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20 YEARS OF CAZRI
REGIONAL RESEARCH STATION
KUKMA- BHUJ

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Regional Research Station

Bhuj - 370105, Gujarat, India

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PREFACE

Central Arid Zone Research Institute (CAZRI) was established on 1st October 1959, based on the recommendations of UNESCO advisor, Dr. C. S. Christian, with the objective to develop technologies for sustainable development of arid regions in India. Looking into the importance of arid region in Gujarat and its contribution to agricultural production in the area, a Regional Research Station was established on 26th March, 1987 at Kukma, Bhuj in the Kachchh district of Gujarat, for proper assessment of the problems and for identification and development of situation specific agro-technologies for the sustainable development of agriculture and allied sectors in the arid regions of Gujarat.

Since then, the scientists and researchers at RRS, Kukma- Bhuj, have been engaged in identifying the problems and constraints and developing suitable location specific technologies for enhancing agricultural production in the region. Over the period of 20 years, many research activities were undertaken at the station and economically viable and sustainable technologies were developed. These included identification of improved genotypes of grasses, characterization of resource base, identification of suitable forage legumes, development of silvipastoral, and agri-horti models and identification of improved cultivars of important field crops along with efficient intercropping systems.

The Station is also in the fore front in disseminating the agriculture knowledge base and giving advice/ training to farmers of arid regions of Gujarat. The Station also conducted many outreach programmes aimed at demonstration of tested technologies in the real farming situation. Various training programmes have been conducted at the Station for the benefit of stake holders.

We thank all the previous workers at the Station, whose untiring efforts helped to develop useful technologies for the benefit of farming community. We hope this publication will be useful to the researchers, the extension agencies, the farmers and the stake holders for the sustainable development of arid regions in Gujarat.

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Date: 20 November, 2009
Place: Kukma,Bhuj


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1. Introduction

The arid zone of India covers about 12% of the country's geographical area and occupies over 31.7 m ha of hot desert and about 7 m ha under cold desert. The arid regions of Rajasthan, Gujarat, Punjab and Haryana together constitute the Great Indian Desert known as Thar Desert that accounts for 89.6 % of the hot arid regions of India. In Gujarat, 6.22 m ha area is under arid zone which constitute 19.6 % of the arid area of the country. In Gujarat, eight districts falls under arid zone, namely, Kachchh (100 % of districts area), Jamnagar (80 %), Surenderanagar (29 %), Junagadh (20 %), Banaskantha (18 %), Mehsana (7 %), Ahemdabad (6%) and Rajkot (6 %) (Fig. 1).

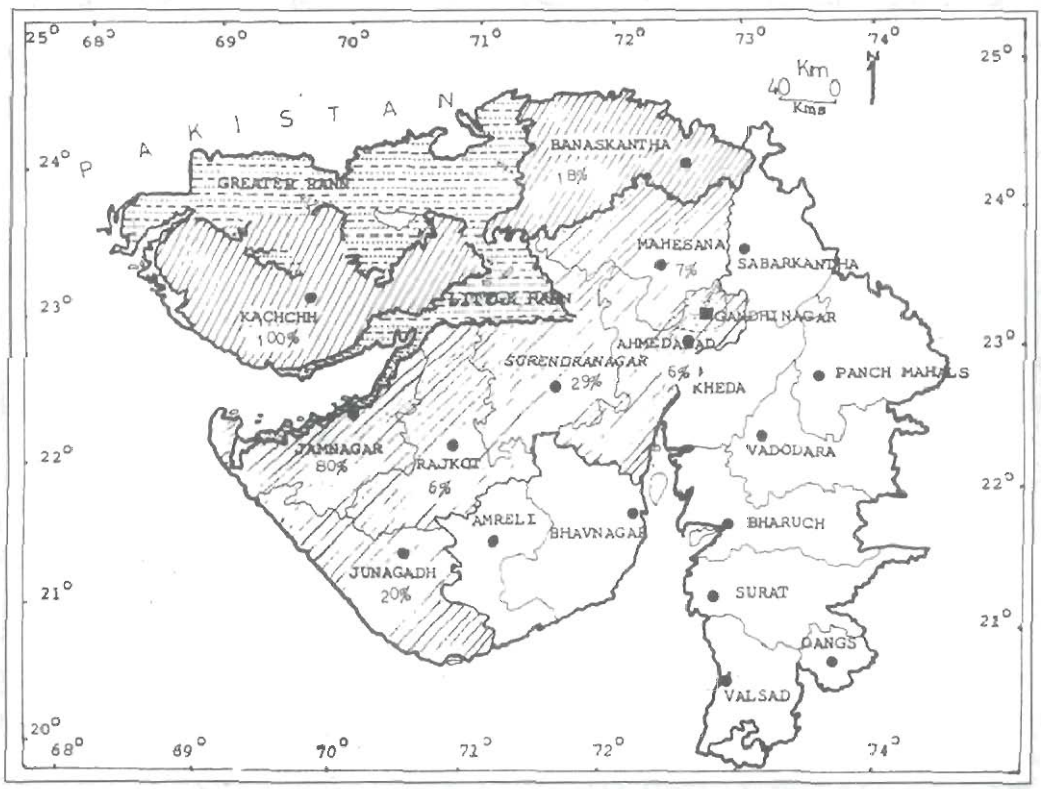

Fig. 1. Map of Gujarat showing the distribution of arid zone

The production and life support systems in the hot regions are constrained by low and erratic precipitation (100-420 mm/year), high evapotranspiration (1500-2000 mm/year), and poor soil physical and fertility conditions. The local inhabitants have evolved suitable land use and management systems of farming, pastoralism and animal husbandry. Of late, these local survival systems have become inadequate to fulfil the ever increasing needs. This has resulted in over-exploitation of the resources causing rapid and widespread land degradation and decline in productivity.

The station was established on 26th March 1987 as Regional Research Station of the Central Arid Zone Research Institute with the objective of transferring the arid zone management technologies to Kachchh region, besides conducting researches on grasses, forestry, dry land farming and arid horticulture, appropriate to the region. The station is located 2 km away from the village Kukma and 13 km from Bhuj, on the Bhuj-Gandhidham highway. Later based on the QRT recommendations, the mandate of the Station was redefined as follows.

1. Evaluation of suitable farming/ cropping systems.
2. Assessment, fine tuning and demonstration of technology.
3. Seed production of crops, grasses and trees.

The work carried out at the Station from 1987-88 to 2007-08 is presented in this publication.

2. Research work on Grasses

Indian subcontinent is characterized by tropical monsoon climate, and active growth of grazing land occurs only during monsoon. Since ancient times, cattle breeding and milk production have been the second most important profession in India after agriculture. Free grazing was practiced and became a way of life. Presently also, livestock production is largely based on free range grazing. The grazing activity is mainly dependent on the availability of grazing resources from pastures and other grazing lands, viz., forests, miscellaneous tree crops and groves, cultivable wastelands and fallow land. Such lands represent 40 % of the total geographical area of the country. The grazing intensity in the country is as high as 12.6 Adult Cattle Units (ACU /ha) compared with 0.8 ACU/ ha in the developed countries. Therefore, our task is two- fold, viz. improvement of pasture and judicious implementation of grazing management. However, pressure of livestock (number of livestock per 100 ha) in Kachchh district of Gujarat over the land increased from 1725 in the year 1972 to 2384 in the year 1982, an increase of 1.38 times. Such increase in livestock population over the time, without any increase in the feed resources, can lead to serious imbalances in the feed and fodder supplies. According to the ancient history, Banni area of the Kachchh district in arid part of Gujarat was the biggest grassland of the South Asia just like the Savannah grassland of Australia. Livestock composition in the sample farms revealed that in the coastal plains and Banni, cattle and buffaloes constituted more than 95 per cent of the total livestock. In view of this, attempts were made to identify the superior genotypes, its agronomic management for higher productivity and develop agroforestry/ silvipasture models for this eco-fragile region of Gujarat.

2.1 Germplasm Evaluation

A total of 36 germplasm accessions of three range grasses from different habitats namely; Banni, Naliya, Rapar, Khavda, Mandvi and Bhuj of Kachchh district of Gujarat were collected. These germplasm accessions included 24 of *Cenchrus setigerus,* 6 of *Dichanthium annulatum* and 6 of *Sporobolus marginatus* (Fig 2 and 3). Germplasm accessions were established at the research farm of Central Arid Zone Research Institute, Regional Station, Kukma, Bhuj, in a randomized block design with three replications. Among various germplasm of *Cenchrus setigerus*, accession no. CAZRI- BH-CS-5 from Banni region produced maximum green (1.14 kg/plant) and dry fodder (0.55 kg/plant). The plant height ranged from 42.3 to 64.0 cm. In *Dichanthium annulatum,* germplasm accession CAZRI-BH-D-3 produced 1.93 kg/plant green and 1.03 kg/plant dry forage yield.

In the second year of germplasm evaluation, the dry fodder yield of *Dichanthium annulatum, Sporobolus marginatus* and *Cenchrus setigerus* varied from 184 to 468 kg ha^{-1}. Germplasm accession CAZRI- BH- CS-5 of *Cenchrus setigerus* and germplasm accession CAZRI-BH-DA-5 of *Dichanthium annulatum* produced significantly higher dry forage but there was no such difference among *Sporobolus marginatus* germplasm.

In the third year of germplasm evaluation of range grasses, growth observations like plant height, number of tillers per plant and tussock diameter were recorded. Germplasm accession CAZRI- BH-CS-5 of *Cenchrus setigerus* and CAZRI- BH-DA-3 of *Dichanthium annulatum* performed better in respect of all parameters but there was no such difference among *Sporobolus* germplasm. Performances of the selected strains of both the grasses are given in the table 1.

Table 1. Germplasm evaluation of different range grasses at RRS, Kukma-Bhuj

Strain	Plant height (cm)	Number of tillers/ plant	Tussock diameter (cm)
CAZRI-BH-CS-3	45.4	56.1	47.0
CAZRI-BH-CS-5	88.6	115.3	82.7
CAZRI-BH-CS -6	79.2	97.5	57.5
CAZRI-BH-CS-18	66.7	81.8	51.9
CAZRI-BH-DA-1	112.5	110.4	77.2
CAZRI-BH-DA-3	123.7	133.3	93.4
CAZRI-BH-DA-5	95.9	97.7	67.8
CAZRI-BH-DA-6	68.6	64.8	55.6

2.2 Varietal evaluation of *Cenchrus ciliaris*

Ten genotypes of *Cenchrus ciliaris* were evaluated over the years to ascertain their suitability to agro-climatic conditions of Kachchh. Field trials were conducted following the standard package of practices. The evaluation of ten genotypes of *C. ciliaris* (CAZRI-75, CAZRI-358, CAZRI-531, CAZRI-1106, CAZRI-1263, IGFRI-660, IGFRI- 678, IGFRI-1414, IGFRI-1228 and IGFRI-391) indicated that the fodder yield varied from 418.3 to 940.0 kg ha $^{-1}$. Genotype CAZRI-1263 produced the highest average fodder yield and performed significantly better except the genotypes CAZRI-75, IGFRI-1228 and IGFRI-391. It was also noticed that CAZRI genotypes possessed large diversity in yield potential while IGFRI genotypes did not show significant differences in their production potential.

2.3 Varietal evaluation of *Cenchrus setigerus*

Six genotypes of *Cenchrus setigerus* were evaluated over the years to ascertain their suitability to agro-climatic conditions of Kachchh. The trials were conducted following the standard package of practices. The evaluation of six genotypes of *C. setigerus* (CAZRI-1, CAZRI-75, CAZRI-175, CAZRI-296, CAZRI-415 and CAZRI-569) indicated that the genotype CAZRI-175 gave the highest average dry fodder yield of 32.86 g/plant. However, the fodder production of genotypes CAZRI-75, CAZRI-296 and CAZRI-415 were at par with that of CAZRI-175.

2.4 Varietal evaluation of *Lasiurus sindicus*

Sixteen genotypes of *Lasiurus sindicus* were evaluated over the years to ascertain their suitability to agro-climatic conditions of Kachchh. The trials were conducted following the standard package of practices. The evaluation of sixteen genotypes of *Lasiurus sindicus* (20-2, 1825, 1891, 20-5, 1883, 319, 1669, 1939, 1840, 1855, 1969, 1827, 317, 1952, 1850 and 1831) indicated that the genotype no. 1952 recorded the highest average dry weight 296.66 g per/ plant.

2.5 Seed Production of range grasses

Seed production of fodder range grasses was started from year 2004 under the National Seed Project. A total of 110 kg seed of *Cenchrus ciliaris* was produced from 2 ha newly developed and 5 ha old established pasture land. Thereafter, the ICAR Mega Seed Project was started in the year of 2006 with the objective to provide the quality seed to the farmers of the region. The table 2 depicts the grass seed production under ICAR mega seed project from 2006 to 2008.

Table 2. Seed Production of *Cenchrus ciliaris* under ICAR Mega Seed Project

Fodder Crop	Year	Production (kg)
Cenchrus ciliaris	2006	106
Cenchrus ciliaris	2007	54
Cenchrus ciliaris	2008	250

Fig. 2. Field view of *Cenchrus ciliaris*

Fig. 3. Seed production plot of *Cenchrus setegerus*

3. Research on Forage Legumes

Three perennial forage legumes, namely, butterfly pea, wild groundnut and stylosanthes were evaluated for their establishment, growth and fodder yields at Kukma, Bhuj during rainy season of 2008. The significant findings are summarized below:

3.1 Butterfly pea (*Clitoria ternatea*)

a. Evaluation of different accessions

Fifteen accessions of butterfly pea collected from CAZRI, Jodhpur and IGFRI, Jhansi were evaluated for their growth and yield at Kukma, Bhuj. The accessions differed significantly in growth parameters namely, plant height, primary branches and leaves/plant, and yield attributes. The fresh and dry weight/plant ranged from 23.3 to 33.7g and 11.5 to 20.1 g/plant, respectively. The dry fodder yield ranged from 1123 to 2107 kg ha^{-1}. The accessions EC 15331-1, IGFRI 173-1, IGFRI 23-1 and CAZRI 1440, CAZRI 1441 yielded more than 2t/ha (Table 3).

b. Nutrient management

Four levels each of nitrogen (0, 15, 30 and 45 kg ha^{-1}) and phosphorus (0, 20, 40 and 60 kg P_2O_5/ha) were applied at the time of sowing to clitoria and evaluated in a factorial RBD. The results indicated that clitoria responded significantly and linearly for green and dry fodder yields to the application of nitrogen (R^2 0.95 and 0.85) and phosphorus (R^2 0.99 and 0.98). However, response for protein yield was both linear and quadratic to nitrogen (R^2 0.88 and 0.96) and phosphorus (R^2 0.94 and 0.98) application. The application of 45 kg ha^{-1} of nitrogen and 60 kg of P_2O_5 per ha yielded the highest production of fresh weight (3883 kg ha^{-1}) and dry weight (1617 kg ha^{-1}) of clitoria (Fig 4).

Table 3. Evaluation of clitoria for growth and yield attributes at Kukma, Bhuj

Growth/yield parameters	Range	Mean	SE±
Plant height (cm)	41.6-186.2	70.92	1.96**
Primary branch/pl	4.4-8.0	5.68	0.22**
Leaves/pl	165.9-390.8	261.64	8.80**
Fresh wt/pl (g)	23.3-33.7	28.82	1.30**
Dry wt/pl (g)	11.5-20.1	16.76	0.94**
Dry fodder yield (kg ha^{-1})	1123-2107	1731	150.9**

Fig. 4. Clitoria- A promise for better feeding of livestock

3.2 Wild groundnut

Four species of wild groundnut namely, *Arachis glabrata*, *A. prostrata*, *A.rigonii* and *A. pusilla*, collected from Junagadh (Gujarat) were evaluated for establishment and growth. The survival of *A. glabrata* and *A. prostrata* were more than 87%, however, it was less than 50% for *A. rigonii* and *A. pusilla* (Fig 5).

Fig. 5. Evaluation of wild groundnut at Bhuj

3.3 Stylosanthes

Stylosanthes hemata was evaluated for growth and fodder yield at Kukma, Bhuj. The growth of stylo was luxurious with plant height of 72.3 cm, no. of primary branches of 5.3, and dry weight of 130 g/plant. It produced dry fodder of 3900 kg ha^{-1}. (Fig 6)

Fig. 6. Performance of stylosanthes at Bhuj

4. Agroforestry

4.1 Evaluation of different Silvi- pastoral systems

Under this programme, three tree species namely, Neem (*Azadirachta indica*), Su-babool (*Leucaena leucocephala*) and Israeli babool (*Acasia tortilis*) were planted in *kharif*, 1988 along with two grass species, *Cenchrus ciliaris*, Var. CAZRI-358 and *Cenchrus setigerus* Var. CAZRI-175 (Figures 7 and 8).

The bio-metric observations on growth of tree and grasses during kharif, 1995 are presented in tables 4 and 5 and it indicated that the tree height was more for Su-babool in the control plot followed by su-babool with *Cenchrus ciliaris*. The maximum collar diameter was noticed in case of Su-babool (12.67 cm) followed by Neem (11.91 cm) and Israeli babool (10.75). Among the grass species, *Cenchrus ciliaris* was found to be superior to *Cenchrus setegerus* in terms of fodder production.

Table 4. Effect of various grass species (*C. ciliaris* and *C. setigerus*) on growth of Neem, Su-babool and Israeli babool (*kharif*-1995)

Tree species	Plant height (cm)			Collar diameter (cm)		
	C. ciliaris	*C. setigerus*	Control	*C. ciliaris*	*C. setigerus*	Control
Neem	354.50	425.83	403.00	9.84	11.67	11.91
Su-babool	599.16	555.83	719.00	10.42	10.29	12.67
Israeli babool	368.38	345.83	401.00	8.56	8.27	10.75

Table 5. Effect of various tree species (Neem, Su-babool and Israeli babool) on growth and fodder yield of grasses (*C. ciliaris, C. setigerus*), *kharif*-1995

Tree species	Plant height (cm)				Collar diameter (cm)			
	Neem	Su-babool	Israeli babool	Control	Neem	Su-babool	Israeli babool	Control
C. ciliaris	*46.26*	48.26	86.40	425.83	12.77	14.60	10.77	12.32
C. setigerus	49.26	41.86	46.33	45.00	10.20	10.20	12.33	11.41

In the second year of the study, under the silvi-pastoral system, the growth of grasses (*Cenchrus ciliaris*) in terms of dry matter yield was least reduced under Neem (33.5 %) followed by Su- babool (37.3 %) and Israeli- babool (43.4%).

Table 6. Fodder yield (kg ha^{-1}) of *Cenchrus ciliaris*

Tree species	*C. setigerus*	*C. ciliaris*
Neem	207	321
	(11.1)	**(33.5)**
Su-babool	135	303
	(42.1)	**(37.3)**
Israeli babool	167	273
	(28.3)	**(43.4)**
Control	233	483

* Values within parenthesis indicate % decrease over control.

Fig. 7. Silvipastoral system involving *Cenchrus ciliaris* with *Acacia tortilis*

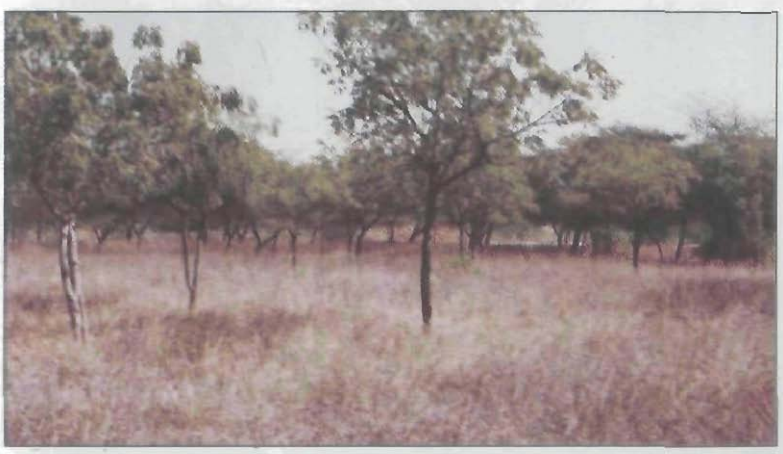

Fig. 8. Silvipastoral system involving *Cenchrus ciliaris* with *Neem*

5. Research works on Crops

5.1 Oilseed crops

5.1.1 Sesame: The fertilizer trial on sesame with three doses of nitrogen (0, 30, and 60 kg ha^{-1}) indicated that the seed yield and dry matter production were linearly increased. The higher dose of nitrogen increased the yield and dry matter by 53.8 and 45.6 %, respectively. The application of P- solubilisers was found to increase the yield by 24.3 % while the yield increase by Azotobacter was only 17.0 %. The addition of nitrogen and irrigation increased plant height, no. of leaves, no. of branches, no. of pods and 1000 seed weight.

5.1.2 Mustard: The performance evaluation trials of mustard varieties showed a maximum seed yield of 1.9 t/ha for RH-30, followed by variety Rajat that produced 1.8 t/ha (Fig 9). The studies on application of biofertilisers on *Brassica* indicated the improvement of seed yield by 27.9 % by *Azotobacter* and 6.7 % by phosphorus solubilizing bacteria over control (Fig 10). The application of nitrogen @ 30 kg ha^{-1}, improved the seed yield by 15.8 % and application @ 60 kg ha^{-1} of nitrogen could enhance the yield by 20.5 %.

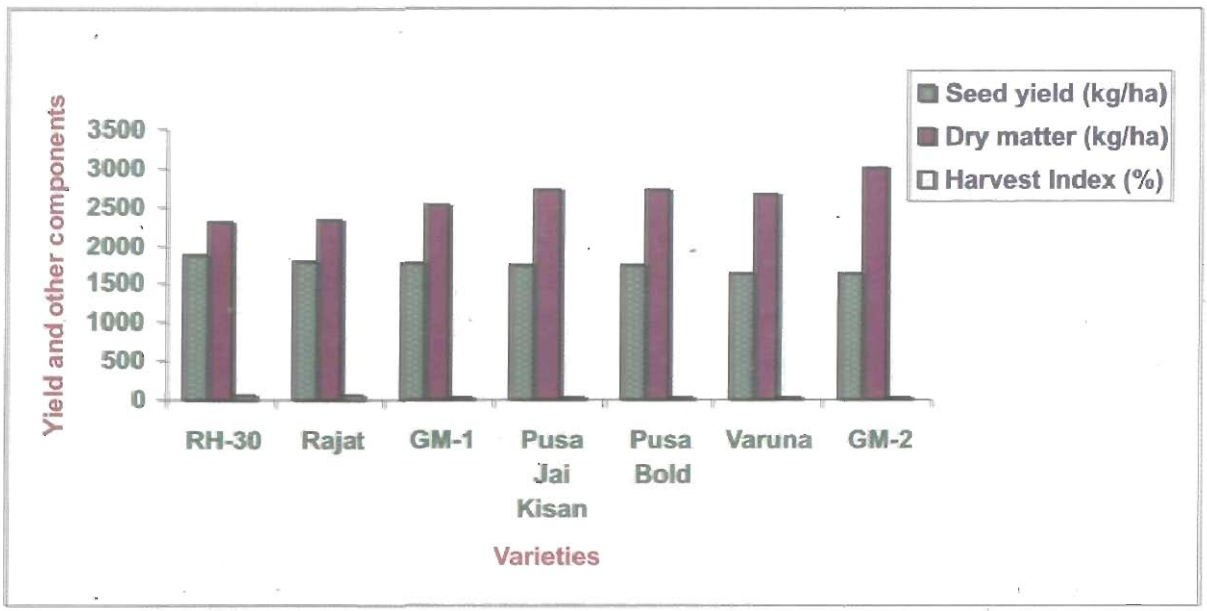

Fig. 9. Performance of Brassica varieties at Bhuj

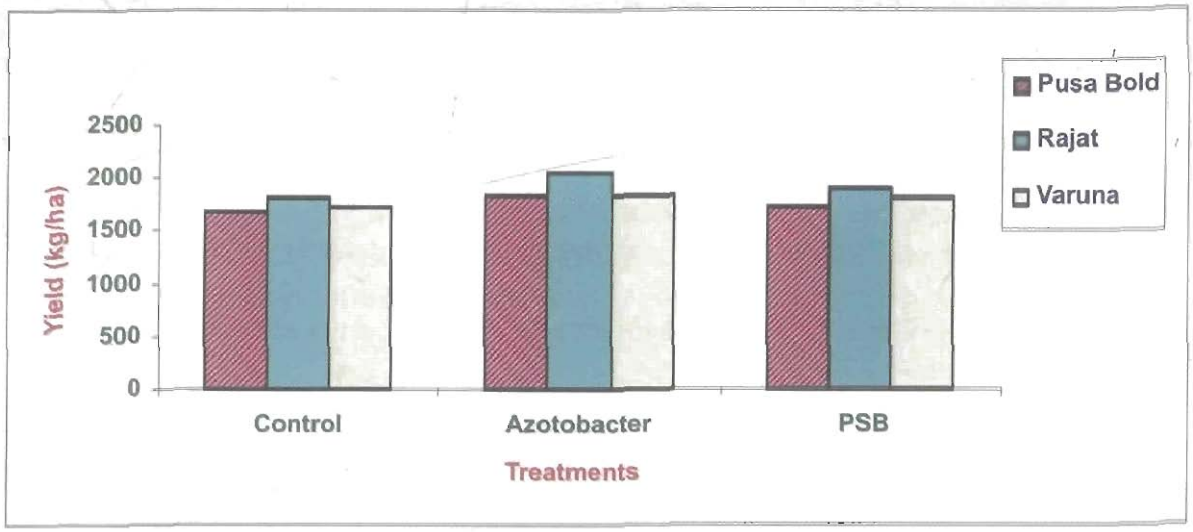

Fig. 10. Effect of biofertilisers on Brassica

5.1.3 Sunflower: The varietal evaluation trial of sunflower was undertaken under the All India Co-ordinated Project in 1991-92. Out of eleven early hybrid strains (HB-1 to HB-11) evaluated, the highest grain yield of 2.47 t/ha was recorded by HB-6. The grain yields of HB-10, HB-7, HB-5, HB-11 and HB-3 were found to be at par with that of HB-6.

5.2 Pulses

5.2.1 Clusterbean: The early and late genotypes of clusterbean evaluated at Kukma, showed no significant differences in plant height, no of branches and number of pods. The seed yield of early *Suvidha* and late *Maru* guar were comparable. However *Maru* guar produced 6.7 % more dry matter compared to *Suvidha*. Moderate irrigation (30 mm) at post flowering stage is useful to increase the grain yield by 9.5 %. The water use efficiency of *Maru* guar (1.24 kg/mm/ha) was found to be better among the three (*Suvidha*, *Maru* and local) due to its high seed yield. Decreasing plant population to 1.25 lakh plants per hectare is found to have a positive and significant effect on seed yield and dry matter production.

5.2.2 Moth bean: Evaluation of 15 genotypes of mothbean was carried out at Kukma. The biomass yield of various genotypes varied from 371 to 825 kg ha^{-1} and CZM- 45 and GMO- 012 produced maximum and minimum dry matter, respectively.

5.3 Cereals

5.3.1 Pearl millet: The varietal evaluation trial on pearl millet conducted at RRS, Kukma in the year 1997-98, indicated yield ranging from 380.9 to 615.9 kg ha^{-1}. The highest seed

yield was recorded by MH-179 followed by CZP-9505 (565 kg ha^{-1}), although there was 31.5 % more dry matter production by CZP-9505, and the least seed yield was for the local KTC-1. The straw production varied from 527 to 927 kg ha^{-1}. The assimilate partitioning capability ranged from 17.7-30.3% (Fig 11).

The studies on fertilizer application indicated that nitrogen application linearly and significantly improved the seed yield and dry matter production. Application of FYM, pond clay each @ 5 t/ha produced 1.62 t/ha of pearl millet against 1.2 t/ha in untreated control. The application of FYM alone at 5 or 10 t/ha produced yield at par with FYM+pond clay @ 5 t/ha.

The studies on biofertiliser application on pearl millet indicated that *Azospirillum* had a favourable effect on dry matter production to the tune of 10%.

Fig. 11. Performance of pearl millet variety ICTP 8203 at RRS, Kukma-Bhuj

5.3.2 Minor millets: Minor millets are crops of harsh environments. It has remarkable adaptability in arid environment owing to its drought tolerance and drought evading characters. The minor millets like finger millet, barnyard millet, foxtail millet etc are generally grown as rainfed crop in India. Alternative farming systems involving minor millets were evaluated for their performance at Bhuj. Two genotypes each of Proso millet (GPUP-19, K-1), Barnyard millet (K-1, VL-171), Foxtail millet (SIA-326, PS-4) and Finger millet (VR-708, GPCL-26) were evaluated in 2003. Under the arid environments, the grain yield of these millets varied from 513- 1785 kg ha^{-1}. Among these millets, foxtail millets gave maximum grain yield (1785.7 kg ha^{-1}) followed by proso millet (968.7 kg ha^{-1}) and finger millet (848.2 kg ha^{-1}). Variety PS-4 of foxtail millet, K-1 of proso millet, GPCL-26 of finger millet and VL-171 of barnyard millet produced 29.0, 18.0, 2.0 and 17.0 % respectively, more grain compared to other varieties tested.

6. Cropping systems - Intercropping

Intercropping is a form of multiple cropping that is prevalent in arid and semi arid tropics of the world. The spacing, number of plants and their geometric arrangements play an important role in deciding the success and economic viability of any intercropping system. Considering the importance of intercropping in the arid zones, experiments were conducted to test the feasibility of different intercroppings in arid Kachchh region of Gujarat.

6.1 Castor + sesame intercropping

The studies on castor+ sesame intercropping indicated that castor and sesame as sole crop produced 635 and 324 kg grain yield/ha, respectively. Though the adoption of intercropping in the row ratio of 1:3 decreased the yield by 27.4 and 17.3% over sole crops of castor and sesame, respectively, it was more than compensated by producing additional yield of intercrops (castor 461 kg ha^{-1} and sesame 268 kg ha^{-1}) in the system. Thus, the intercropping of castor+ sesame (1:3 ratio) gave the gross returns of Rs 16897 /ha with BCR of 1.40 as against Rs 12, 382 with BCR of 1.37 and Rs 9,558 with BCR of 1.39 by sole crops of castor and sesame, respectively. It is observed that intercropping sesame with other rainfed crops was more profitable than sole sesame under arid region of Gujarat (Fig 12).

Fig. 12. Castor + sesame intercropping

6.2 Castor + groundnut intercropping

The studies on castor with groundnut revealed that sole crops of castor and groundnut produced an average yield of 570 and 150 kg ha^{-1}, respectively. The pod yield of groundnut reduced significantly due to deficient rainfall particularly during the reproductive stage (in September only 6.3 mm rainfall). The grain yield under intercropping was found to be reduced by 31.9% in castor and 16.6% in groundnut as compared to their sole crop treatments. However, considering the economics of the system, intercropping of castor + groundnut (1:3) gave gross return of Rs 11, 566/ha which was higher by Rs 1451/ha over the sole castor and by Rs 8,026/ha over the sole groundnut (Fig 13).

Fig. 13. Castor + groundnut intercropping

6.3 Sesame + clusterbean intercropping

The studies on intercropping of sesame + clusterbean indicated that grain yield under intercropping system reduced by 28.8% in clusterbean and 40.4% in sesame as compared to their sole treatments. However, considering the net returns and BCR, intercropping of sesame with clusterbean (1:2) gave the maximum net returns of Rs 7,440/ha along with BCR of 1.80 compared with Rs 5,945/ha and BCR of 1.68 in sole clusterbean and Rs 2,851/ha and BCR of 1.37 in sole sesame. The Sustainable Yield Index (0.74) and Sustainable Value Index (0.76) were also higher in intercropping of sesame+ cluster bean (1:2) than that recorded by sole sesame (0.73 and 0.73) and sole clusterbean (0.71 and 0.72). From the studies, it is concluded that intercropping involving clusterbean and sesame was more profitable and sustainable than sole cropping (Fig 14).

Fig. 14. Seame + clusterbean (1:2) intercropping

7. Arid Horticulture

7.1 Ber

Ber (*Zizyphus jujube*) is an ideal fruit for the arid and semi- arid regions of India where most of the other fruit crops can not be grown either due to lack of irrigation facilities or adverse climatic and soil conditions. Its cultivation has received a great impetus in recent years in the northern part of India, especially in the states of Punjab, Haryana, Rajasthan, Uttar Pradesh and Gujarat. The ber fruits are mostly eaten as fresh but the other forms, such as dried, candied, pickled and also other products like squash or juice and ber butter can also be prepared and used. Various Ayurvedic and Yunani medicines contain ber extract which is said to be a blood purifier and also helps in digestion. The powder and decoction prepared from the roots are effective in case of fever, ulsers and old wounds. The stem bark is considered to be a remedy for diarrhea. The ber plant itself yields many economic products. The leaves are used as a fodder in the dry regions; the stem gives a quality wood which is used for making various agricultural implements. The wood is also considered as valuable timber and is used in the construction of buildings.

The research on arid horticulture was started in 1990 and two varieties of ber (Seb and Gola) were evaluated. The seedlings were planted in 0.9x0.9x0.9 m pits dug at the spacing of 6X6m. The data on growth parameters of the ber varieties recorded in 1995-96 are given in Table 7.

Table 7. Growth characteristics of ber

Variety	Plant height (cm)	Basal collar diameter (cm)	Crown area (m^2)
Gola	243.5	8.098	9.146
Seb	235.0	8.951	7.864

The variation in growth of ber varieties in terms of plant height, basal collar diameter and crown area was not considerable. Variety Gola came to fruiting earlier by 20 days as compared to var. Seb (Fig 15).

To find out a suitable variety of ber for the arid region of Kachchh, a varietal trial of ber was initiated in June 1994. Five varieties of ber with varied duration namely, Mundia, Tikdi, Ilaichi, Banarsi and Umran were included in the study. The seedlings of ber varieties were planted in 0.9x 0.9 x 0.9 m deep pits dug at 6X6m spacing.

In the second year, performance evaluation of five genotypes viz. Umran, Mundia, Banarsi, Tikdi and Illaichi indicated that the plants attained an average height of 2.21 m. The tree spread was around 3.4 and 3.6 m in NS and EW direction, respectively. On an average fruit yield of 2.34 kg was received during the year. Tikdi performed better than other genotypes in growth but variety Umran gave the highest fruit yield per plant.

According to third year performance, variety Takadi had superior growth potential as compared to Mundia, Banaarasi, Umran and Illaichi. This variety had the highest plant height (2.1 m) while illaichi had the minimum height (1.3 m). A similar trend was observed in collar diameter and canopy spread also. Plants in general had more spread in east- west direction than in north –south sides.

Studies on time of pruning indicated that early pruning (15th April) had plant growth in term of height (32 %) and tree spread (37%) as compared to plant pruned at 15th may. As regards severity of pruning it was observed that half pruned trees showed better height, spread, shoot length, and number of secondary branches as compared to unpruned plants. However, the sprouting was 6 days earlier in 3/4th pruned plants.

7.1.1 Agronomic Management of ber

Application of nitrogen linearly increased the plant height and spread as compared to unfertilized plants, this effect was further enlarged when plants received phosphorus. Simultaneous application of phosphorus and nitrogen reduced the fruit yield by about 10 per cent as compared to application of nitrogen alone (Table 8).

Table 8. Effect of nitrogen on ber plants.

Nitrogen (g pit^{-1})	Height (m)		Crown diameter		Fruit yield (kg ha^{-1})	
	P (g pit^{-1})		P (g pit^{-1})		P (g pit^{-1})	
	0	160	0	160	0	160
0	2.25	2.30	4.12	4.22	2.10	2.40
200	2.35	2.40	4.25	4.27	3.33	2.70
400	2.40	2.50	4.35	4.35	4.20	3.95
600	2.60	2.55	4.50	4.50	3.90	3.65

Variety Takdi had the highest plant height, collar diameter, crown diameter and fruit yield among the ber varieties (Mundia, Banarsi, Umran, Elaichi and Tikdi) while Elaichi was slow grower as well as low yielder. It was also observed that Tikdi was more or less resistance to fruit fly but was susceptible to powdery mildew.

In the second year, nitrogen and phosphorus application increased the growth in height, collar diameter, tree spread and fruit yield in Gola and Seb varieties of ber, however, the effect was more prominent in variety Seb. The beneficial effect of nitrogen were more prominent than phosphorus (Table 9). Nitrogen and phosphorus when applied simultaneously (600+ 160 g/pit), reduced yield of Gola by 50 percent, however, in variety Seb the fruit yield increased by 13.8 per cent. This indicated differential nutrient requirement of two varieties. Variety Seb seems to be efficient in utilization of applied nutrients and thus produced more fruits (Table 9).

Table 9. Influence of nitrogen and phosphorus on yield (kg/plant) of Gola and Seb.

Nitrogen	Gola		Seb	
	Phosphorus (g/plant)			
g/ pit	0	160	0	160
0	0.5	2.0	4.7	7.5
200	2.5	1.2	6.5	6.2
400	2.0	1.5	6.8	6.7
600	3.0	1.5	7.2	8.2

In the third year of the study, application of nitrogen fertilizer increased number of branches by about 14.4% in Gola as well as Seb varieties but did not have much effect on plant height. Phosphorus application increased plant height and collar diameter by 15 % and 16 %, respectively. The north- south as well as east- west spread of plant was more under application of nitrogen 400 and 600 g/plant along with of phosphorus 160 g/plant.

Fig. 15. Performance of Gola variety of ber at Bhuj

7.2 Pomegranate

Pomegranate (*Punica granatum*) is commercially grown for its sweet-acidic taste. The fruits are mainly used for dessert purposes. The fresh fruit is of exquisite quality while its processed products, such as bottled juice syrups and jelly are highly appreciated. *Anar rub* is a product locally prepared from the juice by adding sugar and heating to a thick viscous consistency. It keeps well and is used like tomato sauce or ketchup. The fruit juice easily ferments and may be used for the production of wine. The bark of the stem and root contain a number of alkaloid belonging to the pyridine group. It is also employed in the therapeutics in dysentery and diarrhohea.

A trial involving nine varieties of pomegranate (Jalore seedless, Ganesh, Jodhpur red, Dholka, G-137, GKVK-1, P-26, Bassein seedless and P-23) was established to study the prospects of growing pomegranate in the region. Cultivar Bassein seedless indicated highest survival (100 %) followed by Jalore seedless (95%), whereas, cultivar G-137 had minimum (75%) survival in the region. The average survival of plants of all the varieties was around 86.6 per cent (Table 10).

In the second year of studies on evaluation of cultivar revealed that Jodhpur red was more vigorous in growth in term of plant height, canopy and collar diameter while Jalore seedless recorded minimum values for these parameters. Other varieties indicated intermediately values. Height, spread and collar diameter varied between 80.7 to 130.5 cm, 1.8 to 2.8 m and 1.6 to 3.0 cm, respectively (Table 10).

Table 10. Growth performance of pomegranate cultivars

Genotype	Height (cm)	Canopy spread (m)	Collar diameter (cm)
P-23	107.3	2.4	2.7
Bassein seedless	95.0	1.9	1.6
P-26	101.2	2.3	2.6
GKVK-1	101.0	2.2	2.5
G-137	97.4	2.0	1.8
Dholka	113.2	2.6	2.8
Jodhpur Red	130.5	2.8	3.0
Ganesh	104.4	2.3	2.5
Jalore seedless	80.7	1.8	1.8

7.3 Custard Apple

Custard apple is very delicious fruit. The other important features of custard apples are their adaptability to soil and climate conditions and freedom from pest and diseases. Due to their hardy nature and escape from animal damage, custard apples have become naturalized in many tropical and subtropical parts of the word along with a tremendous scope for further expansion. They are, however, yet to be established as commercial fruits and usually find a place only in gardens or home orchards. The fruits of custard apple are mostly consumed as table fruit. They are also used in ice- creams and other milk products and preserved as jam, jelly or other products on limited scale. The edible portion or pulp is creamy or custard like, granular with a good blend of sweetness and acidity which vary with the species. The pleasant flavour and mild aroma have a universal liking. Custard apple is propagated both by sexual and asexual methods. Seed propagation is widely prevalent resulting into variability in plant vigour, prolonged juvenility and inferior fruit quality. The clonal propagation is, therefore, a necessity to maintain the genetic uniformity for obtaining higher yield of better quality fruits.

7.3.1 Response of custard apple to compost and fertilizer application

In a field study on custard apple, application of compost @ 2 kg per pit increased plant height, crown and collar diameter by 38.8, 50.1 and 8.3 per cent, respectively, over unfertilized plants. Increasing dose of urea linearly increased these parameters. Combined application of compost (1 kg /plant) and 100 g urea per pit promoted growth of these parameters equal to application of 200 g urea per pit alone.

7.4 Date palm

Date palm is a prominent tree of the desert oases. In India, dates are almost exclusively imported from the Near- East and North African countries. It provides nutritive fruits rich in sugar, iron, potassium, calcium and nicotinic acid. Small amount of protein, copper, magnesium, chlorine, sulphur, vitamins A, B_1 and B_2 are also present in date pulp. The flesh of date with a moisture content of 20 per cent from 60-65 per cent sugar, about 2.5 per cent fibre, 2 per cent protein and somewhat less than 2 per cent each of mineral matter and pectic substances. Such fruits provide about 3,150 calories per kg.

7.4.1 Phenotypic variability in date palm fruits

Study on phenotypic variability in fruit characteristics of the elite landraces of datepalm from Mundra taluka of Kachchh was carried out. It was observed that average fruit size ranged from 3.17 x 4.23- 2.83 cm, fruit weight, seed weight and TSS ranged from 10.38 to 21.78g, 0.93 to 1.16g and 28.2 – 34.6^0 brix, respectively. Among various land races collected, landrace BHD-3 had better fruit quality in term of size and TSS content.

7.5 Performance of nursery and in –situ raised seedling

Nursery and in-situ raised seedlings of mango, aonla and custard apple indicated that under nursery condition, the germination and girth index of these fruit crops were better than in-situ condition, however, plant height was better at in- situ raised seedlings. The survival percentage under nursery condition at 90 days after sowing was also 19.19, 2.81 and 14.61 percent more than in-situ condition in mango, aonla and custard apple, respectively (Table 11).

Table 11. Comparative effect of nursery and in-situ raised seedlings on germination, survival and growth

Fruit	Nature of seedling	Germination Time (days)	Germination (%)	Survival at 90 DAS (%)	Plant height at 180 DAS (cm)	Stem girth (cm)
Mango	In situ	35.67	67.47	73.61	59.40	0.84
	Nursery	29.34	74.13	92.00	58.20	0.95
Aonla	In situ	8.67	64.00	96.00	37.60	0.93
	Nursery	7.34	81.31	98.70	30.40	1.10
Custard	In situ	41.34	61.34	76.00	43.40	0.47
apple	Nursery	34.13	75.00	89.00	36.34	0.56

A comparative study of in-situ and nursery raised fruit plants in the second year of growth indicated that in-situ raised aonla plant had 12.2 per cent higher growth compared to nursery raised plants. The collar girth however, was more in nursery raised plants. Survival per cent after second year of planting was higher in aonla and c. apple plants raised under nursery condition than planted in field. Where as in case of mango, there was not much difference. In custard apple, planting techniques did not have any significant effect on growth performance (Table 12)

Table 12. Growth performance of different type of fruit plants

Fruit trees	Planting techniques	Survival percentage (%)	Plant height (cm)	Collar diameter (cm)
Mango	In-situ	48.6	41.2	1.31
	Transplanted	48.3	47.7	1.02
Aonla	In-situ	79.2	131.9	1.89
	Transplanted	98.5	117.2	1.68
Custard apple	In-situ	77.7	57.3	0.84
	Transplanted	81.7	56.9	0.94

8. Introduction of New crops

8.1 Henna

Henna "*Lawsonia inermis* L." , a busy, glabrous, much branched shrub is often cultivated as hedge plant. The leaves of the plant contain dye "lawsone". The dye is used in colouring palms of hands, sole, nails and hair etc. It is utilized in printing of value – added textile product and dyeing of leather. Plant is also used as a prophylactic agent against skin diseases in the Indian system of medicine. Flower and seeds yield essential oils and fatty acid respectively. The crop produce are in high demand in export market which fetch considerable foreign exchange in national exchequer. This is being extensively grown as a cash crop for arid wastelands of Rajasthan. Looking to the importance of the crop, its suitability as a crop for arid Gujarat was studied and agro techniques were developed (Fig 16). The spacing trials were conducted with 40 X40, 40 X 50 and 40 X 60 cm spacing so as to get a plant population of about 62,500, 50,000 and 41,700 plants per hectare, respectively. The study revealed that maximum dry leaf yield was obtained at the plant population of 50,000 plants per hectare at which the plant developed highest leaf: stem ratio. Net maximum returns were also obtained at the plant population of 50,000 plants per hectare (Rs.16,346) followed by Rs.13,216 and 10,443 under the plant populations of 41,600 and 62,500, respectively, against the investment of Rs. 3000 per hectare.

Application of biofertiliser like *Azospirillum*, P- solubilising bacteria alone or in combination to 3 year old ratoon crop found to increase the leaf yield by 20.9, 15.9, and 11.6 %, respectively, over the unfertilized control. Field studies on alley cropping of henna with senna indicated a yield reduction by 27.8 % in henna; however the system produced 585.9 kg dry leaf of senna additionally.

Fig. 16. A field view of Henna at RRS, Kukma-Bhuj

8.2 Amaranth

The feasibility studies were conducted for amaranths cultivation in Kachchh, which was not a practice of the region due to want of irrigation. The varietal trial showed a 19.3 % more seed yield by variety GA-2 than GA-1. The studies revealed that application of nitrogen @90 kg ha^{-1} and irrigation of 200 mm water at four growth stages in equal quantity produced 8382 kg ha^{-1} dry biomass and 1206 kg ha^{-1} grain yield for the variety GA-2. A net economic return of Rs 20,000 were obtainable and the study indicated the cultivation of amaranths in Kachchh has a commercial viability and will be helpful for meeting the protein requirement in the diet (Figure 17 and 18).

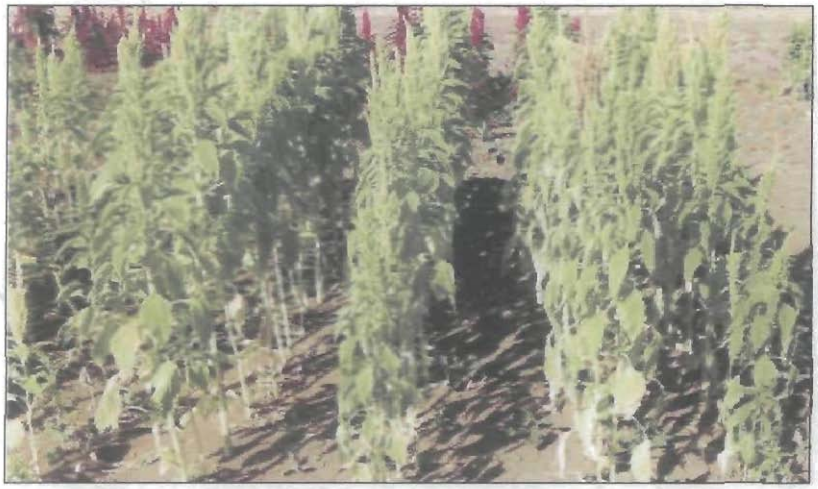

Fig. 17. Amaranths variety GA-1

Fig. 18 . Amaranths variety GA-2

9. Watershed development

The arid zone is defined in terms of moisture deficit. The water conservation and watershed management are essential components of arid zone management. With this objective watershed development activities were undertaken at RRS, Kukma. A farm pond of 22,000 m^3 capacity with length of 110m, width of 80 m and depth of 3.5 m was made to harvest the excess rain water for life saving irrigation of the experimental crops. The watershed activities were strengthened with the farm bunding and plotting activities in the year 2008 (Figure 19 and 20).

Fig. 19. Pond in October 2007

Fig. 20 . Pond in August 2009

10. Studies on natural resources

10.1 Soil resources of the farm

The soil resources of the farm were studied. The depth of soils of the farm ranged from less than 15 cm to more than one metre. The soils were low in organic carbon (0.23 to 0.59%), nitrogen (134.85 to 309.08 kg ha^{-1}), phosphorus (6.2 to 24.8 kg ha^{-1}), low to high in potassium (159.9 to 690.0 kg ha^{-1}) and deficient in Mn (3.58 to 4.98 ppm) and Zn (0.42 to 0.46 ppm) . The soils are very hard and compact in the lower layers and behaved like an impervious layer with a high content of calcium carbonate at many locations.

10.2 Studies on carbon sequestration

Information regarding the spatial distribution of carbon both in soil and vegetation in the ecosystem is important in better understanding of biogeochemical processes and formulation of policies and action especially in the post Kyoto regime. Apart from reducing the effects of global warming, the carbon sequestration provides additional benefits like improvement of soil quality, sustaining and improving soil productivity etc. Therefore, a project was initiated in 2008, to estimate the carbon sequestration potential under different cropping systems in the Kachchh region of Gujarat.

Soil samples were collected from five different depths (0-5, 5-10, 10-20, 20-40 and 40-100 cm) from (a) three different date palm growing sites at Kera, Mundra and Anjar (b) forest plantations at Mochirai, Mandvi, Naliya and Birindiyari (c) grass land at Nakhatrana, Naliya and Banni (d) Greater Rann and (e) waste lands at Netra, Naliya, Kaladungar in addition to 12 crops/ cropping systems in the CAZRI, RRS, Kukma-Bhuj experimental farm.

10.2.1 Soil organic carbon stock

The soil pH under different land uses varied from 7.7 to 10.4 in the top 0-5 cm layer. The highest pH was noticed in the soils of Greater Rann. Among the 3 grasses studied (*Cenchrus ciliaris, C. setigerus* and *Lasiurus sindicus*), the total carbon stock was more under *Cenchrus ciliaris* (26.75 t/ha). In the major grass lands of Kachchh at Banni, Naliya and Nakhtrana, the soil organic carbon stock in the upper 5 cm layer was 4.67, 3.19 and 2.64 t/ha, respectively. The carbon stock in different date palm growing eco-regions ranged from 2.15 to 3.00 t/ha in the top 5 cm layer. Among the three silvipastural systems studied, maximum soil organic carbon stock was noticed under the system involving *Neem* and *Cenchrus ciliaris* (3.49 t ha^{-1}), followed by Acacia and *Cenchrus ciliaris* (3.34 t/ha) and Acacia and *Cenchrus setigerus* in the top 5 cm layer. In the next 5 and 10 cm soil layers, the trend followed the order Acacia + *Cenchrus ciliaris, Neem* + *Cenchrus ciliaris* and Acacia + *Cenchrus setigerus*.

10.2.2 Biomass carbon stock

The average above ground biomass of *Prosopis juliflora* plantations under study was 3.22 t ha^{-1}. Among the three silvipastoral systems, the total biomass carbon stock was highest in the system involving Acacia + *Cenchrus ciliaris*. The total carbon stock of *Cenchrus ciliaris* found to be 4.26 t ha^{-1} of which 57.28 % was contributed by the above ground biomass (Figure 3). In the monoculture pasture of *Cenchrus setigerus*, the above ground biomass contributed to 59.43 % of total carbon stock. The henna recorded an average total biomass of 3.27 t ha^{-1} with 54.67 % contribution of above ground biomass to the total carbon. Among the arid horticulture, ber recorded 1.34 t ha^{-1} of total carbon stock and pomegranate of 0.80 t ha^{-1}.

11. Extension and farmers' participation

Since its beginning, the Station has been conducting training as per the mandates given to the Station from time to time. The Station was also frequently visited by practicing farmers and officials of development departments. Initially training focus was on range land management looking into the fact that livestock rearing is an important activity of the region. The Station helped in the establishment/ rejuvenation of grass lands in collaboration with forest department, in addition to actively participating to the development of silvipastural system under social forestry activity of forest department. The station was instrumental in supplying quality seeds of improved grasses and trees.

Later with the broadening of mandates to include crops and other activities leading to overall improvement of arid zone, the Station conducted trainings on management of *Prosopis juliflora*, watershed management (Figure 21 and 22), training on improved cultivation of clusterbean (Figure 23), improved cultivation of horticultural crops (Figure 24) and soil testing (Figure 25) *etc.*

Fig. 21. Training on watershed management

Fig. 22. Farmers' field day

Fig. 23. Training on improved cultivation of clusterbean

Fig. 24. Field level training on improved cultivation of date palm

Fig. 25. Demonstration on soil sampling

The technical and scientific staffs were involved in delivering invited lectures at meetings organized by development departments, NGOs and agricultural and traditional universities. Radio talk by the staff members were another avenue for delivering/ transmission of arid zone technologies developed by CAZRI and other organizations working for the development of arid zone.

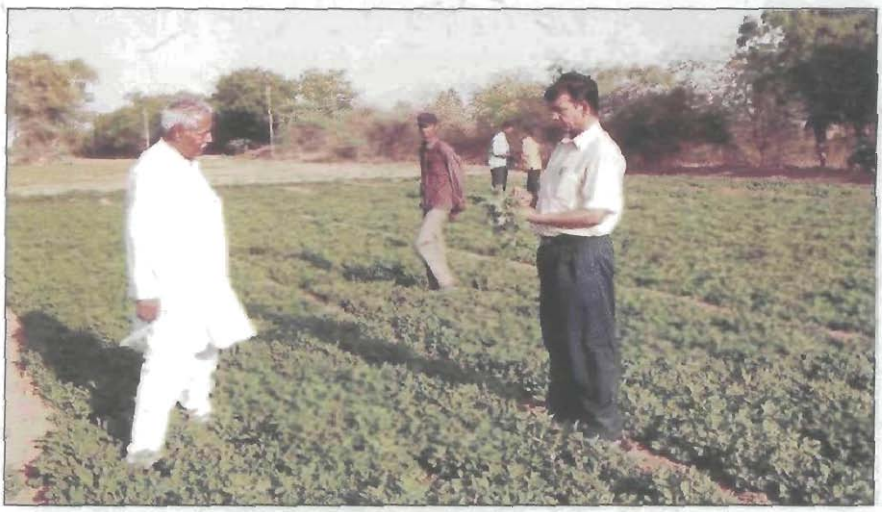

Fig. 26. Farmers field visits by scientist

The Station was also in the forefront in implementing outreach programmes. Under the Farmers Participatory Action Research Programme of the Ministry of Water Resources, New Delhi, ten demonstrations of improved cultivation of ber and 5 demonstrations of cropping system for irrigated condition, 5 demonstrations on popularization of varieties and 10 demonstrations on rodenticidal bait were performed in participating villages in the year 2008-09.

Fig. 27 . Implementation of Farmers Participatory Action Research Programme

Fig. 28. Farmers Participatory Action Research Programme for popularisation of ber in Kachchh

12. Publications

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Training manual

Shamsudheen. M., Devi Dayal, Bhagirath Ram. 2009. Improved cultivation of ber (*Ziziphus mauritiana*) in arid Gujarat, (Gujarati language), pp. 6.

Workshop/ Seminars/ Trainings

Workshop on "Desertification and its control" November 5-7, 1996, in collaboration with Gramin Vikas Vigyan Samiti, Jodhpur (35 participants from Gujarat and Rajasthan)

One day training on Management of *Prosopis juliflora* on August 24th, 2000.

Five days training on Management of *Prosopis juliflora* 7-12, May 2001

Demonstration of watershed technologies on 27th March 2003 and 26th December 2003 (25 participants each)

Farmers training on improved cultivation of clusterbean in Kachchh region of arid Gujarat at village Kuda Jampar, Rapar on 02-06-09 (Attended by 75 farmers)

Awards / Recognition

Best Poster Presentation Award in 3rd National Symposium on *enhancing productivity, nutritional security and export potential through arid legumes*, was bestowed upon Drs. Samrath Lal Meena, Shamsudheen, M. and Devi Dayal for the poster presentation "Improving productivity and profitability of clusterbean (*Cyamopsis tetragonoloba* L. Taub) + sesame (*Sesamum indicum* L.) intercropping system with optimum row ratio & balanced fertilization under arid region of Gujarat" at Central Arid Zone Research Institute, Jodhpur, India during June 28-30, 2008.

A view of *Cenchrus ciliaris* field at RRS, Bhuj

Live stock population is more than human population in Kachchh

Inauguration of new office cum laboratory building

Establishment of forage legumes at RRS, Bhuj

Traditional house (locally called *Bhunga*) in Kachchh

Deepening ground water table has added to the drudgery of women in rural areas

A view of ber orchard at RRS, Kukma- Bhuj

Seed production plot under ICAR mega seed project