	14.0	14.9	12.6	4234	5430
40.0 (Imed)	—	2.5	10.0	5.0	10.0	12.5	—	3528	4724
20.0 (Ilow)	—	2.5	—	5.0	7.5	5.0	—	2472	3668

**Summation of yield from irrigation and yield from plot simulated to represent unirrigated "Khadins"*

Given a definite level of water supply, how farmers should allocate areas under different crops so as to maximise their gross returns ? In the current context of

severe restrictions on fertilizer availability, it is also of interest to know, in terms of farm plans, what impact this has on the farmer's gross returns ? From a comprehensive research initiated since 1971, a procedure for planning allocations of four constant-rate water supplies (available from tube wells of 2, 4, 10 and 50 thousand gallons/hr pumping capacities) to four important crop alternatives viz., wheat, mustard, sunflower and safflower has been developed. The results showed that the area irrigated should be proportional to the available water supplies. Wheat, mustard and safflower occupy, respectively, 38, 31 and 31 per cent of the area irrigated, from whatever may be the available water supply. After assigning 56 cm water, 150 kg/ha N, and 125 kg/ha seed to wheat; 17 cm water, 30 kg/ha N,, and 40 cm row spacing to mustard; and a preplant irrigation, 50 kg/ha N, and 40 cm row spacing to safflower, this optimal plan showed the largest profit potential and the employment prospects. Sunflower was found uneconomical. An 80 per cent water deficit later in the season, or 50 per cent less fertilizer availability, does not materially alter the plan or the acreage, but to cope with the scarcity, the plan suggests transfer of 37 per cent of the total wheat area from the optimum to suboptimum (29 cm) level of irrigation, and withdrawal of fertilizer from safflower. However, if water deficit expectations shift to the earlier part of the growing season, it would pay to transfer water from wheat to mustard, but as soon as 11 cm of seasonal water is used, wheat crop would have to be assigned priority.

Use of Saline Water for Irrigation

Use of highly saline waters has been rightly looked upon with great scepticism. It is, however, undeniable that in a major part of the arid region saline water is the primary source available for irrigation. Therefore, a comprehensive investigation was made into various aspects of saline water irrigation, its limitation and potential. Results have shown that high to very high salinity build-up in soil does take place in course of irrigation with saline waters. However, the salinity so build-up is amenable to leaching during following rainy season. The leaching is accomplished with one season's rainfall on loamy soils and two season's rainfall on heavier soils. The system has not led to an extra-ordinary built-up of alkali hazard. In fact, after leaching the alkali hazard in surface layers has been rather low. In wheat (Kharchia), irrigation with water of 5 to 10 mmhos E.C. gave yield of 15 q/ha. Irrigation with waters of 10 to 15 mmhos E. C. reduced yield to 10 q/ha. Where nitrates are naturally present in saline waters, yields are still better. Waters of 3 to 5 mmhos E.C. permit a variety of cash crops like plantago, coriander, cumin and chillies.

Another study revealed that irrigation water of E.C. up to 9 mmhos/cm could be used for irrigation of sunflower, castor and *bajra* crops. Sunflower was relatively more tolerant to salinity. *Bajra* and sesamum were sensitive to an E.C. level of even 6 mmhos/cm. Application of one-third of irrigation water in each infraction helped in maintaining lower salinity in the root zone and gave higher yields. Furrow irrigation with saline water maintained lower salinity and exchangeable sodium in the root zone as compared with flat irrigation, thus giving higher crop yields.

Agricultural Pests and their Control

Rodent Ecology

Rodents are responsible for causing serious damages to foodgrains, grasses and pastures, stored materials, orchards, natural vegetation and tree plantations. Certain rodent species exhibit a habitat-specificity, e.g. *Gerbillus n. indus* exclusively inhabits the sandy habitat. *Rattus c. cutchicus* and *Mus cervicolor phillipsi* are found in the rocky habitat, *Rattus rattus* and *Mus musculus* in the urban and village complex, and *R. meltada pallidior*, *Golunda ellioti*, *Nesokia indica* and *Mus booduga* in the agricultural crop fields. Other species of rodents inhabit a variety of habitats representing various vegetation types. Data on the relative abundance of rodent pests in all the desert districts of Rajasthan have indicated that *Meriones hurrianae* and *Tatera indica* are the most abundant species, followed by *Gerbillus gleadowi*, *Rattus meltada* and *Rattus cutchicus*.

The ecological studies on rodent pests have yielded information regarding the optimum season for control operation (based on population fluctuations and breeding cycles), effective ways of bait placement (on the basis of habitat preference) and optimum distances between bait stations (on the basis of home range data). The ecological evaluation of rodent control is very helpful in organising rodent control campaigns in a more effective manner.

Control of desert rodents

On the basis of studies on bait preferences, seed consumption, and lethal dosages of various toxic chemicals, two methods for the control of field rodents have been recommended.

The first method is an improvement of the old one in vogue. Experiments conducted at the Institute have revealed that mixing of 1.5 to 2 per cent zinc phosphide

in a carrier is sufficient for rodent control, although the use of the poison at 5 per cent level has been practised in the past. The decrease in the poison concentration not only increases the palatability of the poison-baits but also reduces chances of secondary hazards and pollution of the environment. The other improvement made is replacement of *gur* (jaggery) by 3 to 5 per cent of groundnut oil in the bait. The third change found advantageous is poison-baiting after three days of pre-baiting which brings about significantly higher mortality of the field rodents. The fourth improvement is poison baiting only on one day. If it is continued for more than a day, not only the consumption of the poison-bait is so low as to be wasteful of labour and material but the rodents develop bait shyness also. The modified method is to pre-bait the active burrow openings in the field with 6 gm bait per rodent per day. Pre-baiting is to be done with :

Bajra flour	97 parts
Groundnut oil	3 „

On the fourth day, the burrow openings should be poison baited at the same rate with :

Bajra flour	95 parts
Groundnut oil	3 parts
Zinc phosphide	2 parts

The second method is based on three principles, the food grains should be saved for human consumption instead of using them for baiting rodents, the pre-baiting and poison baiting should be done together, and thirdly, the method should be fairy cheap. It has been found that *ber (Jhadberi,* dried berries of *Zizyphus nummularia)* is preferred by the rodents to seeds of most of the desert vegetation. These are usually collected by the farmers when they prune the bushes for *'Pala'* (leaves of *ber,* an excellent concentrate feed for livestock, and the thorns are used for fencing). *Ber* grows in the desert in abundance. Even if it is bought the dried berries are quite cheap at 50 *paise* per kg. In addition to their high palatability, the air-dried berries possess sufficient soaking capacity. This 'non-food-grain' material is, therefore, used as a carrier of poison for rodent control. The air-dried berries are soaked in a solution of compound 1080 (Sodium monofluoroacetate) having a dosage of 3 mg/kg body weight. After soaking for 24 hours, each berry is impregnated with a lathal dose for rodents weighing upto 100 gm. One lethal *ber* and four ordinary ones are pushed inside the burrow openings. This

one-shot baiting technique is fairly economical. Including the cost of labour, *ber* and poison, a farmer needs to spend only 30 to 45 *paise* per hectare for effective rodent control. If, however, he collects *ber* from the wild and does the job himself, the method will cost him as little as 0.5 to 1 *paise* per hectare as compared to an expenditure of Rs. 3/- to Rs. 15/- per hectare incurred in rodent control operations by the conventional methods.

Summer is the most appropriate season when large scale rodent control should be taken up. If rodents are controlled on a district level, i. e. in a large area, reinfestation will be slow but if it is carried out only in plots of one hectare or so, naturally the immigration of rodents from the surrounding areas will make reinfestation quick.

Baits for the control of rodents

For the effective control of other rodent species, intensive studies have revealed that for *Gerbillus gleadowi*, *R. meltada* and *Rattus cutchicus* the most suitable baits are *Chana* flour and cracked or whole *bajra*, *jowar-bajra* flour + 10 per cent sesame oil, and wheat flour + 10 per cent groundnut oil respectively.

Bait shyness among rodents

Zinc phosphide is the poison most used for rodent control in India. Our studies have indicated that five rodent species *(Tatera indica, Meriones hurrianae, Rattus r. rufescens, R. meltada pallidior* and *R. cutchicus)* which are of economic importance, develop bait shyness, even after a single exposure to the poison-bait. This bait shyness persists for 25 to 135 days. This finding points out (a) that poison baiting with zinc phosphide against these rodents should be done for one day only, (b) that if it is necessary to poison bait the residual population of rodents, both the bait and the poison should be changed, and (c) that a grave situation is likely to be encountered as no other toxic poison is available indigenously in India for controlling the residual population of field rodents.

Role of scent gland

A ventral marking scent gland has been discovered in three rodent pests. Besides investigating its structure and morphology, work is in progress to use the extract of this gland as a phago stimulant.

Bird pests and their control

Damages caused by bird pests to the standing crops cause a loss of about 10 per cent of the total production. The food habits and breeding cycles of a large

number of bird pests have been studied with a view to evaluate efficient methods for their control.

Insect pests and their control

White Grubs

Studies on white grubs, a predominant insect pest of the desert, have revealed the occurrence of 25 species which are of economic importance. Out of these, *Holotrichia insularis* Br. is the most predominant and serious pest. Some host plants for this pest, hitherto unreported, have been recorded. The maximum density of the grub has been recorded as 61000 per ha during the months of August-September. Their intensity is highest in localities where intensive farming is in practice with the use of F. Y. M., sheep manure and irrigation facilities. The grub population has been found to be appreciably high in areas of grasses or weed growth. The grubs show a preference for sandy loam and river bed soil. Ecological and biological studies have been made on important white grub species.

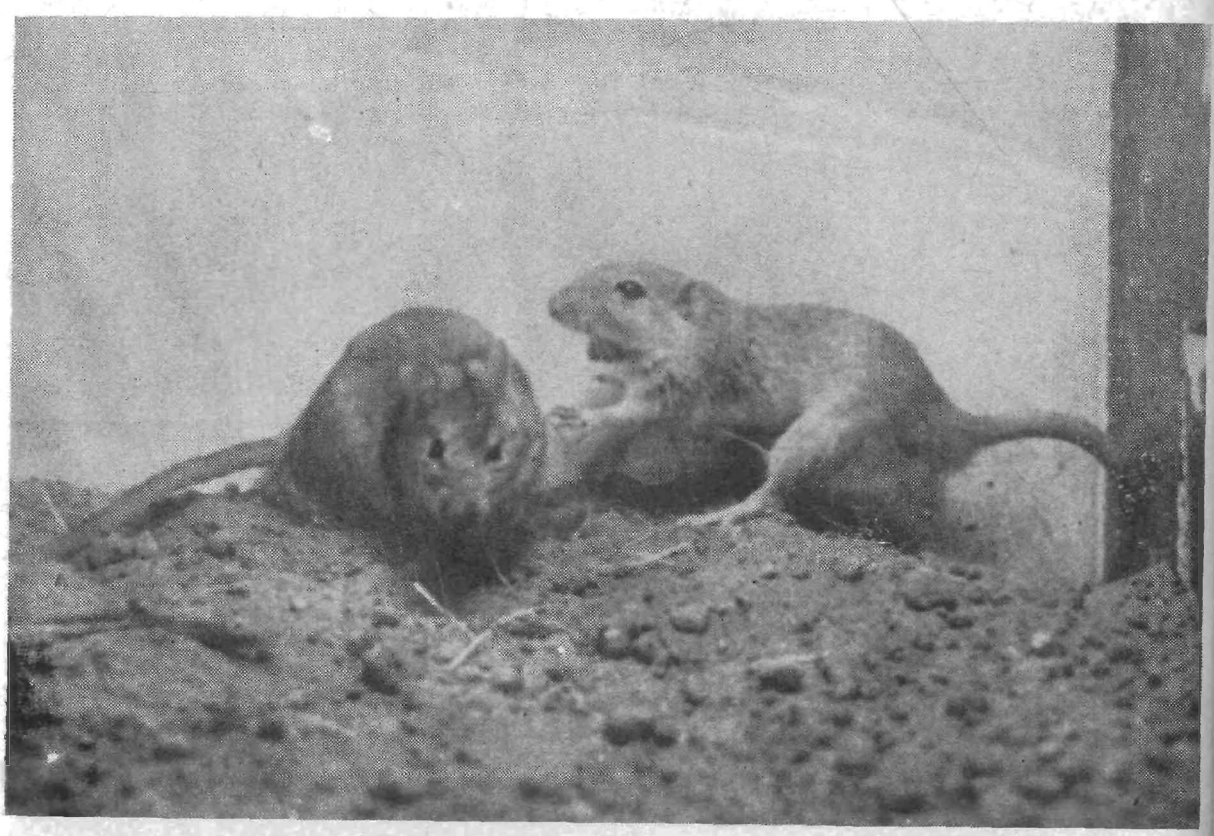
Chemical control studies against *Holotrichia insularis* Br. were taken up in some cultivators' fields in endemic areas. B. H. C. 10 per cent dust @ 100 kg/ha and Sevidol (Carbaryl + gamma B. H. C. 4 : 4) @ 25 kg/ha have given the best results by reducing the grup population by 70-80 per cent. None of the cakes used *(Tumba, Mahua, Neem, Karanj)* have shown any insecticidal or repellency effect. The granular insecticides can be applied in the plant rows and B. H. C. dust can be applied in plots and incorporated in the soil at 4–6" depth.

Termites

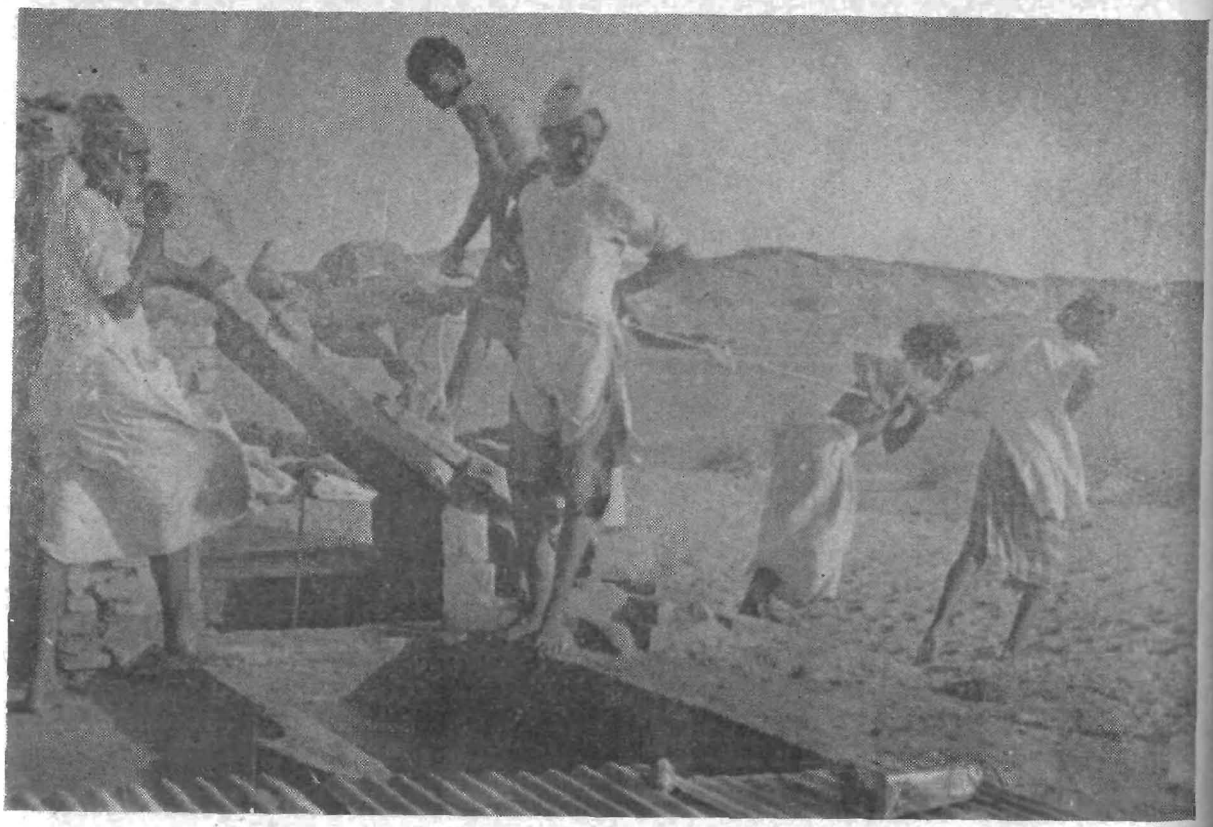
Termites are a serious pest problem in forestry plantations of this region. Chemical control studies conducted on 7 year old trees of *Dalbergia sissoo* heavily infested with termite at Pali have indicated that for economical and successful protection to forestry plantations comprising seedlings to 7 year old plants, 10 gm of Aldrin or heptachlor per tree should be applied once in $1\frac{1}{2}$ years. The cost of insecticide per tree comes to 5 to 8 paise and labour charge for mixing the insecticide per tree are approximately 10 paise only. Studies on the seasonal incidence, population estimates and nature of damage of various insect pests of grasses have revealed that grasses grown under rainfed (without irrigation) conditions are markedly different in their insect pests incidence as compared to grasses grown under irrigated conditions. In the former case insect infestation is very little. Varieties of *Ber viz. Gola, Seb, Jogia* and *Mundia murehra*, recommended for profitable cultivation

Nomads on the move

A banjara with his household belongings



The Desert Gerbil — depletes the sparse vegetation



Water — a scarce commodity for the desert dwellers

in western Rajasthan, have been tested for varietal susceptibility to the fruit fly. Of these varieties S*eb* has been found to be the least susceptible to fruit fly damage, with a record of only 4% damaged fruits, closely followed by *Jogia* with 8% damaged fruits. *Mundia murehra* has been found to be highly susceptible to fruit fly (average fruit damage 20%) while fruit damage in *Gola* has been of the order of 17%. Timely control operations reduce the damage to the fruits to a negligible order.

Residue analysis

In the soil treated with BHC dust @ 10 a.i. kg/ha, an initial deposit of 10.34 ppm was reduced to 4.85 ppm after one month and it was 2.41 ppm after two months. The BHC residue in chilli fruits grown on the treated soil was below tolerance level at various stages.

Man in the desert

The crucial problem of Rajasthan Desert is one of human ecology. Over exploitation by man of vegetation and other resources has disturbed the ecological balance of the region, leading to progressive degradation of its resources. Recognising this, investigations have been conducted among different nomadic groups to assess their role in the economy of the region and to suggest welfare measures. Socio-economic surveys of the sedentary population of the arid zone of Rajasthán have been conducted to collect socio-economic date which could form the base for drawing up developmental plans for raising the standard of living of the desert people.

Socio-economic surveys

Nomads : An important social problem of the arid region is of the nomads. Historical, political and cultural factors combined with climatic and geographical factors give rise to nomadic life.

The nomadic groups of the arid zone may be broadly grouped into four categories, viz., (a) the pastoral nomads *(Raikas, Sindhis, Parihars, Billochs etc.),* (b) the trading nomads *(Banjaras, Ghattiwala Jogis,* and *Gowarias)*, (c) artisan nomads (the *Gadoliya Lohars, Sansis and Sattias* and (d) miscellaneous type of nomads (*Nats, Kalbeliyas, Jogis).*

In olden days the nomads performed an important complementary function in the economy of the region. In recent years, however, due to changes in the

political, social and econmic set up of the tract, the sources of livelihood of the nomads have considerably contracted.

Each nomad group is associated with some kinds of livestock which make indiscriminate use of the meagre available grazing resources and defeat the local soil conservation measures. In the changed economy, the nomads are a menace for the whole society and their sedentarization is desirable. The opening up of means of communication has reduced the importance of distributive functions of the trading nomads. Shrinkage of grazing lands due to extension of cultivation has created difficulties for the cattle breeder nomads. Villagers are no longer dependent upon the nomads who rendered specialised services in the past. Studies have shown that the sedentary population, in general, do not welcome the nomads for various reasons.

This rupture of relationship of mutual dependence between the nomads and the sedentary population points to the need for the formulation of a policy for the welfare of the nomads.

Detailed rehabilitation schemes have been prepared for the *Banjaras* (the trading nomads), the *Gadoliya Lohars* (the artisan momads) and for the nomadic cattle breeders of the Anupgarh-Pugal region of Western Rajasthan, keeping in view their present cultural values, kinship structures and other important social and economic factors.

Studies have shown that the *Gadoliya Lohars* desire sedentarization in small agnatic groups within their own *choklas*. Sedentarization programmes on this basis will ensure the continuity of their symbiotic relationship with sedentary population through marketing facilities for the articles fabricated by the nomads. Settlements in small, scattered groups will make it easier for the Government to allot land for cultivation to the *Gadoliya Lohars*. Moreover, such sedentarization should rule out any chance of fueds occuring amongst the households of different clans. The *Gadoliya Lohars* should, therefore, be settled in bands of small kinship groups within their own *choklas* or their present areas of movement.

Nomadic *Banjaras* should be sedentarised *tandawise* i. e. in small kinship groups. Settled *Banjaras* work in agriculture and animal husbandry, trading in cattle and salt. The *tanda* should be treated as the unit for settlement purposes. Any approach to the *Banjaras* should be through their *Mukhias* who are not only their best spokesmen but also the best media for communicating with them.

Settled population

The population of the hot Indian arid zone is of the order of 19 millions according to the 1971 census. Within the Indian arid zone, the percentage of population in Rajasthan, Gujarat, Punjab, Haryana, Andhra Pradesh, Mysore and Maharashtra accounts for 44, 15, 14, 10, 11, 5 and 1 per cent respectively.

The coefficient of correlation between rainfall and the density of population in the Indian arid zone has been found to be+0.6070. In the arid zone of Rajasthan the density of population declines from the piedmont belt of the Arravalies, to the narrow zone between the Sutlej and the dry bed of the Ghaggar to the thirsty sands of the desert. The density of population in Jhunjhunu is 157 persons per sq km, in Sikar 135, in Pali 78, in Nagaur 71 and in Jalore 63. Towards the west, the density decreases fairly rapidly from 52 persons/sq km in Churu and 50 in Jodhpur to 27 in Barmer, 21 in Bikaner and only 4 in Jaisalmer.

The decennial growth rate of population in the Indian arid zone during 1961-71 was 26.04 per cent against 24.66 for the country as a whole, indicating that the rate of growth of population in the arid regions is higher than that in the rest of the country. The increase of population in the arid zone of Rajasthan between 1901-1971 has been of the order of 157.35 per cent against 149.89 per cent for the entire state of Rajasthan. Within the arid zone, the percentage increase in population during the period 1931–1971 has been 143.8, 132.1 and 107.2 in the regions receiving annual rainfall of less than 300 mm, between 300-400 mm, and above 400 mm respectively. Thus the 143.8 per cent increase in population during 1931-71 in the areas receiving less then 300 mm of rainfall, as compared to only 119.0 per cent increase, for the entire Rajasthan state during the same period, poses an alarming problem, particularly when viewed in the context of the limited potentialities for agricultural and industrial development in the arid regions.

The present age and sex structure and the marital status of the desert people revealed a high concentration of population in the lower age groups, and a high percentage of married women in the productive period. Thus the present demographic features of the population revealed high potentialities for future growth. It is, therefore, essential to initiate population control measures immediately, in the lesser rainfall areas. Early marriage and begetting of children are integral parts of the social ethos of these people. Any deviation from the established norms is looked down upon as an aberration and as wholly incompatible with the social fabric of the

society. Divorce is a rarity, if not altogether unknown, and widowhood soon culminates in remarriage. If the birth rate does not fall, the present gap between births and deaths will further widen and the region will be faced with an inevitable population explosion. Family planning programmes undertaken in the region after independence have yet to make in-roads, mainly due to their inherent weaknesses in terms of negligence of cultural variables which are mainly responsible for creating chain of resistances. It may be emphasised that the obstacles to small family norms are not primarily technological but sociological. Unless the ancient prejudices, deeply ingrained beliefs and traditional cultural practices are taken into account it will deprive us of the sources of support to any family planning programme and lead us to centres of resistance.

Inspite of the low soil fertility, scanty and erratic rainfall, cultivation, and not animal husbandry, forms the major occupation of the people in the region. The occupational distribution patterns (1971 census) revealed that the percentage of workers engaged as cultivators, agricultural labourers and in other occupations was of the order of 52.96, 19.18 and 27.86 respectively in the Indian arid zone against 42.87, 25.76 and 31.37 respectively in the country as a whole. The percentage of cultivators and agricultural labourers in the rural areas of the arid zone of Rajasthan was 72.6 and 9.8 respectively. The distribution of land holdings has been uneven and there are marginal, small, middle and upper class farmers. As an example, 49.3 per cent of the land holders in the Luni basin had 16.2 per cent of the total cultivated land and 82.2 per cent of the holders had 51.5 per cent of the total cultivated land.

The system of agriculture followed is expressive of the limitations imposed by aridity. The availability of economically viable units of cultural land, the proper mix of agricultural inputs and, above all, water, are only a dream for the farmers. Subsistence farming is largely in vogue which tends to make the farmer security oriented. This is an important cause of their low level of income, low capital investment, labour intensive agricultural operations. Poor communication, and inadequate marketing facilities impose further checks on efficient agriculture. Additionally the rural structure has functioned to conserve the hold of traditional, and the adoption of improved innovations has made only a small lee-way in arid Rajasthan.

A study on the relative importance of some socio-economic factors in the adoption of agricultural innovations in the arid region has revealed that the

important factors for predicting innovativeness are the membership participation score, and the knowledge test score, followed by the material possessions, land holding and irrigated land held by the households. The value orientation, age of the head of the family, and the number and type of livestock owned by a family, which accounts for the socio-economic status of the household, explained variations in the adoption score only to the extent of 3.19 per cent, negligible and 0.06 per cent respectively. Caste and education do not appear to have been relevant in this particular case study as the surveyed population belonged to the same caste and educational stratum.

These findings suggest that it will be useful to encourage as much participation and involvement of the people in various activities as possible, and to fully explore the ways and means to provide full knowledge of the improved package of practices and the qualities of the innovations, as knowledge of these two factors predisposes farmers to a quicker adoption of innovations. It may also be useful to start extension activities among people who have comparatively greater participation in various activities and possess more knowledge about the innovations rather than giving greater material possessions and better value orientations and to those belonging to certain particular age groups. All measures to increase production should be widely distributed geographically and should embrace all groups. At present, the *Dhanis* receive comparatively lesser attention, primarily on account of the difficulties of communication with the inhabitants. It has further been found that in the propagation or diffusion of innovations, inter-personal communication along informal channels play a far more effective role than addressing through mass communication media.

The region has potentials for animal husbandry. The livestock population exceeds human population both in the State of Rajasthan as well as in its arid areas. The livestock population of the arid zone of Rajasthan (1972) worked out to a total of about 170.60 lakhs, of which cattle constituted about 37.10 lakhs (21.77%), buffaloes 11.70 lakhs (6.85%), sheep 53.4 lakhs (31.28%), goats 61.10 lakhs (35.82%), camels 6.3 lakhs (3.70%) and other livestock 1.0 lakhs (0.58%). Thus the relative growth rate of the livestock population is higher in the arid regions. The over-all increase rate for the state from 1956 to 1972 was of the order of 19.68 per cent for the total livestock population while for the arid regions it was 15.87 per cent.

The desertic areas possess some of the best breeds of livestock. Although the sheep population in Rajasthan is about 20 per cent of that of the country, yet it

produces about 15.47 million kg of wool which is about 45 per cent of the total wool production of the country. 25 per cent of the wool produce of the desert is fit for apparel production. About one million sheep, mostly males, are slaughtered annually for meat, and more than half a million sheep are exported annually to other states. The arid zone of Rajasthan has 63 per cent of total sheep found in Rajasthan. The goat breeds of the arid region are reputed for high milk production potentials, and are prolific breeders even under adverse conditions.

The usual husbandry practice in the region is to raise the sheep and goats in mixed flocks. The goat has been branded as the most harmful animal towards soil conservation measures hence, it has often been recommended that goats should be eradicated. The importance of goats, however lies not merely in the returns that this hardy animal gives to the owner but also in its role in the raising of sheep. Goats often act as foster mothers to lambs as well as assist the shepherd in grazing and herding the sheep. Also, in case of any attack by wild beasts it is only the goats which bleat and give an instant indication to the owner about the attack. The rate of mortality among sheep is comparatively much higher than in goats during scarcity conditions. It is a common saying that "*Oont chodde akaro aur bakri chodde kankro*" *i.e.* during scarcity conditions, the camel will only leave the *Calotropis* but the goats will leave only pebbles. This implies that the goat can survive on the most scanty vegetation. The goat also acts as a poor man's cow. If, therefore, the goat is to be displaced because of its alleged association with rapid range denudation and soil erosion, a suitable substitute has to be found in order that there may not be a functional vacuum with consequent difficulties in sheep rearing which is an important arid zone industry.

Animal husbandry practices are still largely traditional. The produce is meagre and the sale of livestock produce is extremely limited. The decidedly greater advantage of keeping a smaller number of animals of superior breeds is appreciated by the farmer. It is, therefore, suggested that facilities for exchange of poor quality livestock with better ones be provided. This should include providing bullocks in exchange of bulls as, due to prejudice against castration, the exchange of bulls for bullocks done by the villagers at present are to their disadvantage.

SHEEP AND GOAT HUSBANDRY

Breeding sheep for finer and heavier wool

The desert is the home of some of the hardiest breeds of sheep in the country, but the quality and the quantity of wool yielded by these animals is generally too

poor to ensure any worthwhile income to the stock-owners. Attempts have been made here to develop a biochemical approach to sheep production to obviate the delay inherent in the time consuming conventional method of selection based on performance tests. Three biochemical polymorphic traits have been intensively investigated in the blood of six breeds of sheep. These are (1) blood potassium type (high, HK or low, LK), (2) haemoglobin type (Hb A, Hb B or Hb AB), (3) erythrocyte reduced glutathione type (high, GSH^H or low, GSH^h).

Physiological investigation on heat and water stress in sheep

Availability of drinking water being the most critical limiting factor for survival in the desert, a detailed comparative study of the physiological response of different sheep breeds to imposed heat and water stress has been made. These studies have pointed to the unusual ability of the desert breeds (e.g. Marwari) to maintain circulation even when faced with considerable haemo-concentration. When water intake was reduced to below 75 per cent of the normal daily requirement, there was a steady decline in the body's water stores. On an average, there was an 18 per cent loss in body weight in all the breeds after remaining without water for 3 days during winter and 25 per cent during summer. Interestingly, the digestibility of crude fibres has been found to be increased in water-restricted sheep while nitrogen balance does not seem to be affected due to water stress. The rate of passage of feed is slow in water restricted sheep in comparison to normally hydrated animals.

The desert sheep apparently relies on reduced urine and faecal water output as the means for combating water stress. This, alongwith their ability to derive sustenance from poor quality forages, helps in maintaining animal productivity in this region. Studies conducted at this Institute so far point to the physiological superiority of the Marwari breed of sheep over the other breeds studied in maintaining productivity under desert conditions.

Prolonged intermittent (twice weekly) watering has been found to have no adverse effect on the animal production in terms of body weight, wool growth and lambing performance of ewes of the Marwari and Magra breeds. Water restricted (twice weekly) animals of both the breeds consumed less than half the quantity of water consumed by the daily watered groups. Thus, with a flock of 100 adult sheep, about 6,500 litres of drinking water could be saved per month by resorting to a twice weekly watering schedule. The daily watering of sheep would, therefore, appear to be a dispensable practice, atleast in the management of desert adapted breeds.

Water use economy and feed utilization efficiency of the desert goat

The Barmer goat has been found to be more desert hardy than the desert sheep breeds. Even when watered every fourth day over a prolonged period, the goat gained in body weight and did not register any reduction in feed consumption, unlike the Marwari sheep. Even during peak summer on a daily water ration of only a quarter of the actual requirement, these goats continued to register body weight gains.

Salinity tolerance in sheep

Studies made on the Marwari breed of sheep have indicated that a salinity level of one per cent of the drinking water may be taken as safe upper limit for this breed. Since the plasma chloride level of the saline drinking animals of this breed remain unaffected over a long period, it is evident that these animals have a very efficient renal excretory mechanism.

An improved nutritional technique for increasing wool production

In the arid and semi-arid parts of India, the leaves of the thorny plant *Zizyphus nummularia* (locally called *Pala*) constitute an important protein rich roughage and are of special value as drought feed. A simple chemical treatment, involving dilute formaldehyde solution, of these leaves *(Pala)* has proved to be very effective in inducing increased wool growth when the treated leaves are fed to the animals in small quantities daily. This chemical protection of feed proteins from ruminal degradation and the subsequent more efficient utilisation has considerable possibilities in the field of animal production.

Performance of cross-bred sheep

The Institute's flock of F_1 cross-bred sheep (Russian Merino sire X Marwari dam) has done exceedingly well so far as adaptation to the desert conditions and wool production characteristics are concerned. These animals yield significantly heavier and finer wool than any of the indigenous breeds. Their superior wool producing efficiency is not, however, associated with higher dry-matter intake or digestibility.

The physiological responses of white and black wool cross-bred sheep to grazing stress in early summer have been studied. Both groups tended to maintain rectal temperature within a narrow limit during the observation period. Respiratory rate was consistently and significantly lower and water intake similarly higher in the

white animals in comparison to the black ones. Also, in the black group, water intake was significantly correlated with both rectal temperature and respiratory rate, while no such significant correlation was observed in the white group. The albedo, which is a measure of the reflectivity of the body surface, is almost 3 times higher in the white wool in comparison to that in the black wool animals.

Semen quality of indigenous and exotic rams in the desert

The observed sexual inactivity of exotic (Australian) Corriedale rams under the desert conditions have been successfully counteracted by a single injection of 250 mg of testosterone enanthate. This corrective therapy has opened up the way to the large-scale use of the high-yieldings Corriedales for improvement of the indigenous sheep. The semen of this exotic breed is apparently not so inferior in quality in comparison to the local breeds, as to preclude its propagation here.

Economic Evaluation of Arid Zone Technology

For the study of inter-district variations, and the factors affecting crop output growth rates in respect of the principal crops in the arid zone of Rajasthan, data on area, production and productivity have been compiled for a period of nineteen years (1951-52 to 1969-70) for *bajra, Kharif* Pulses, Sesamum, *Jowar*, Gram, Barley and Wheat. Linear time trends for all the 12 arid districts have been computed. From these, the growth rates of area, production and productivity of the principal crops have been worked out. Growth co-efficients thus computed have been ranked on the basis of absolute magnitudes, so as to identify their trends in different districts. On the basis of this procedure, it has been inferred that *Jowar*, *bajra* and *Kharif* pulses are predominantly area-intensive crops. *Gram, Barley* and wheat are, on the other hand, predominantly yield-intensive crops.

For economic evaluation of sand dune stabilisation technology, after employing alternative concepts of ammortization and absolute magnitudes, cost-benefit ratios have been compared. The results revealed that a minimum period of 10 years is necessary for economic appreciation of such projects. In experimental sites like Jhunjhunu and Udramsar where the gestation period of 10 years has been completed, the technology has proved its economic soundness.

The people inhabiting the arid zone face a constant threat of scarcity of fuel to meet their day-to-day requirements. As a result of this scarcity, cow dung cakes, which could have better marginal productivity as manure, are burnt and trees are lopped and fell indiscriminately, resulting in continued aggravation of

the already existing disequilibrium in the desert eco-system. The economics of four tree species, namely *Azadirachta indica*, *Prosopis juliflora* and *Acacia tortilis* have been worked out. Out of these four species, *Acacia tortilis* ranks first in recording the highest cost-benefit ratio.

Solar Energy Potential and its Utilization

Average useful solar energy available for utilization, through use of flat plate collectors kept at optimum tilts at ten stations in India, viz., Ahmedabad, Bhavnagar, Calcutta, Delhi, Jodhpur, Kodaikanal, Madras, Nagpur, Poona and Port Blair has been worked out for typical winter and summer months.

During January the total solar radiation on a horizontal surface varies from 341 Cal/cm^2/ day in respect of Delhi (North India) to 508 Cal/cm^2/ day in respect of Kodaikanal (South India). However, with proper orientation and optimum tilts it is possible to collect on the flat plate collectors considerably more solar energy comparable to summer values at most of the stations. In January the values exceed 600 Cal/cm^2/ day at Jodhpur and Poona.

Based on these data, generalised design curves for water heating by flat plate collectors, giving the ratio of useful solar energy collected by the flat-plate collector to the heat removal efficiency factor in terms of inlet temperature rise over embient temperature were prepared.

Because of the intermittent nature of the radiation and its high day-to-day variation due to cloudiness, such design curves based on the solar radiation values which exceeded on 10 per cent, 50 per cent and 90 per cent occasions have also been prepared for Jodhpur and New Delhi in addition to those using average values.

For instance, the collector area (m^2) required for heating 140 litres of water upto 55° C in the winter afternoon for various exceedance values have been worked out in case of Delhi and Jodhpur (Table 7).

Table 7 : *Collector area (m^2) required for various exceedance values of total solar radiation*

	Delhi	Jodhpur
10 per cent	1.88	1.42
50 per cent	2.27	1.62
90 per cent	2.87	1.97

It has been estimated that 2 sq m of collector area at Jodhpur and 3 sq m at Delhi would be adequate for 90% occasions of exceedence of solar radiation values.

For increasing the efficiency of flat plate collectors air gap between absorber plate and cover glazing has been optimised by considering free convective losses and shading of absorber due to side walls. It has been found that for minimum convective heat losses and minimum shading a gap of 4 to 5 cm should be kept between absorber plate and cover glazing for efficient harnessing of solar energy.

Indoor test set up has been developed for the direct measurement of overall heat loss co-efficient in flat plate collectors. The overall heat loss coefficient of different collectors has been measured for rating them and it was in a good agreement with the theoretical models.

Solar water heating

An improved type of built-in-storage solar water heater was designed, fabricated and its prototype installed for tests at the Central Arid Zone Research Institute, Jodhpur. Its main design features are as follows.

The heater consists of galvanised iron (20 guage 112 x 80 x 10 cm) rectangular Tank of about 20 litres capacity, placed in a rectangular mild steel sheet tray with ordinary window glass on the front side and a 5 cm thick layer of glass wool insulation on the back and the sides. Bulging of the tank under water pressure is minimised by using angle iron flats bolted on the sides of the tray. The front of the tank is blackened by lamp black paint after treatment with a primer. The hot water is taken out from an out-let pipe at the top by opening the gate valve from the inlet pipe side of the heater fixed at the bottom. A vent pipe is provided at the out-let pipe of the heater for safety purposes. For use in rural areas without running water facilities, an ordinary bucket sized funnel is fixed at the top of the heater and is connected to the inlet tube.

It has been worked out that during winter, this heater should be oriented south at an optimum tilt of the latitude of the place plus 15 degrees by providing an adjustable angle iron stand. Tests (1973-74) indicate good performances of this heater with the efficiency factor of 70 per cent (ratio of total heat collected to the amount of radiation incident). This heater can supply hot water in the afternoons at 50°C to 60°C in winter months (i.e. December, January and February) and at

60°C to 75°C in summer and monsoon months. If the heater is covered with a 5 cm thick insulation or if the water is stored overnight in a double-walled storage drum then water at 36°C to 40°C can be obtained in winter morning till about 8.00 A. M.

Total cost of this heater works to about Rs. 350.00. Assuming its life as 10 years and 12 per cent interest of an outlay and maintenance, the cost of the energy developed is 8 paise per KWH (one-fourth the prevailing electric power rates).

Solar distillation

Optimum orientation studies of the conventional double-sloped solar stills at Madras (low latitude) and Jodhpur (high latitude) indicated that at Jodhpur, the orientation of the still with its major axes facing east-west receives more radiation than when facing south north. For Madras there is not much difference between these orientations. However, a single-sloped solar still receives more radiation as compared to the double-sloped solar still of equal area at both the stations.

Based on the above observations, two small single-sloped solar stills, each having a basin area of 0.58 sq m were built and their performance studied for two years (1973-74). The output of the stills sharply increased after March and reached a maximum value of 5.27 litres per day per sq m in the 19th week in the case of the uninsulated still. The average outputs in summer, monsoon, post-monsoon and winter were 4.23, 2.53, 1.21 and 1.38 litres per day per sq m respectively. About 81 per cent of the variation in the distillate collected in the stills could be explained by the difference in solar radiation, ambient temperature and wind speed.

The effect of design parameters such as glass angle, insulation in the base, orientation, etc., on the distilled water output have been studied with the help of four experimental double-sloped cement concrete type solar stills each having a basin area equal to 3.0 sq m. The stills each having a lower glass angle (10 degrees from horizontal) performs better. A further improvement of about 7 per cent in the distilled water output can be obtained by providing a 2.5 cm thick layer of saw dust insulation in the base. It has also been observed that both the channels (facing north and south) of the stills collect almost the same amount of distillate.

Energy balance studies of the solar still based on experimentally measured values of temperature, radiation, wind speed and humidity, etc., indicated that the efficiency of the still was only 33 per cent, which could be improved upon by

controlling the major heat losses occurring through the base (26 per cent) and those due to absorption by glass and imperfect blackening of tray (20 per cent).

Solar Drying

A simple solar cabinet dryer based on the principle of the hot box, suitable for drying agricultural produce like chillies, copra, peas, tobacco, etc. was designed and fabricated with a base area of 1.37 sq m and a volume of 0.324 cu m.

During winter this solar cabinet dryer was tested for drying chillies having an initial moisture content of 79 to 85 per cent on wet weight basis. In the dryer the average air temperature exceeded the day time average air temperature by 22.8°C when chillies were kept inside. These tests indicated that the drying time of chillies can be reduced to nearly half of that by the open drying method. The quality of the chillies dried by the solar dryer was also superior.

A forced convection type solar agricultural dryer having a capacity to dehydrate 100 kg of fruits and vegetables in a day, has been designed and fabricated. The dryer is useful for drying practically all types of vegetables and fruits viz., chillies, date palm *ber*, etc. Initial testings have been found to be satisfactory.

Solar Cooking

Five different types of solar cookers were designed and the prototypes installed at Jodhpur. Two of them are of the hot box type, one with a single folding glass reflector and another with an octagonal glass reflector. The third solar cooker is of the steam generating type and consists of a tube in plate type of flat-plate collector. Two other reflector type cookers have been designed using aluminium paraboloid and aluminium strips. All these cookers are being compared for technoeconomic studies.

Preliminary studies on the solar oven have revealed that the plate temperature reaches up to 250°C in clear sunshine and one litre of water comes to the boiling point in 45 to 60 minutes. This oven can meet household requirements like cooking, baking, roasting etc., for a family of five persons. One kg of potatoes, vegetables, etc. can be boiled within 45 to 60 minutes, $\frac{1}{2}$ kg of *arhar dal* can be boiled in 60 to 90 minutes.

Wind Power Utilization

A study on wind power potential in the arid zone of western Rajasthan was completed. The normal number of days in a month when wind speeds suitable for

the pumping of water by wind mills occur, exceed 20 during April to September in Jodhpur, March to September in Jaisalmer and June to August in Bikaner.

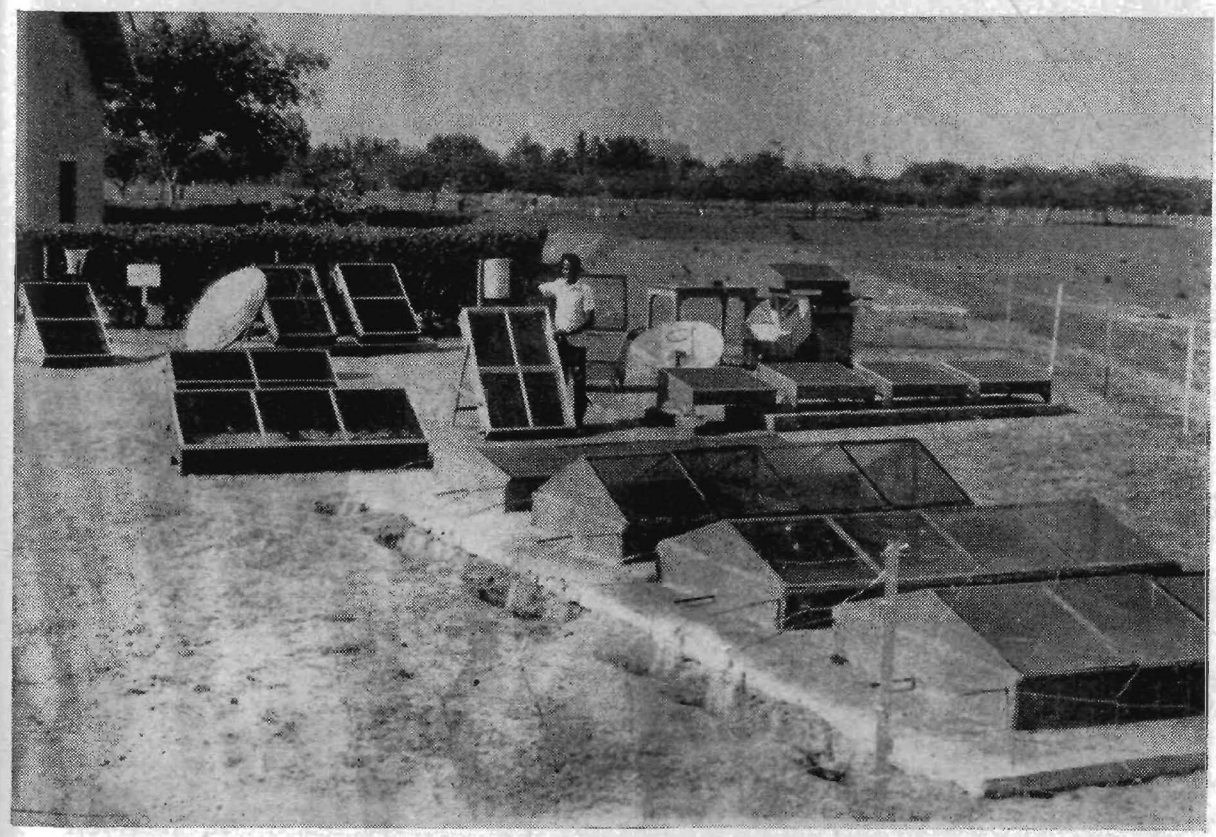
Since the conventional type of wind mills earlier developed in India (WP–1 and WP–2 types) have become costly, a low cost sailwing type of wind mill costing Rs. 3,000/- was developed and field tested. The design of the mill is so simple that its fabrication and maintenance can be undertaken by village technicians. It can function even at a low wind speed of 8 kmph and can adjust automatically to the changing wind direction. The mill is capable of pumping water from a level 3.5 m below the ground at an average rate of 1050 and 1225 litres/hr on days with a mean daily wind speed of 15–20 and 26 km/hr respectively.

A vertical shaft wind mill for pumping water has been designed, fabricated and is being field tested. The wind mill is rugged and is more suited for regions of strong wind regime.

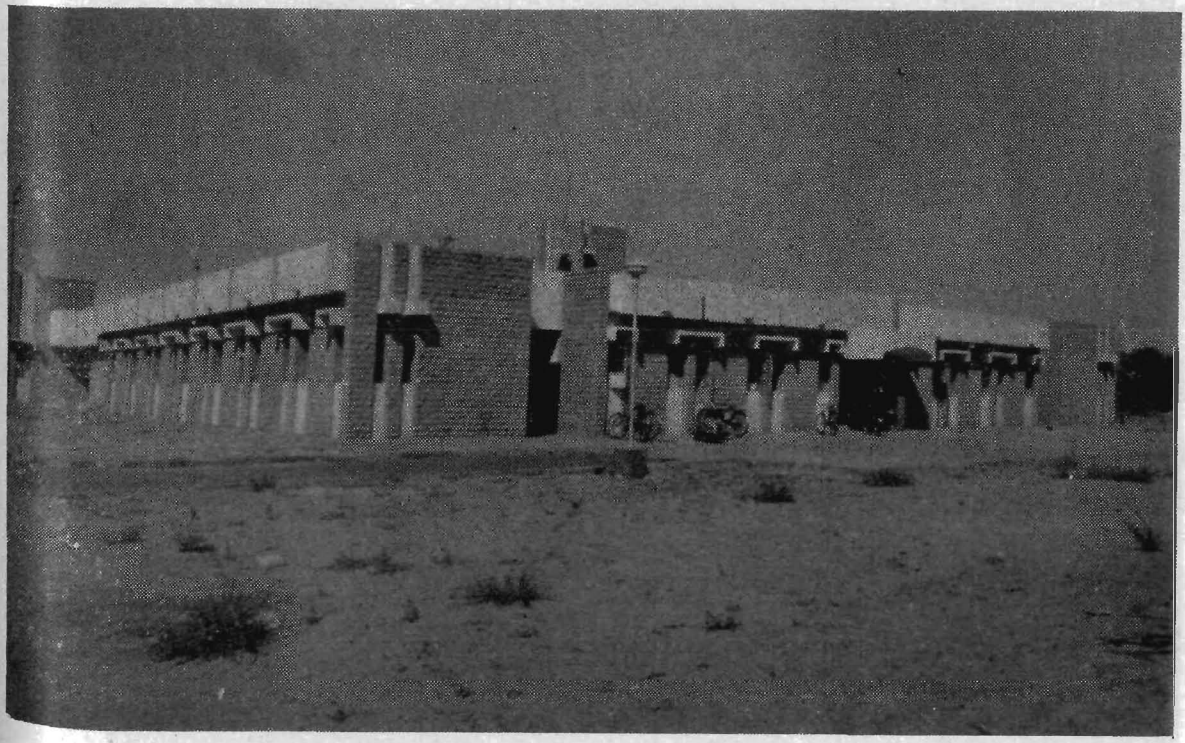
Transfer of Technology and Operational Research Project

To bridge the huge gap between the technologies available at the research farms and those practised at the farmers fields, extension work is being done for accelerating the transfer of proven technologies from the researeh laboratories and farms to the lands of the agents of change. This is being effectively accomplished through the Operational Research Projects operating in a cluster of 5 villages 16 km from Jodhpur. In this area, since 1974 the scientists of CAZRI in collaboration with the State Development Departments are working for the transfer of technology evolved by them. While demonstrating technology the scientist study the socio-economic and technological constraints in its transfer and acceptance by the farmers. The major technologies in practice at the farmers lands include sand dune stabilization, afforestation and shelterbelts plantation, pasture and grassland development, watershed management for stable crop production, improved management of rainfed and irrigated crops, optimum water utilization methods (drip and sprinkler system), rodent and pest management, sheep and goat development, solar energy and bio-gas utilization and community organization. Thus there is an effective link between the agricultural scientists and the farmers, thereby accelerating the feed back mechanism.

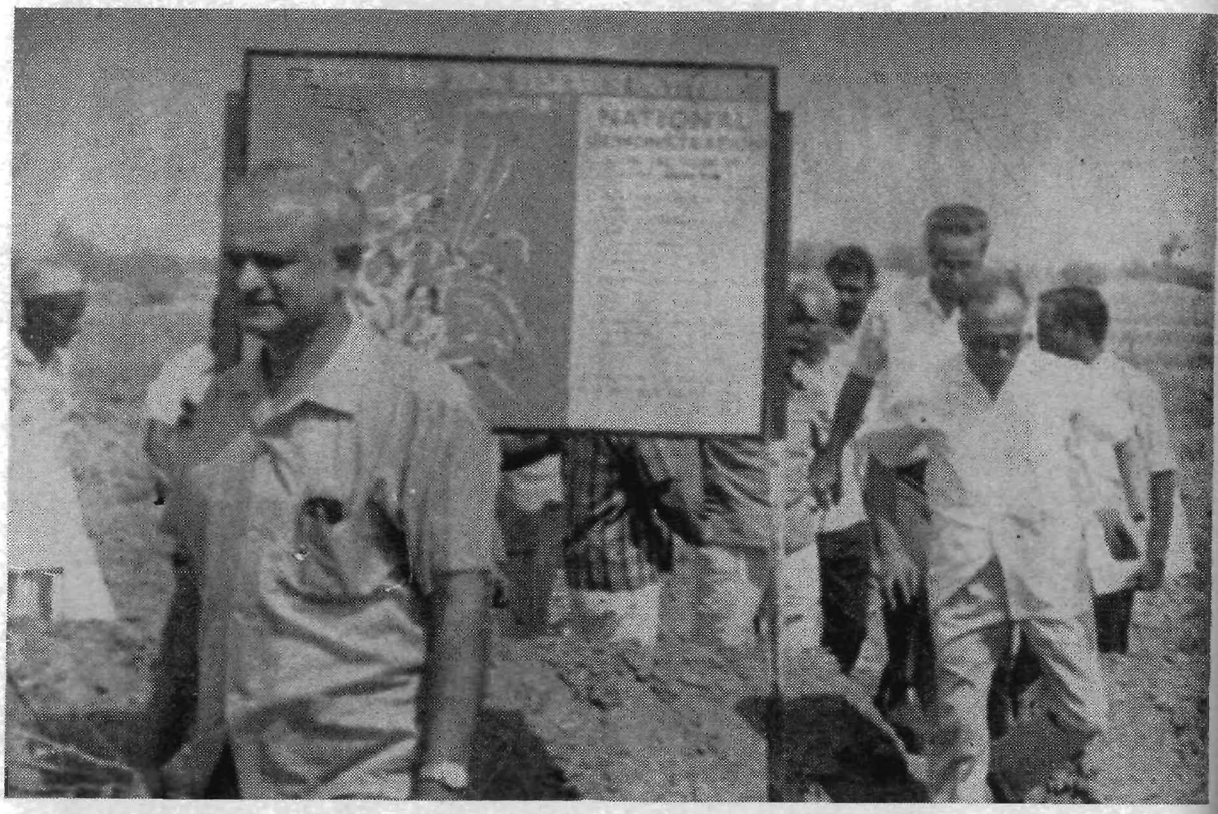
By and large, the methods and results of demonstration of crops have proved successful and have provided a base for creating a good rapport between the Institutes scientists and the farmers which would help in launching further development programmes.



A view of the solar energy yard at CAZRI



Energy Laboratories, CAZRI



Dr. M.S. Swaminathan, Director General and Dr. J.S. Kanwar, Deputy Director General, ICAR, Visiting National Demonstration Centre

Transfer of knowledge to farmers (Operation Research Project)

Impact and Transfer of Technology

An analysis of the adoption of the different technologies revealed that majority of the farmers in the area are aware of different technologies. Diffusion of such technologies where return against investment is quick and initial investment is comparatively low, is faster. Lineage heads and local village leaders are among the effective media of communication. For an early impact it is not only the problem of technologies and reaching the farmers with the package of technologies but there are a large number of social and institutional constraints in deciding the response. Among other extension methodologies, approach involving community as a whole and entire farming system, and effective training programmes for different levels of workers including farmers are suggested remedies for quicker and lasting impact.

Extension Training and Educatianal Activities

Organisation of farmers fair/field days

To demonstrate improved package of practices farmers fairs are organised at the C.R. Farm of Institute at Jodhpur and also at sub-stations. Farmers of surrounding villages participate in the day-long activities. Question posed by the farmers regarding various problems faced by them in the cultivation of crops, grasses and trees, and in the utilisation of water and problems of salinity, application of fertilisers, rodent control and choice of pesticides are answered by the scientists of the Institute. Besides, stalls for exhibiting different types of improved agricultural implements, sale of seeds of improved varieties of crops and for demonstrating pesticides, etc. are also installed.

Field days are also organised in kharif and rabi season to demonstrate the practices on the spot. Farmers scientists discussions are arranged from time to time on specific topics related to the farmers need. Extension literature on individual technologies have been prepared and distributed to the farmers for their use. Twenty two such leaflets, reports and handouts in Hindi and English, providing information on different dryland agricultural techniques and on forestry, sand dune stabilisation, rodent pest control etc. are distributed amongst the farmers at such occasions.

Navyuwak Mandal also participates for the quick transfer of technologies to the farming communities

Radio/Press programme

Talks relating to agricultural technologies on 'cultivation of millets', 'use of bio-gas and solar appliances' and 'what to grow where' etc. are given by various

scientists through radio. Important events and technologies available at the Institute are also published through Press.

Scientific Consortium

Before actual implementation, the programme is discussed with the scientists of the Institute under the chairmanship of the Director, and with State Development Officer, selected farmers and extension specialists at Jodhpur. Review and progress of the work done during the preceding year is also made in these meetings. Time to time group discussions are held with State agencies for specific problems as and when noted in the areas.

Role of CAZRI at International and National Level in Combating Desertification

CAZRI, being the pioneer organisation in the field of arid zone research, having one of the biggest data-base on the subject of desert development and monitoring of desertification, has received a number of international and national recognitions and responsibilities. A brief account of its activities and participation at international and national level in combating desertification is given below :

UNEP and CAZRI

UNEP entrusted CAZRI to conduct a special case study on the Problems of Desertification in western Rajasthan. The study, undertaken in Luni Development Block, was presented at the UN Conference on Desertification held at Nairobi, during 1977. Dr. Mustafa. K. Tolba, Executive Secretary, UNEP personally visited the CAZRI in April, 1976 to guide the preparation of this case study.

The UNEP Panel Meeting on Monitoring of Desertification Processes and Related Natural Resources in Arid and Semi-Arid Areas of South-West Asia was also arranged at CAZRI during January, 1977. It was attended by participants from Pakistan, Iran, U.S.A. and India, besides consultants from the UNEP, ESCAP and UNDP.

International Training Courses

CAZRI has arranged two International Training Courses under the auspices of UNESCO.

"Seminar on Integrated Survey and Range Ecology and Management" 9-27 November, 1970.

"Integrated Natural Resources Survey," 21 January-20 February, 1978.

These courses were attended by participants of about 25 developing countries.

International Symposia

CAZRI, in collaboration with UNESCO and other national and international agencies, organised the following international symposia in which a number of delegates from different countries participated :

'Symposium on Problems of Indian Arid Zone', 23 November-2 December, 1964. Organised by Ministry of Education and UNESCO South Asia Science Cooperation Office, New Delhi.

'Symposium on Arid Zone', 22-29 November, 1968. Organised by XXI International Geographical Congress in collaboration with ICAR.

'International Symposium on Arid Zone Research and Development', 14-18 February, 1978. Organised by the Arid Zone Research Association of India with the support of ICAR, UNESCO and DST.

'International Symposium on Anthropology and Desertification', 19-21 December, 1978. Organised by ICAR and The Smithsonian Institution.

UNRISD and CAZRI

In recognition of the work done on socio-economic aspects of desert spread, U. N. Research Institute for Social Development, Geneva, collaborated with CAZRI in the Project entitled "Social Aspects of Desertification in Rajasthan" with an objective to study the human factors for diagnosing the processes by which resources are being depleted and for indicating the remedies.

U. N. Agencies and CAZRI

Directors of the CAZRI and a number of scientists of the Institute have surved as consultants/panel members of U. N. and other International Agencies and participated in their meetings. These include :

United Nations Education Scientific and Cultural Organisation (UNESCO)
United Nations Environment Programme (UNEP)
United Nations Research Institute for Social Development (UNRISD)
United Nations University (UNU)
Food and Agricultural Organization (FAO)

World Health Organization (WHO)
World Meteorological Organization (WMO)
Organization for Economic Cooperation and Development (OECD)
American Association for Advancement of Sciences (AAAS)
International Geographical Union (IGU)
Union of Soviet Socialists Republic Academy of Science (USSR)

Participation in International Conferences, Symposia and Meetings

In addition to the consultative role of various scientists, due to their experience and expertise, they also participated in the inter-country meetings, symposia and seminars :

Agro-meteorological Conference, Reading, UK, 1966.

UNESCO Symposium on Plant Response to Climatic Factors, Uppsala, Sweden, 1970.

FAO Panel Meeting on Vertebrate Pest Management, Thailand, 1973.

Joint Annual Meeting of the Canadian Society of Botany, Genetics and Forestry, Canada, 1973.

Desertification Conference at the University of Cambridge, 1975.

Scientific Panel, International Foundation for Science, Sweden, 1975.

Panel on UNEP'S "Feasibility Study on Monitoring of Desertification Processes and Related Natural Resources in Arid and Semi-Arid Areas of South-West Asia," Iran, 1976.

International Physiological Congress, Paris, 1976.

First Meeting of the Regional Committee on Desertification UNEP, Kabul, 1977.

International Conference on Alternate Strategies for Desert Development and Management, Sacramento, USA, 1977.

Seminar on Rodent Research, Philippine-German Crop Protection Programme, Phillipines, 1977.

UNESCO'S Meeting to finalise the paper entitled, "Trends in research and application of science and technology for arid zone development," France, 1977.

AAAS Seminar on "Critical Indicators" on Desertification. Pre-Conference Seminar, Nairobi, Kenya, 1977.

UN Conference on Desertification, Nairobi, Kenya, 1977.

UN Post-Desertification Conference and Orient Workshop, Nairobi, Kenya, 1977.

Workshop on 'Critical Indicators' of Desertification', American Association for the Advancement of Science, Washington, June, 1977.

International Congress on Energy and the Ecosystem at the University of North Dakota, June, 1977.

United Nations Conference on Desertification, Current International Activities to Combat Desertification, Asia and the Pacific, New Delhi, India, 1977.

Annual Meeting of Australian Society of Range Management, Broken Hill, Australia, 1977.

OECD/FAO/WHO Expert Consultants Meeting on Rodent Problems, Control and Research, London and Paris.

First Meeting of the Consultative Group for Desertification Control, UNEP, Nairobi, Kenya.

Sixth Meeting of the Governing Council of the UNEP, Nairobi, Kenya.

International Seminar on Desertification Control in China, arranged by UNEP.

UNRISD Workshop on "The Role of Perceptions, Attitudes and Values of People in Relation to Environmental Developmental Measures and Programmes', Egypt.

CAZRI Experts in Various Countries

The Services of a number of scientists of the CAZRI have been requisitioned by developing countries as experts to translate well proven and viable technologies evolved in the Thar Desert for the improvement of their respective arid lands.

Country	Field of Specialisation	Sponsoring Agency
Chile	Grassland Improvement	FAO
Egypt	Irrigation	UNESCO
Iran	Forestry	FAO
Iraq	Forestry & Sand dune Fixation	UNESCO
Iraq	Soil	Iraq Govt.
Iraq	Hydrology	Iraq Govt.
Iraq	Agricultural Statistics	Iraq Govt.
Tanzania	Geo-hydrology	Tanzania Govt.

Somalia	Range Management	World Bank
Qatar	Salinity Problems	Qatar Govt.
Algeria	Agricultural Engineering	Algeria Govt.
Philippines	Soil Salinity and Rice Production	Philippine Govt.
Nigeria	Hydrology	Nigerian Govt.

International Trainees at CAZRI

A number of trainees from different countries visited CAZRI for receiving trainings short term as well as long term.

Field of Training	Countries	Sponsoring Agency
Rodent Ecology	Australia	ANU
Rodent Behaviour	USSR	UNESCO
Forestry	Sudan, Yemen, Iraq	Respective Govts.

Activities at National Level

CAZRI has actively participated in the national efforts to combat desertification processes. The technologies developed by the Institute, for enhancing the productivity of arid lands, have received wide recognition. It has organised a number of training courses, summer/winter schools, workshops etc. which were attended by the scientists from various state organisations, universities and other development departments.

Training Courses

Apex Level Training in Rodent Pest Management
Aerial Photo-interpretation
Rural Engineering Survey
Grassland Management Utilization & Afforestation
Dry Farming

Summer/Winter Schools and Workshops

Workshop on Soil Conservation, 1969.
Winter School on Development of Rajasthan Desert, 1973.
Summer Institute on Rodentology, 1975.
Workshop on Grassland Development & Utilization, 1976.
Workshop on Guar Research, 1977.
Summer Institute on Resources Inventory and Land Use Planning, 1977.
Workshop on Rodent Research, 1978.

Advisory Role of CAZRI

The Institute scientists have been requisitioned on a number of Advisory Committees of Govt. of India, State Governments and Universities. Some of them are :

National Commission on Agriculture
National Committee on Science & Technology
India Meteorological Department
Working Group on Solar Energy
National Pulse Development Council
National Rodent Control Advisory Board
National Programme for Rodent Pest Management
Desert Development Board
ICAR Regional Committee No. 6
ICAR Scientific Panels on Soils & Agronomy, Entomology-Nematology, Animal and Plant Biochemistry and Physiology and Horticulture
Task Force for Agricultural Atlas of India
Indian Council for Social Science Research
National Council for Applied Economic Research
Indian Standards Institute
Board of Management of several Universities.

Besides, the assistance of the Institute scientists was also made available to the following agencies :

State/agency	Fields in which assistance sought
Gujarat, Mizoram, Arunachal Pradesh and Lakshadweep	Rodent Control
Rajasthan, Gujarat and Haryana	Desert Development
Gujarat, Haryana and Andhra Pradesh	Integrated Natural Resources Survey
Haryana and Gujarat	Sand Dune Stabilization and Afforestation
West Bengal	Combating Flood Damage
Rajasthan Canal Project	Land Use Survey, afforestation and Range Management
Rajasthan Government	Luni Basin Development Scheme

Participation in Scientific Committees, Editorial Boards, etc.

Scientists of the Institute are Editors or Members of a number of international and national journals. A few of them are presently on the Editorial Boards of the following important journals :

Advances in Desert and Arid Land Technology and Development (USA)
Agricultural Administration (UK)
Arid Lands Abstracts (USA)
Annals of Arid Zone (India)
Forage Research (India)
Indian Journal of Agronomy (India)
Indian Journal of Rodentology (India)
Pestology (India)
Transactions of Indian Society of Desert Technology (India)
Udyanika (India)

Events Of Significance

Awards

By virtue of their outstanding contributions in the respective fields of specialisation, the following awards were conferred upon the scientists of the Institute.

Shri C.P. Bhimaya- Golden Shield by His Highness Shahan Shah of Iran in recognition of the services in Forestry and Soil Conservation.

Shri R.B. Das - FAO medal for excellent work in Chile.

Dr. Ishwar Prakash- Rafi Ahmed Kidwai Memorial Prize for the biennium 1974-75 in the field of Agricultural Zoology.

Dr. Ram Niwas - Jawaharlal Nehru Award for Post-Graduate Research in Agronomy.

Dr. A. Krishnan - National Fellowship for work in the field of Agricultural Meteorology.

Sh. P.C. Chaterjee- A bronze medal by the Mining, Metallurgical and Geological Institute of India for the original research paper in the field of Geology.

Besides, a number of scientists have been awarded UNESCO and Colombo Plan Fellowships for visiting various countries.

Dr. M. S. Swaminathan, Director General, ICAR, on a visit to Central Research Farm, Jodhpur

Members of the Second Achievement Audit Committee on a visit to Central Research Farm

Mr. C.S. Christian and distinguished delegates to the International Symposium on *"Arid Zone Research and Development"*

Hon. Minister for Agriculture and Irrigation, Chowdhury Brahm Perkash, Dr. M. S. Swaminathan, Secretary, Agriculture and Rural Development, Government of India, on a visit to CAZRI

Achievement Audit Committees

The work done by the Institute was reviewed by the two Achievement Audit Committees during the years 1966 and 1972. The constitution of these committees was as under :

1st Achievement Audit Committee (1966)

Dr. A.B. Joshi, Deputy Director General (Crop Sciences) ICAR, New Delhi.	Chairman
Dr. N.D. Rege, Director (Soils), Water Utilization Cell, Ministry of Food & Agriculture, New Delhi.	Member
Shri C.R. Ranganathan, Executive Director, Fertiliser Association of India, New Delhi.	Member
Dr. J.S. Kanwar, Director of Research, Punjab Agricultural University, Hissar.	Member
Dr. H. R. Arakeri, Director of Agriculture, Banglore, Mysore.	Member

2nd Achievement Audit Committee (1972)

Dr. H.R. Arakeri, Member, National Commission on Agriculture, Vigyan Bhavan Annexe, New Delhi.	Chairman

Shri S. K. Seth, Member
President,
Forest Research Institute,
Dehradun.

Dr. S. P. Luthra, Member
Dean,
Indian Institute of Technology,
Hauz Khas,
New Delhi.

Dr. B.P. Ghildyal, Member
Prof. & Head of Department of Soil,
U.P. Agricultural University,
Pant Nagar.

Shri C. R. V. Raman, Member
Director,
Agricultural Meteorology,
Poona.

Dr. V. Rathnasabapathi, Member
Dean,
Madras Veterinary College and Director of Veterinary Education, Madras.

PUBLICATIONS

The CAZRI has published over 1,320 research papers in various national and international journals. These have been listed in a publication entitled "Bibliography of CAZRI publications". In addition, a number of books, monographs, bulletins, etc., have also been published.

Books

1 ICAR, 1977 : Desertification and its Control, ICAR, New Delhi, 1-358.

2 Barnett, S.A. and Prakash, I., 1975 : Rodents of Economic Importance in India. Arnold-Heinemann, New Delhi, 1-175.

3 Fitzwater, W. D. and Prakash, I., 1973 : Handbook of Vertebrate Pest Control, ICAR, New Delhi, 1-92.

4 Gupta, R. K., 1971 : Planning Natural Resources. Navyug Traders, New Delhi, 1-269.

5 Gupta, R. K. and Prakash, I., 1975 : Environmental Analysis of the Thar Desert. English Book Depot, Dehra Dun, 1-484.

6 Kaul, R. N. (Ed.), 1970 : Afforestation in Arid Zones. Dr. W. Junk, b. v. Publishers, The Hague, i-xi, 1-435.

7 *Prakash, I. and Ghosh, P. K. (Eds.), 1975 : Rodents in Desert Environments.* Dr. W. Junk, b.v. Publishers, The Hague, i-xvi, 1-624.

8 Raheja, P. C , 1966 : Soil Productivity and Crop Growth. Asia Publishing House, Bombay, i-xv, 1-474.

9 Sen, A. K. 1972 : Agricultural Atlas of Rajasthan. ICAR, New Delhi, 1-51.

10 Shankaranarayan, K.A. and Dabadghao, P.M., 1973 : The Grass Cover of India, ICAR, 1-113.

Souvenirs

1 Anonymous, 1964 : Recent Development in Rajasthan, 1-155.

2 Anonymous, 1977 : Arid Zone Research in India (Silver Jubilee, 1952-77).

Monographs & Proceedings of the Symposia and Workshop

1 Anonymous, 1964 : Proceedings of "Symposium on Problems of Indian Arid Zone," Ministry of Education, and UNESCO, South Asia Science Cooperation Office, New Delhi : 1-495.

2 Anonymous, 1978 : Proceedings of the "International Symposium on Arid Zone Research and Development" (Abstracts), Arid Zone Research Association of India (with support of ICAR and UNESCO), 1-178.

3 Garg, H. P., 1975 : Solar Energy Utilisation Research, CAZRI Mimeo. No. 3, 1-48.

4 Mann, H. S., 1977 : Desert Ecosystem and Its Improvement. CAZRI Monograph No. 1, Jodhpur, 1-390.

5 Pal, S. K., 1977 : White Grubs and their Management, CAZRI Monograph No. 5, 1-30.

6 Prakash, I., 1975 : Proceedings of Summer Institute on Rodentology, CAZRI Mimeo. No. 2, 1-365.

7 Prakash, I., 1976 : Rodent Pest Management-Principles and Practices, CAZRI Monograph No. 4., 1-28.

8 Prakash, I., 1977 : The Amazing Life in the Indian Desert, CAZRI Monograph No. 6, 1-18.

9 Sen, A. K., 1978 : Landuse Classification System in Indian Arid Zone, CAZRI Monograph No. 9, 1-43.

10 Shankarnarayan, K. A., 1977 : Proceedings of Summer Institute on "Resource Inventory and Landuse Planning", CAZRI Monograph No. 8, 1-373.

11 Singh, R. P., 1977 : Proceedings of the First ICAR Guar Research Workshop, CAZRI, Jodhpur, 1-132.

12 Surendra Singh, 1977 : Geomorphological Investigations of Rajasthan desert, CAZRI Monograph No. 7, 1-44.

Bulletins

1 Anonymous, 1977 : Operational Research Projects Report, CAZRI, Jodhpur, 1-19.

2 Ganguly, J. K. and Kaul, R. N., 1969 : Wind Erosion Control, ICAR, New Delhi, 1-57.

3 Malhotra, S. P., 1977 : Socio-Economic Structure of Population in Arid Rajasthan, CAZRI Technical Bulletin No. 3, 1-51.

4 Muthana, K.D., 1977 : Improved Techniques for Tree Plantation in the Arid Zone, CAZRI Technical Bulletin No. 2, 1-22.

5 Muthana, K.D. and Arora, G.D., : *Acacia tortilis* (Forsk) A Promising Fast Growing Tree for Indian Arid Zone, CAZRI Technical Bulletin No. 5. (In press).

6 Paroda, R.S., Mann, H.S. and Verma, C.M., : Management of Indian Arid Rangelands, CAZRI Technical Bulletin No. 4. (In press)

7 Raheja, P.C., 1961 : Double Cropping. ICAR Review Series No. 8, ICAR, New Delhi, 1-32.

8 Raheja, P.C., 1961 : Water requirements of Indian Field Crops. ICAR Research Series No. 28, ICAR, New Delhi, 1-25.

9 Singh, R.P., 1976 : Improved Dryland Agriculture for western Rajasthan, CAZRI Technical Bulletin No.1, 1-28.

10 Singh, R P., 1976 : Five Years of Dryland Agriculture Research (1971-75), CAZRI, Research Report Series No. 1, 1-60.

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1 Aminullah, 1970 : Bibliography of "CAZRI Publications" Arid Zone Research Association of India Bulletin (Priced Publication).

2 Aminullah, 1972 : Catalogue of Periodicals, CAZRI Library Publication Series, No. I.

3 Garg, H.P. and Aminullah, 1976 : "Bibliography on Indian Applied Solar Energy (1950-75)", CAZRI, Jodhpur (Mimeo.).

4 Garg, H.P. and Aminullah, 1976 : "Bibliography on World Applied Solar Energy (1940-75)", CAZRI, Jodhpur (Mimeo.).

5 Garg, H.P. and Aminullah, 1976 : "World Bibliography on Bio-Gas Technology and its Utilisation", CAZRI, Jodhpur (Mimeo.).

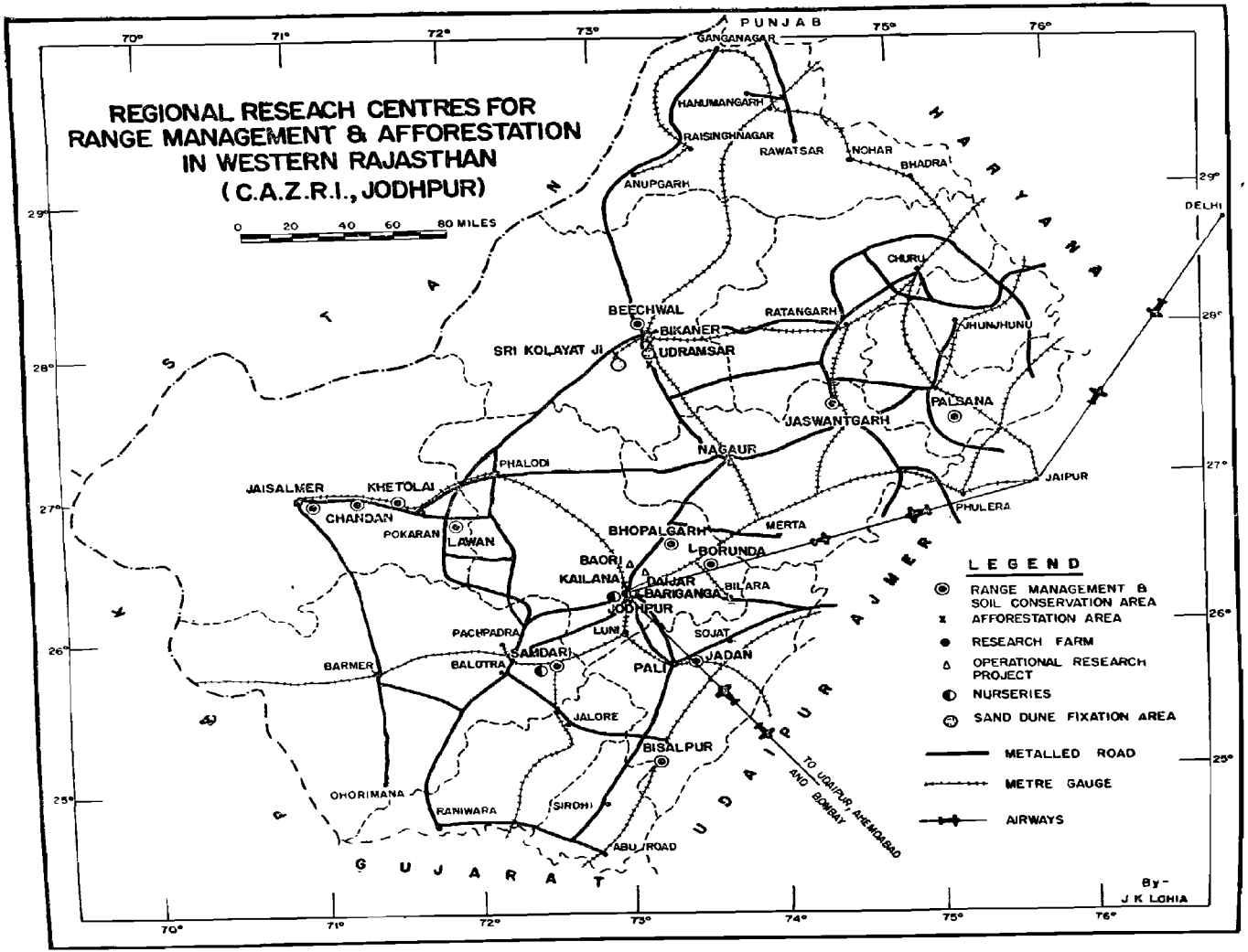
ACKNOWLEDGEMENTS

A resume of this nature is obviously based on the work of the predecessors and the present team of scientists at the Central Arid Zone Research Institute. The scientific work reviewed and results summarised in this bulletin have been achieved and contributed by a large number of scientists during the last 25 years.

The valuable guidance and encouragement received in the formulation and conduct of research programmes from Dr. B.P. Pal and Dr. M.S. Swaminathan, Director Generals, I.C.A.R., is acknowledged. Dr. J.S. Kanwar, and Dr. D.R. Bhumbla, Deputy Director Generals, I.C.A.R., provided unstinted help for the efficient functioning of the Institute.

The research programmes of the Institute were reviewed by the two Achievement Audit Committees and we record our gratitude to the members of the Committees for their contributions.

The earlier two bulletins were published in the year 1974 and 1976 with the assistance of Dr. G.C. Taneja, Shri S.P. Malhotra and Dr. P.K. Ghosh, Head of Divisions in this Institute. The present edition was revised and updated by Shri Gian Chand, Technical Officer.


REGIONAL RESEACH CENTRES FOR
RANGE MANAGEMENT & AFFORESTATION
IN WESTERN RAJASTHAN
(C.A.Z.R.I., JODHPUR)
0 20 40 60 80 MILES
PUNJAB
HARYANA
DELHI
GANGANAGAR
HANUMANGARH
RAISINGHNAGAR
RAWATSAR
NOHAR
BHADRA
ANUPGARH
CHURU
BEECHWAL
BIKANER
RATANGARH
JHUNJHUNU
SRI KOLAYAT JI
UDRAMSAR
PALSANA
JASWANTGARH
NAGAUR
PHALODI
JAISALMER
KHETOLAI
CHANDAN
POKARAN
LAWAN
JAIPUR
PHULERA
BHOPALGARH
MERTA
BORUNDA
BAORI
KAILANA
DAIJAR
BARIGANGA
BILARA
JODHPUR
PACHPADRA
LUNI
SOJAT
SANDARI
JADAN
BARMER
BALOTRA
PALI
JALORE
BISALPUR
TO UDAIPUR AHMEDABAD AND BOMBAY
OHORIMANA
RANIWARA
SIROHI
ABU ROAD
GUJARAT
RAJASTHAN
UDAIPUR
AJMER
LEGEND
RANGE MANAGEMENT & SOIL CONSERVATION AREA
AFFORESTATION AREA
RESEARCH FARM
OPERATIONAL RESEARCH PROJECT
NURSERIES
SAND DUNE FIXATION AREA
METALLED ROAD
METRE GAUGE
AIRWAYS
By-
J K LOHIA
70°
71°
72°
73°
74°
75°
76°
29°
28°
27°
26°
25°

ERRATA

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