NABARD RESEARCH STUDY - 26

NABARD

Cactus Pear *(Opuntia ficus indica)* as a Source of Fodder in Dry Areas of Rajasthan and Gujarat

Implemented by:

BAIF Development Research Foundation

Central Research Station, Urulikanchan, Dist. Pune 412 202

Email: crsbaif@baif.org.in • www.baif.org.in

आर्थिक विश्लेषण एवं अनुसंधान विभाग

Department of Economic Analysis & Research

राष्ट्रीय कृषि और ग्रामीण विकास बैंक, मुंबई

National Bank for Agriculture and Rural Development, Mumbai

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DISCLAIMER

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Introduction of Cactus Pear *(Opuntia ficus indica)* **as a Source of Fodder in Dry Areas of Rajasthan and Gujarat,** 40 pages

Authors: Dr. Vitthal Kauthale, Mr. Sagar Kadao and Dr. Manoj Aware

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About NABARD Research Study Series

The NABARD Research Study Series has been started to enable wider dissemination of research conducted/sponsored by NABARD on the thrust areas of Agriculture and Rural Development among researchers and stakeholders. The study on *'Cactus Pear (Opuntia ficus indica) as a Source of Fodder in Dry Areas of Gujarat and Rajasthan*' completed by BAIF Development Research Foundation, Pune is the twenty-sixth in the series. The list of studies in the series is given at the end of this report.

Fodder shortage is common and often acute in arid and semi-arid areas. The spineless cactus (*Opuntia ficus indica,* also known as prickly pear or cactus pear*)* can potentially serve as forage while generating a host of ecological benefits. It is extremely water-use efficient and thus strongly suited to water-stressed conditions. The cladodes (modified leaf/pads) are highly succulent (comprising about 85% water) and can keep foragers well hydrated for long periods. Besides having industrial and medicinal uses, the cactus is also climate change-resilient.

A study was commissioned to BAIF between 2015-17 to conduct a research trial on spineless cactus as a source of fodder. The present study report is the phase two of the research wherein the technology was taken to the farmer's field after standardisation. 600 demonstrations (300 each in Kutch, Gujarat and Barmer, Rajasthan) were conducted at farmers' fields covering 29 villages to promote the cactus on large scale. The results have been encouraging and have been well documented in this report.

Hope this and other reports we are sharing would make a good reading and help generate debate on issues of policy relevance. Let us know your feedback.

Dr. KJS Satyasai
Chief General Manager
Department of Economic Analysis and Research

Contents

1) Executive summary:

The spineless Cactus (*Opuntia ficus indica*), is gaining increased interest amongst farmers because of its unique characteristics which provide resilience to the harsh conditions. Based on the research outcomes of first phase of the NABARD supported project (2015-2017), it was decided to take this technology to the farmer's field with NABARD support during 2019-2021. The general purpose of the project was to cater the fodder requirement of the farmers in arid and semi-arid regions especially during water stress conditions / lean period. The specific objectives were promotion of cactus as a source of green fodder for goat/sheep/cattle/buffalo, validation of the research results through field demonstration of cactus cultivation and cactus use for livestock feeding and new research initiative on feeding trial in milking cattle, assessment of soil fertility in cactus plantations and study the water use efficiency of cactus.

During this second phase, 600 demonstrations (300 each in Bhuj, Kutch, Gujarat and Barmer, Rajasthan) were established at farmer's field covering 29 villages to promote cactus cultivation. The required planting material (> 62000 cladodes) were supplied from the existing cactus nurseries at Urulikanchan for establishing the field demonstrations. Hands on training on cactus cultivation and utilization was provided to participating farmers. The periodical survival and growth observations were recorded during the plant growth. The overall plant survival (80 to 88 %) was considered satisfactory and plant growth performance indicated its better adaptation in both the regions. The fresh biomass yield recorded was in the range of 2.80 to 7.30 kg per plant and 0.100 to 3.23 kg per plant in Bhuj and Barmer respectively at 16 months of plant growth. Barmer being the typical desert having sandy soils and scarcity of water, the plant growth was comparatively slower than the Gujarat. Most of the farmers had started harvesting of cladodes after one and half year of plant growth and utilized it for feeding their goats, cattle and buffaloes. It was found that cactus is a potential source of green fodder especially during the lean period / summer season when other green fodder is not available for feeding. Few farmers have sold cladodes as a planting material to nearby farmers for planting in their field.

Under new research initiatives, a study on cactus feeding in lactating cows was undertaken and results showed total body weight gain of cows and increased milk production without any adverse effect. Cactus exhibited its acceptance and high palatability in cows. The field level cactus feeding trials in goats and buffaloes also indicated total body weight gain and daily weight gain in body weight. Cactus was one of the important source of green fodder and cactus feeding has partially fulfilled the water requirements of animals during harsh conditions at both locations. The research study on water use efficiency (WUE) of cactus indicated a higher WUE than other crops like rice and pearl millet. It has remarkable ability to withstand long period of dry spell due to inherent physiological adaptations, such as CAM photosynthetic pathway. The soil status over a period of two years reveled slightly increase in organic carbon content at both locations which may be due to application of organic inputs to cactus plants during the growth period. Similarly, there was overall increase in rhizospheric flora of bacteria, actinomycetes and yeast/fungi estimated by total viable count due to cultivation of cactus.

During this period the networking was developed with International Center for Agricultural Research in Dry Areas (ICARDA) and signed a MoU for cactus promotion in India. The linkages with ICARDA has impacted receiving of 15 new cactus accessions from Indian Grasslands and Fodder Research Institute (IGFRI), Jhansi which were planted in cactus arboretum at BAIF, Urulikanchan. Currently total of 101 accessions are maintained in the cactus arboretum at Urulikanchan. Research collaboration and a MoU executed with CSIR-Central Leather Research Institute, Chennai, to explore developing bio leather from cactus. Networking with ICAR-Indian Grassland and Fodder Research Institute (IGFRI) Jhansi, Central Arid Zone Research Institute (CAZRI), Jodhpur was developed. Efforts were also made to scale up this technology through existing projects implemented by BAIF, Govt. schemes and dairy cooperatives. Extension and promotional activities like video clips, popular articles, *e*-learning modules, radio talks and TV shows etc. were undertaken during the project period.

The selected project locations (Bhuj and Barmer) are drought prone and an arid regions and problem of water scarcity, damage to cactus plants by rats, rabbits and birds were observed as some of the limitations in cactus cultivation.

The policy level recommendations like cultivation of cactus in dry regions of selected states through Govt. schemes and dairy cooperatives, a model project on cultivation of cactus for the introduction of this new fodder crop. NABARD ROs (Rajasthan and Gujarat) were requested to incorporate this fodder crop in the state-level Unit Cost Committee in arid and semiarid climates, incorporate this new fodder in Potential Linked Plan (PLP) by the concerned DDMs. The effort needs to be taken for its large-scale adaptation in dry regions and develop decentralized nursery by the farmers to cater the demand of planting material.

Introduction of Cactus Pear (*Opuntia ficus indica*) as a Source of Fodder in Dry Areas of Rajasthan and Gujarat

Project implementing agency	: **BAIF Development Research Foundation,** BAIF Bhavan, Dr. Manibhai Desai Nagar, Warje, Pune 411058.
Name of the Principal Investigator	: **Dr. Vitthal Kauthale** Sr. Thematic Program Executive
No. and Date of NABARD's letter advising Sanction	: NB/DEAR/R&D-Projects/2743/P-321/ 2018-19 dated 31 January 2019
Total amount sanctioned	: **Rs. 35,68,332/-**
Project period	: **1st March 2019 to 30th June 2021**

Actual location where the project work carried out:

a) Cactus Field demonstrations

i) Raper block of Bhuj district in **Gujarat**: 5 villages.

ii) Barmer districts of **Rajasthan**: 24 villages

b) Research trials: BAIF, Central Research Station, Urulikanchan, Pune

2) Background of the study:

i) Cactus and its importance:

Almost 53.4 per cent of India's land area comprises arid and semi-arid regions. Occurrence of very extreme temperature (50^0 C in Summer to - 4^0 C in winter) very low and erratic precipitation, (between 25 to 450 mm), high wind speed (30-40 Km/ hour), High evapo-transpiration (1500-2000 mm/year) scarcity of water, low content of organic matter and presence of soluble salt in the soil leading to very low productivity of agriculture crops and poor availability of Natural resources of the area, which is badly affecting the livelihood of the people.

The increased anthropogenic pressure and livestock population has further depleted the Natural Resources. Land degradation accompanied by acute shortage of water, perpetual drought, which is near famine situation, lead to food insecurity and poverty that force the people to migrate to other areas for their survival. Cactus has a potential for growing in worst soil and environmental conditions to provide food, fodder and other economic benefits.

Livestock plays important role in the livelihood of the farmers in the dry areas of arid and semi-arid regions in India. There is always acute shortage of green fodder during the post monsoon season. The cultivation of traditional fodder crops has limitations due to the poor soil conditions and water scarcity. Being a xerophytic plant cactus has a great potential as a green fodder in these areas and needs to promote good spineless accessions of cactus on wider scale.

Cactus for Climate change:

Climate change is one of the biggest challenges the world must meet today and in the future. Prolonged droughts and desertification are among the issues faced by many countries, especially in Africa and Asia, where the rural poor and smallholders are most heavily affected. If people are to survive in these ever harsher conditions, their crops need to withstand drought, high temperatures and poor soils. Cactus are gaining increasing interest across the globe, in particular cactus pear (*Opuntia ficus indica*), because of its unique characteristics which provide resilience to the above mentioned harsh conditions. Cactus pear is able to grow on land where no other crops are able to grow. Cactus pear plantations can function not only as a water reserve but also absorb carbon dioxide in arid and semi-arid regions.

Rational for introduction of Cactus in Arid and semi-Arid regions of India

a) Has capacity to produce good biomass throughout year using minimum water

b) Multipurpose plant

c) Drought tolerant

d) Easy to establish

e) Potential for rangeland and pastureland management

f) Helps in soil and water conservation

g) Source of a variety of agri-foods available in more than 50 products: Marmalades, juices, nectars, candies, frozen pulp, alcoholic beverages, pickles, sauces, shampoos, soaps and lotions.

h) Medicinal uses such as Antacid, arterio sclerosis, anti cholesterolic, prostatis and hyperglycaemia.

i) It has now proven potential for diversification and improving livelihood for sustainability in drylands of India.

j) Ecosystem services in land reclamation, erosion control etc.

ii) Global Scenario:

Countries growing *Opuntia ficus indica* are Mexico, Malta, Spain, Sicily, Italy, Greece, Libya, Tunisia, Morocco, Algeria, Lebanon, Syria, Egypt, Saudi Arabia, Yemen, Israel, Chile, Brazil, Turkey, France, Bulgaria, Portugal, Albania, Cyprus, United States.

As part of the eight-country Mashreq/Maghreb Project, the International Center for Agricultural Research in the Dry Areas (ICARDA) has been investigating cactus cropping and its uses at pilot sites in Algeria, Libya and Morocco as well as Tunisia. The results have led to a major expansion in planting cactus to provide livestock feed, improve degraded rangelands, halt erosion and increase soil cover. Community surveys have shown that not only has cactus expansion been successful, but cactus fodder has improved livestock productivity and kept flocks alive throughout the year.

The report points out that the flat oval stem of the cactus shrubs known as cladodes or paddles remain green and succulent in all seasons throughout the year and contain about 90 percent of moisture. Though not sufficient, the scientists say that this amount of water can keep the animal surviving for a longer period of time. "Under normal circumstances, a well fed lactating cow consumes between 80 and 120 liters of water per day, depending on the size of the animal. The cactus feeding drastically reduces the water intake / requirement of the animals.

ICARDA has recently conducted extensive research and developed best agronomic practices to maximize the productivity of a multifunctional crop that millions of farmers in semi-arid and dry areas can cultivate. This plant can grow in harsh environments and on otherwise unproductive land where very few other crops will grow. This crop is the *Opuntia ficus-indica*, better known as the cactus pear, and is said to be the most important economic cactus species worldwide. Against the backdrop of ongoing climate change, prolonged droughts, land degradation and desertification, this hardy crop demonstrates significant social, environmental and socio-economic benefits. Coupled with its ability to reduce soil erosion and enhance the capacity of soil to store water, there is growing appreciation of the versatility of cactus pear as a source of livelihoods, as fodder for livestock and as a nutritional source of food for humans. (*ICARDA/ Policy brief / Cactus pear cultivation*)

Generally, cactus is drought tolerant and makes use of little moisture in rainy season to produce large quantities of forage. Scientists say that it has the highest water-holding capacity than any other known drought tolerant fodder in arid and semi-arid areas. Tolerant to high temperatures and able to survive with little and erratic rainfall, cacti can thrive in the most arid conditions where nothing else will grow: in central and southern Tunisia, cactus plantations provide large amounts of fodder for livestock and play a key role in natural resources conservation. The plants contain a high percentage of water - up to 90 per cent when fresh - and research has shown that, when fed to livestock, water requirements can be reduced by 40 to 100 per cent.

iii) Indian Scenario:

Though Cactus is being cultivated in many countries of the world for quite some time, its commercial cultivation in India is yet to start. It is still at the research stage with limited field trial initiated by ICAR-CAZRI in Kutch district of Gujarat and in some select areas with the support of ICARDA. The limited Research on Cactus was initiated by ICAR- CAZRI, Jodhpur, in seventies but the comprehensive work on Cactus was started by Nimbkar Agriculture Research Institute, Phaltan with the collection of good number of imported accessions. However, the work could not be pursued to its logical end. During the last two decades the research was conducted by many public sector research Institutes in India especially those are working in arid agricultural crops, but the outcome of this work is yet reach to the famers. Some of the recent works on Cactus that has been undertaken by various Research Institutions in India are indicated hereunder:

Central Arid Zone Research Institute (CAZRI) is the nodal agency for cactus research in India supported by International Center for Agricultural Research in the Dry Areas (ICARDA) network Programme. The cactus research work is in progress at Jodhpur as well

as its Regional station, Bhuj in Kutch, Gujarat. 70 cactus accessions of cactus have been received from ICARDA during the year 2012. They are undertaking trials on various aspect of Cactus like production, propagation and post-harvest management.

Cactus is ideal feed for livestock in arid and a semi-arid region where drought is common and animal feed is scarce. Animal feeding trials at Central Arid Zone Research Institute have shown good acceptability and palatability of chaffed thorn less cactus pear pads both by small ruminants and cattle. The intake of chaffed cactus cladodes per animal increased from 3.07$\pm$ 0.41kg in the first week to 5.0$\pm$1.87 kg in the fifth week with accompanied increase in water intake and body weight gain in the test animals. The total dry matter intake (DMI) in growing kids and lambs fed on 1:1chopped *Opuntia* pads and lentil straw was almost similar but kids had higher intake of fresh *Opuntia* pads while the lambs had higher intake of lentil straw. Another comparative feeding trial with Cactus (*Opuntia ficus-india*) mixed with pearl millet (*Pennisitum typhoides*) and with normal pelleted balanced cattle feed was conducted at CAZRI for stall fed Tharparkar Bull calves. Significant higher live weight gain was observed when feed with cactus. (Mathur *et.al*. 2009).

Indian Grassland and Fodder Research Institute (IGFRI), Jhansi is a network partner of ICARDA for cactus research. 15 cactus accessions received from ICARDA during 2013 are under testing. The accessions are originally from Mexico, Brazil and Italy. Trials on planting seasons and irrigation management, inclusion of cactus in various crop production systems are in progress at this institute.

Research on performance of various cactus accessions, planting methods, biomass production was made in Central Agro Forestry Research Institute (CAFRI), Central Soil Salinity Research Institute (CSSRI), Karnal and Central Institute for Arid Horticulture (CIAH), Bikaner. Farmers field adaptation trials are being conducted through ICARDA programme by CAZRI in Bundelkhand region by IGFRI and CAFRI. NDDB actively involved in spreading cactus among dairy farmers in Gujarat state.

iv) NABARD support for Cactus Research at BAIF:

Appreciating the importance of cactus, NABARD approved a small exploratory Research project to BAIF initially for 2 years (Phase 1 during 2015-2017), to undertake various agronomical trials primarily to assess the feasibility of introducing this crop by the farmers of India, by standardizing the production technology. Based on the Research outcome, it was decided to take this technology to the farmer's field so as to cater the fodder requirement in arid and semi-arid regions especially during water stress seasons.

Accordingly, NABARD approved one development project (Phase 2 during 2019-2021) for developing cactus on farmer's field in arid and semi-arid areas of Rajasthan and Gujarat. This in turn will also validate the technology at the field.

3) Objectives of the project:

i) Promotion of cactus as a source of green fodder for goat/sheep/cattle/buffalo
ii) Validation of the research results through field demonstration of cactus cultivation and feeding of cactus to goats/sheep/cattle/buffalo
iii) New research initiative on feeding trial in cattle, assessment of soil fertility in cactus plantations and Water use efficiency of Cactus.

Practical/Scientific utility: (Practical utility of the project including socio-economic implications of the results likely to be achieved through this project, necessity for further research indicating the gap in the knowledge on the subject.)

At present the income from the agriculture production, under rain fed condition, in the arid and semi-arid areas of Rajasthan and Gujarat is very low leading to subsistence livelihood. Efforts are being made to diversify the present farming system and introduce new crops suitable for this areas and also to increase the farm income.

The Cactus production technology developed at BAIF Urulikanchan needs to be validated in proposed areas of Barmer and Kutch to address the issues of shortage of green fodder as well as water for the livestock. The small adaptation trials at Nanodara (Gujarat) and Barmer (Rajasthan) has shown the adaptability and suitability of cactus in prevailing soil and climatic conditions. The performance of proposed demonstrations at farmer's field will be worthwhile in promotion of the cactus on wider scale which will provide green fodder for animals during scarcity period and thereby bringing the economic prosperity to the farmers.

During earlier project, feeding trials undertaken in small ruminants (goats) at Urulikanchan has shown good results however similar trials needs to be undertaken in large ruminants like cattle. Therefore, further feeding trials in cattle was proposed at CRS Urulikanchan. The changes in physico-chemical and microbial properties of soil over a period of time was monitored in cactus planation at farmer's field.

The water use efficiency i.e. the conversion efficiency of water to dry matter, has been reported to be greater for CAM plants like cactus than either C3 or C4 plants. Therefore, a study was proposed to determine biomass conversion efficiency of spineless cactus plants grown in pot culture.

4) Review of research conducted on the subject at the sponsoring institution:

BAIF has successfully implemented a research project on *'Standardization of nursery and production technology of Cactus (Opuntia ficus indica) for livelihood development in the Arid and semi-Arid regions'* during the period 2015 to 2017. The cactus germplasm collection, establishment of arboretum, development of propagation and production technology, goat feeding trial, nutritional evaluation of various cactus accessions, adaptation trials at Barmer (Rajasthan) and Nanodara (Gujarat) were the major activities under this project. Based on the experimentations for two years, the brief research outcomes in the form of research recommendations are presented hereunder:

a) **Cactus Arboretum:** Established a Cactus Arboretum at BAIF, Urulikanchan having over 90 accessions which were collected from across the country.

b) **Propagation:**
The cactus cladode of 6 months of age and above may be selected for nursery propagation. The survival and growth was influenced by cladode pieces and single cladode gave maximum survival, sprouting and growth. However, the 1/8th piece of cladode may be multiplied into a new plant under limited availability of the elite planting material. The survival was influenced by planting season and February month was the best season for planting with 100 per cent survival. For successful nursery propagation during rainy season, protection of plants from direct rain water by putting the UV polythene sheet on the top of the shade net is recommended.

c) **Cultivation:**
Cactus can be established and grown under very poor degraded type of soil. All the four accessions 1270, 1271, 1308 and 1280 have showed potential for fresh biomass production and any accession may be selected for planting as a fodder. The application of 60:30:30 kg NPK/ha during planting enhanced the fresh biomass yield however specific trend was not observed over a period of 12 to 21 months and needs further study in long term. The regular irrigation at 15 days' interval has boosted the biomass yield and maximum biomass may be obtained under irrigated condition.

d) **Adaptation:**
The cactus has well adapted at Nanodara in Gujarat and at Barmer in Rajasthan under arid and semi-arid conditions and satisfactory plant growth was observed. Therefore, cactus plantation may be promoted which could be substituted as green fodder for feeding livestock especially during scarcity period.

e) **Nutritional Status:**
The nutritional evaluation of cactus accessions indicated its richness in minerals and moderate level of protein content and the best accessions may be promoted for plantation as a source of green fodder in arid and semi-arid regions.

f) **Cactus feeding in Goats:**
Cactus feeding in Osmanabadi goats and kids enhances the performance in terms body weight gain without any adverse effect. Cactus exhibited its high palatability in goats and large quantities (3.75 kg) may be voluntarily consumed. Goats could be maintained by feeding cactus as a replacement of 25% dry matter with regular grazing without any adverse effect on their health

The technology developed at BAIF Urulikanchan needs to be validated in potential areas like Barmer and Bhuj (Kutch) to address the issues of shortage of green fodder as well as water for the livestock. The adaptation trials at both the locations has highlighted the adaptability and suitability of cactus in prevailing soil and climatic conditions and also shown potential of cactus as a source of fodder for animals.

5) Research Methodology:

BAIF is already implementing livelihood programs in Barmer and Bhuj districts of Rajasthan and Gujarat respectively for the last 20 years and therefore have close contact with the farming community. The farmers having livestock as well as land available for cactus demonstration were selected. Village level meetings were organized initially to identify the interested farmers to undertake cactus demonstrations. After selection of the farmers, training was organized on importance of cactus, package of practices, harvesting and feeding of cactus to the livestock. The planting material of selected best accessions were supplied to the participating farmers for planting. The planting was undertaken in two phases based on the availability of the planting material. The periodical technical support was provided by physical visits to the demonstrations sites and growth performance like survival, sprouting and other growth and yield parameters were recorded. After one and half year of plantation, the matured cladodes were harvested and fed to the livestock (small ruminants in Barmer and large ruminants in Bhuj) available with the farmers. Few farmers have provided cladodes as a planting material for establishment of cactus plantation in nearby areas.

6) Work accomplishment:

a) Maintenance of Cactus plantation at BAIF Urulikanchan:

Cactus arboretum with over 90 different accessions were established at BAIFs Urulikanchan campus during the year 2015-16. These accessions were collected from various ICAR institutes like CAZRI, CAFRI, CSSRI and private institutes. Simultaneously a mother orchard of selected good accessions was also established for production of planting material. All recommended package of practices were undertaken for maintenance of these plantations to produce good quality planting material required for establishment of cactus demonstrations in Gujarat and Rajasthan. The cactus cladodes (>62000) were supplied in the field for demonstration purpose as well as cladodes were also supplied for undertaking feeding trial in milking cows at Urulikanchan.

Additional new 15 cactus accessions were also procured from ICAR-IGFRI Jhansi during the project period and those are well established and growing in the arboretum.

b) Establishment of Cactus field demonstrations:

Total of 600 demonstrations (300 each in Bhuj, Gujarat and Barmer in Rajasthan) were undertaken covering 29 villages. 100 cactus cladodes / pads of assorted accessions were provided for each demonstration plot of 200 m^2 area and were planted at a spacing of 2 m x 1 m in block plantation and at 1 m plant to plant distance for field bund plantation.

Description of the project locations:

Barmer, Rajasthan:

Barmer district is situated between 24^0 40' 00" & 26^0 32' 00" North latitudes and 70^0 05' 00" & 72^0 52' 00" East longitudes covering geographical area of 28,387 Sq. Km. It is the second largest district in the State covering about 8.29% of its total area. The district as a whole forms part of the Great Indian Thar Desert. It is situated in the south western corner of the Rajasthan. The area falls under arid western Plan Zone 1-a. Rajasthan state has cultivated area of 27 m ha which is 53% of the geographical area.

The district experiences arid type of climate. Mean annual rainfall of the district is 281.8 mm whereas normal rainfall is lower than average rainfall and placed at 277.5 mm. Almost 90% of the total annual rainfall is received during the southwest monsoon, which enters the district in the first week of July and withdraws in the mid of September, occurrence of drought is common feature. As the district lies in the desert area, it faces extremes of heat in summer and cold in winter. Both day and night temperatures increase gradually and reach their maximum values in May and June. The temperature varies from 48^0C in summer to 2^0C in winter. Atmosphere is generally dry except during the monsoon period.

Sand dunes and desert soils occupy major area in the zone. There are aeoline soils and loamy fine to coarse and calcareous at places. Undulated soil are affected by soil erosion soils are poor in fertility condition, low water holding capacity and organic matter.

Cactus arboretum at BAIF, Urulikanchan

Cactus Nursery at BAIF, Urulikanchar

New cactus accessions received from ICARDA growing at Urulikanchan

Preparation of cactus planting material for supply to Gujarat and Rajasthan

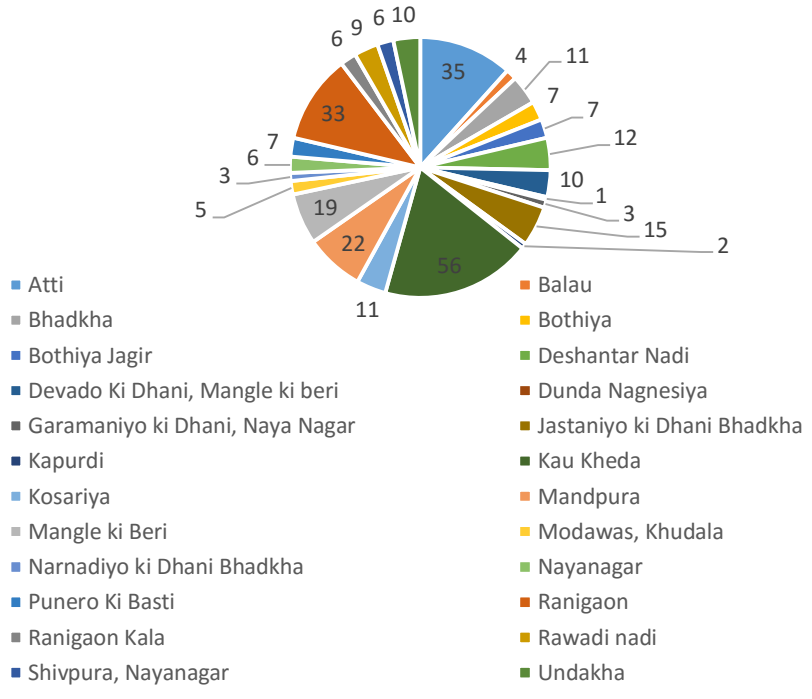
Dispatch of planting material for establishment of demonstrations at farmer's field

Salinity problem is also found in some area. Pearl millet is the predominant crop of the area followed by cluster bean and moth bean. Sesame and green gram are other important kharif oilseed and pulse crops, respectively. Only 7 per cent cropped area is under irrigation. Cumin rapeseed & mustard wheat and Isabgol are major crops grown in *rabi* season.

Total population (as per 2011 census) of the district is 2,603,751 out of which 2,421,914 is rural population and 181,837 is urban population. The major social groups in the area are SC, ST, OBC and general category. There are Meghwl, Jat, Rajput, Bhils and Muslims communities in the Barmer. Mixed communities are residing here. The living standard of the people in the desert is generally low. Agriculture, livestock and related work is the main occupation of people along with seasonal job facilities as a labor work in private companies. Most of the cows found in the area are of mixed type i.e. *deshi* and crosses of Tharparkar. Tharparkar is the main breed type present in the district, it is a dual-purpose breed. Goat breed is of MARWARI and a dense population of small ruminants is found. People seem to prefer sheep over the goat. In the absence of any other alternatives for livelihood generation, desert communities adopt migration as a coping strategy. Mostly men migrate and women are left in villages face a difficult life due to scarcity of water, fuel, and fodder. Women in this part are also engaged in handcraft, which is mostly household activity.

Introduction of Cactus as fodder would greatly help the farmers to cater the fodder problem especially in the summer period. There were 24 hamlets / villages identified to undertake the cactus cultivation. The village wise distribution of cactus field demonstrations in Barmer is presented below.

Fig.1: Village wise distribution of Cactus demonstrations in Barmer



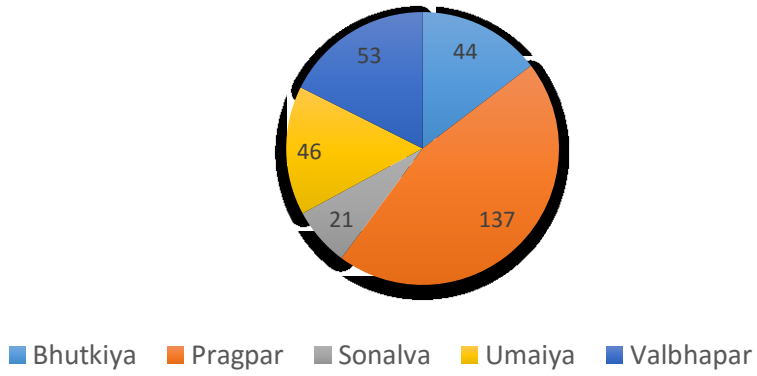
Bhuj (Kutch), Gujarat:

Kutch district, located on the westernmost tip of India is the largest district of Gujarat, the total area of the district is 45,652 Sq. Km that is more than 23% of the total area of the state and lies in the extreme western part of the state. Kutch district is situated between north latitudes 22°44'11" & 24°41'25" and east longitudes 68°09'46" & 71°54'47". The project area Rapar is located at 23.57°N 70.63°E. It has an average elevation of 79 meters (259 feet).

Temperatures in the area vary considerably from season to season. The summers are generally hot and winters are cool. The temperature varies from 45^0C in summer to 7^0C in winter. The relative humidity in the area varies between 43.5% during March and 77% during August. The average annual rainfall is 378.2 mm. Most of the rainfall (about 345 mm) is received during south-west monsoon between June and September. In the area soil are formed due to alluvial deposits due to the river system flowing through the area have subsequently been overlain by the aeolian deposits. These soils are fairly deep, light grey in colour. The texture is sandy to sandy loam with silty clay loam in some areas. The salt content is very high with the sodium chloride as the dominant salt. The major field crops grown in the area are Bajra, Green gram, Castor, Groundnut, Cotton, Wheat and Moth bean, except wheat all other crops are grown in kharif and are rain fed.

With a view to introduce the cactus cultivation for fodder purpose, five villages were identified to undertake the cultivation. The village wise distribution of cactus field demonstrations in Bhuj is presented below.

Fig. 2: Villagewise distribution of Cactus demonstrations in Bhuj



The total population of the district as per 2011 census is 20,90,313, which include 10,96, 343 males and 9,93,970 females. The main castes are Patel, Darbar, Bharwad, Koli, and Harijans. Agriculture and animal husbandry are the main occupations of the people. Women in villages work hard and play an important role in management of livestock and agriculture work on the farm. Salty water in area is main constraint for realizing the full potential of agriculture. Most poor farmers are still practicing traditional cultivation practices. The poor quality natural resource base coupled with low inputs, lack of awareness of good agricultural practices and

poor management led to low production and yields. Normally, only one crop is taken during the rainy season and the yields are poor and the activity can barely contribute to subsistence.

One hundred cactus cladodes were supplied to each farmer to undertake planting on 200 m^2 area at a spacing of 2 m x 1 m in block plantation as well as in rows on field bunds. Considering the availability of the quality planting material, the field demonstrations were established in two phases i.e. August 2019 and February 2020. The details of the demonstrations established are mentioned in table below

Table 1: Establishment of Cactus field demonstrations

#	Locations	No. of demonstrations			No. of villages covered
		Phase I (August 2019)	Phase II (February 2020)	Total	
1	Bhuj (Gujarat)	151	149	300	5
2	Barmer (Rajasthan)	164	136	300	24
	Total	**315**	**285**	**600**	**29**

c) Monitoring growth and yield performance of cactus:

Cactus growth and yield performance was periodically monitored. Data was collected on survival, growth (plant height, no. of cladodes, cladode length and width) and biomass yield. A representative 100 demonstrations (50 each at Bhuj and Barmer) were randomly selected among the 600 field demonstrations. The overall plant survival of 88 % and 80 % were observed at Gujarat and Rajasthan respectively. The growth performance of cactus demonstrations at both locations are depicted in table 2 and 3. It was observed that the plant height, number of cladodes and cladode size was gradually increased over a period of time. The average plant height of 52.39 cm, 12.32 cladodes per plant, 23.64 cm cladode length and 10.94 cm cladode width was observed at 16 months of age from planting at Bhuj in Gujarat.

Table 2: Periodical Growth Performance of Cactus at Bhuj (Gujarat)

#	Months after plantation	Plant height (cm)	No. of cladodes/plant	Cladode length (cm)	Cladode width (cm)
1	5	35.60 *(±0.27)*	2.38 *(±0.04)*	20.24 *(±0.22)*	9.63 *(±0.11)*
2	10	43.54 *(±0.30)*	7.10 *(±0.11)*	25.05 *(±0.18)*	12.75 *(±0.11)*
3	13	47.94 *(±0.31)*	10.19 *(±0.10)*	28.64 *(±0.18)*	14.02 *(±0.11)*
4	16	52.39 *(±0.30)*	12.32 *(±0.11)*	23.64 *(±0.19)*	10.94 *(±0.11)*

**Figures in parenthesis indicates standard error*

At Barmer in Rajasthan, average plant height of 52.79 cm, 6.67 cladodes per plant, 19.40 cm cladode length and 9.34 cm cladode width was observed at 16 months of age from planting. Rajasthan being the typical desert having sandy soils and scarcity of water, the plant growth was comparatively slower than the Gujarat.

Table 3: Periodical Growth Performance of Cactus at Barmer (Rajasthan)

#	Months after plantation	Plant height (cm)	No. of cladodes/plant	Cladode length (cm)	Cladode width (cm)
1	5	30.44 *(±0.39)*	1.95 *(±0.07)*	14.87 *(±0.24)*	8.55 *(±0.14)*
2	10	46.49 *(±0.74)*	4.62 *(±0.18)*	17.25 *(±0.26)*	11.02 *(±0.20)*
3	13	48.50 *(±0.74)*	5.04 *(±0.18)*	19.85 *(±0.25)*	10.05 *(±0.12)*
4	16	52.79 *(±0.82)*	6.67 *(±0.27)*	19.40 *(±0.25)*	9.34 *(±0.13)*

**Figures in parenthesis indicates standard error*

Cactus biomass yield performance data was recorded after completion of 16 months of establishment of cactus plantations at both locations. Among the 600 demonstrations, 50 demonstrations each at Bhuj and Barmer were randomly selected for undertaking yield performance data (Table 4).

It was observed that number of cladodes and fresh biomass yield was in the range of 1.00 to 30.00 and 0.10 to 3.23 kg per plant with an average of 5.33 cladodes per plant and 0.51 kg biomass yield per plant at Barmer, Rajasthan. Higher biomass yield was observed at Gujarat and it was in the range of 2.80 to 7.30 kg per plant with an average of 4.47 kg per plant. The number of cladodes were in the range of 7 to 21 and average was 12.32 cladodes per plant during harvest at 16 months of plant growth.

Table 4: Biomass yield of Cactus at 16 months after Planting at Gujarat and Rajasthan

Locations	No. of cladodes/plant			Biomass yield (kg/plant)		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Barmer (Rajasthan)	5.33	1.00	30.00	0.51	0.10	3.23
SE±(m)	*0.16*	-	-	*0.02*	-	-
Bhuj (Gujarat)	12.32	7.00	21.00	4.47	2.80	7.30
SE±(m)	*0.11*	-	-	*0.04*	-	-

Cactus demonstrations established in Barmer, Rajasthan








Cactus demonstrations established in Raper, Bhuj, Gujarat








d) Cactus feeding trials:

i) Cactus feeding trial in milking cows at BAIF, Urulikanchan

Introduction:

Despite of fact that Cactus plants are high in carbohydrates and vitamin A, protein content is only about five to six per cent (on dry matter basis) and phosphorous and sodium levels are also low, it can be fed to Cattle and small ruminants like Goat and Sheep by mixing it in Total Mixed Ration. A livestock species like goat is already grazing the cactus in certain part of India particularly in dry land systems. Feeding trials with lactating cows have not been reported from India as this crop as a fodder is under study and enough quantities for feeding those cows are not available. The spineless cactus (*Opuntia ficus indica*) *is* an important substitute to farmers due to its considerable survival, propagation capacity and production potential under conditions of little rain and high temperatures. Based on the encouraging results of the earlier feeding trials conducted on Goats, the feeding trials in lactating Cows was proposed under this project.

Objectives: This feeding experiment was planned in lactating cows with following objectives

- To evaluate the performance of the Cactus as a Fodder for Cows through feeding trials.
- To assess the productive performance of Cows fed on Cactus.

Methodology:

An experiment on feeding these spineless Cactus accessions to lactating cows was carried out at the Central Cattle Breeding Farm of BAIF's Central Research Station, Uruli Kanchan, Pune for a period of 90 days (22 January to 23 April 2021). Fourteen Holstein Frisian and crossbred Cows with an average lactation number second to third lactation, post calving three months' lactation phase having average body weight of 529 kg were selected and randomly divided into two equal groups i.e. control group and experimental group including seven Cows in each group. Average milk production and milk fat content was 11 kg and 4 percent respectively for the animals from both the groups. The cows were fed with standard feeding regime as per ICAR Standards and cows in experimental group were supplemented with cactus feeding at the rate 8 kg per day per cow (25% replacement of Cereal Fodder and 10% DM replacement) with other fodder and roughages like maize green fodder, sorghum straw, lucerne, concentrate mixture and mineral mixture for 90 days. All the cows were provided liberal fresh, cool drinking water *ad-libitum*, throughout experimental period.

Observations:

Following observations were recorded and compared between control group and experimental group by recording following parameters:

- Daily Milk Production
- Weekly Milk Fat
- Fortnightly body weight
- Feed Residue

- Daily Dry matter intake
- Total water consumption

Cactus feeding trial in milking cows at BAIF, Urulikanchan

Results:

The average feed intake (kg/day/cow) throughout experimental period in experimental and control groups were 44.87 and 39.50. The average daily dry matter, crude protein and TDN intake (kg/day/cow) throughout experimental period in experimental group were 15.24, 1.88 and 9.73 as compared to control group 14.62, 1.85 and 9.40. Higher feed and dry matter intake in experimental group resulted in higher nutrient intake as compared to control group (Table 5).

Table 5: Performance of milking cows to cactus feeding

Parameters	Experimental Group	Control Group
Daily Milk Yield (kg)	9.60 ± 0.62	6.92 ± 1.45
Milk Fat (%)	4.16 ± 0.11	4.64 ± 0.29
Milk Protein (%)	4.20 ± 0.10	3.89 ± 0.17
Solid Not Fat (SNF) (%)	8.63 ± 0.09	8.53 ± 0.11
Total body weight gain (kg)	59.43 ± 8.16	54.71 ± 15.14
Average daily gain in body weight (g/day)	660 ± 90.68	608 ± 168.29

The results of the experiment indicated that cows in experimental group fed with cactus gained higher total body weight of 59.43 ± 8.16 kg and average daily gain in body weight of 660 ± 90.68 g/day over the control group where the values were 54.71 ± 15.14 kg and 608 ± 168.29 g/day.

The findings of the experiment also shown significant improvement in milk production of experimental animals where average daily milk yield throughout the experimental period was 9.60 ± 0.62 kg for the experimental group cows as compared to 6.92 ± 1.45 kg for the control group cows. Milk fat content was not changed significantly for the experimental group cows as milk yield and fat content inversely proportional with each other. Milk quality in terms of protein and SNF was also improved in experimental animals where the values for milk protein (%) and SNF (%) were 4.20 ± 0.10, 8.63 ± 0.09 and 3.89 ± 0.17, 8.53 ± 0.11 respectively for experimental and control group.

Conclusion:

This study revealed that cactus feeding in lactating cows enhances the performance of cows in terms of total body weight gain and average daily gain in body weight, milk production without any adverse effect. Cactus exhibits its acceptance and high palatability in cows and large quantities may be voluntarily consumed.

ii) Cactus feeding to livestock at farmer's field: The main objective of establishing the cactus demonstrations on farmer's field was to make available alternative source of green fodder to livestock during the scarcity period. After completion of one year of establishment, harvesting of cladodes was started and farmers were demonstrated how to harvest and utilize the fresh biomass for feeding to their livestock. Some of the beneficiary farmers were selected at both the locations to undertake cactus feeding trials in goats at Barmer to observe the growth performance in terms of total body weight gain and daily weight gain in body weight. This feeding trial was also conducted on lactating buffaloes in Bhuj area.

a) **Feeding cactus in Goats in Barmer, Rajasthan:** Goats are the major small ruminant livestock reared by the farmers in Barmer district of Rajasthan having the major livelihood source. Total eight adult goats with same age and body weight were selected for cactus feeding trial from the farmer's field those who are having cactus field demonstration plots and were divided in two groups viz. experimental and control group containing four goats in each group. The trial was conducted for the period of forty days during the period 1st April to 10th May 2021. All the goats covered under experiment were fed with available feed resources like dry fodder of Ber leaves with regular open grazing in the field. The goats in experimental group were fed with cactus with a dose 1.65 kg per goat per day as a supplement besides regular feeding and grazing. Following observations were recorded and compiled to compare the results between control and experimental group:
   - Initial body weight.
   - Final body weight after completion of trial period of 40 days.
   - Quantity of cactus consumed by experimental goats.
   - Quantity of fodder consumed by all goats.

- Grazing time (hours) per day.
- Visual observation on water intake.

Cactus feeding in goats on farmer's field at Barmer

Results: The results of the experiment indicated that goats in experimental group fed with cactus gained higher total body weight of 3 kg and average daily gain in body weight of 75 g/day over the control group where the values were 1.25 kg and 31.25 g/day. It was also found that the water intake by goat fed cactus was reduced by 33 %.

b) Feeding cactus in Buffaloes in Bhuj, Gujarat:

Buffaloes are the major livestock reared for milk production by the farmers in Bhuj district of Gujarat state which contribute major source of livelihood for the farmers. Buffaloes with same average age and body weight were selected for cactus feeding trial from the farmers having cactus field demonstration plots. Total twelve lactating buffaloes were selected and randomly divided into two groups i.e. control and experimental containing six buffaloes in each group. The trial was conducted for 61 days during the period from 1st March to 30th April 2021. All the buffaloes were fed with available feed and fodder resources in the field conditions including Sorghum straw, Lucerne and Cotton seed cake. The buffaloes in the experimental group were fed with cactus at the dose rate of 8 kg per buffalo per day as a supplement along with other feed and fodder resources. Following observations were recorded and compiled to compare the results between control and experimental group:

- Initial body weight.
- Body weight after completion of trial.
- Quantity of cactus consumed by experimental buffaloes.
- Quantity of fodder consumed by all buffaloes.
- Visual observation on water intake in both groups

Cactus feeding to buffalo at farmer's field in Raper, Bhuj

Results: The results of the experiment indicated that buffaloes in experimental group fed with cactus gained higher total body weight of 5.83 kg and average daily gain in body weight of 95.57 g/day over the control group where the values were 3.00 kg and 49.18 g/day. It was also found that the water intake by buffaloes fed Cactus was reduced by 35 %. The milk yield was not influenced in both control and experimental groups.

Conclusion:

This study revealed that cactus feeding in goats and buffaloes enhanced the performance of the concern experimental animals in terms of higher body weight gain and total weight gain in body weight. It was also observed that cactus was one of the important sources of green fodder during the harsh summer season and shown positive effect on overall health of the animals at both locations. Cactus feeding has also partially fulfilled the water requirements of animals during harsh conditions. Cactus exhibits its acceptance and high palatability in experimental animals covering goats and buffaloes.

e) Monitoring the soil health:

Soil samples were collected from the demonstration sites at both locations before cactus plantation and after two years of cactus plantation to see the changes in nutrient content and microbial population. Total of 80 samples (40 from each location at initial and after two years) were randomly drawn and analyzed in soil testing and Microbiology laboratory at BAIF, Urulikanchan.

Soil status at Barmer, Rajasthan: 20 soil samples were randomly drawn from the cactus demonstrations plots before planting the cactus during 2019 and again 20 samples were drawn from the cactus root zone of the same plots at the end of the project (2021) to understand changes in soil nutrient status. It was observed that the electrical conductivity of soil in the year 2019 was found to be 0.23 ds/m while in 2021 it was observed to be 0.25 ds/m. No significant change in case of electrical conductivity was seen. The pH of soil decreased from 7.84 to 7.62 after introduction of Cactus in the field. The pH gets lowered which ultimately help to increase nutrient availability (Table 6).

Among the major nutrient content in these soils available nitrogen content found to be very low, i.e. 147 kg/ha and 154 kg/ha during the year 2019 and 2021 respectively. These changes would be favorable for plant growth. The available phosphorous content of soil was 29 kg/ha and 31 kg/ha during the year 2019 and 2021 respectively. There was slight improvement in status of available phosphorous. Where the values for available potassium in the year 2019 and 2021 were 197 kg/ha and 201 kg/ha respectively.

The organic carbon content of soil increased slightly from 0.31% to 0.38%. Use of organic inputs can be the reason of increased levels of organic carbon. Improvement in status of organic carbon content is expected to cause soil fertility improvement.

The micro nutrients like Copper, Iron, and Manganese content increased from 1.43 ppm to 1.48 ppm, 1.99 ppm to 2.09 ppm and 4.31 ppm to 4.46 ppm respectively in the year 2019 and 2021.

Soil status at Bhuj, Gujarat: 20 soil samples were randomly drawn from the cactus demonstrations plots before planting the cactus during 2019 and again 20 samples were drawn from the cactus root zone of the same plots at the end of the project (2021) to understand changes in soil nutrient status. It was observed that the electrical conductivity of soil increased from 0.56 ds/m to 0.64 ds/m during 2019 to 2021. Similarly, the pH of the soil increased from 8.30 in the year 2019 to 8.42 in the year 2021. The slight increase in the pH and electrical conductivity of the soil may be due to use of salty water for cactus irrigation. The soil at this location found to be slightly alkaline (Table 7).

The available soil nitrogen content in these soils found to be very low i.e. 157 kg/ha and 169 kg/ha, during the year 2019 and 2021 respectively. The available phosphorous content of soil was 32 kg/ha in the year 2019 and 36 kg/ha in the year 2021. The data showed slightly improvement in status of available phosphorous. As seen from the table the values for available potassium in the year 2019 and 2021 were 214 and 221 kg/ha respectively. The data indicated slightly improvement in status of available Nitrogen, Phosphorous and Potassium in the soil due to application of organic matter for cactus cultivation.

The organic carbon of soil in the year 2019 was found to be 0.35% while in 2021 it was observed to be 0.40%. There is slight increase in organic carbon content, however, overall status of organic carbon content in soil was found to be low.

The micro nutrients like Copper, Iron, and Manganese content increased from 1.47 ppm to 1.58 ppm, 1.91 ppm to 1.96 ppm and 6.45 ppm to 6.55 ppm respectively in the year 2019 and 2021.

Table 6: Initial and after soil status of macro and micro nutrients at Barmer

#	Name of Farmer		Village	E.C.		pH		N (kg/ha)		P (kg/ha)		K (kg/ha)		O.C. (%)		Cu (ppm)		Fe (ppm)		Zn (ppm)		Mn (ppm)	
				2019	2021	2019	2021	2019	2021	2019	2021	2019	2021	2019	2021	2019	2021	2019	2021	2019	2021	2019	2021
1	Rana Ram	Kala Ram	Kau Kheda	0.34	0.31	8.03	7.55	152	163	32	37	185	187	0.36	0.42	1.80	1.84	1.28	1.32	1.28	1.32	4.44	4.58
2	Ratana Ram	Kala Ram	Kau Kheda	0.24	0.22	7.88	7.68	138	134	26	27	180	198	0.30	0.33	1.68	1.72	1.32	1.78	1.26	1.57	4.38	4.85
3	Gosai Ram	Punama Ram	Kau Kheda	0.24	0.21	7.91	7.49	120	132	28	30	185	208	0.25	0.37	1.36	1.85	2.31	2.01	1.62	1.32	2.91	2.94
4	Punama Ram	Kala Ram	Kau Kheda	0.23	0.21	7.76	7.57	168	153	27	28	220	240	0.42	0.38	1.42	1.93	1.53	1.73	1.03	1.78	5.67	5.65
5	Jodha Ram	Bhopa Ram	Kau Kheda	0.21	0.23	7.92	7.60	122	132	29	32	185	193	0.20	0.37	1.42	1.58	1.51	1.66	1.13	0.92	5.36	5.34
6	Amba Ram	Kalla Ram	Kau Kheda	0.25	0.22	7.84	7.69	142	150	22	28	235	197	0.38	0.40	1.41	1.37	1.53	1.62	1.62	1.22	3.94	3.49
7	Jagrupa Ram	Kala Ram	Kau Kheda	0.23	0.25	8.01	7.68	172	180	27	22	180	178	0.28	0.33	1.08	1.13	2.26	2.3	1.14	1.44	4.09	4.18
8	Hanuman Ram	Chetan Ram	Kau Kheda	0.21	0.47	7.78	7.62	124	134	29	29	175	178	0.26	0.30	1.13	1.31	1.66	1.6	1.04	1.37	5.07	5.01
9	Bhikha Ram	Deda Ram	Kau Kheda	0.27	0.41	7.73	7.56	172	187	26	28	180	178	0.34	0.36	1.13	1.15	1.62	1.95	1.39	1.34	3.29	4.09
10	Pura Ram	Jalu Ram	Kau Kheda	0.21	0.41	7.82	7.60	120	134	32	34	185	182	0.32	0.42	1.19	1.06	1.05	1.95	1.18	1.13	3.25	4.56
11	Narana Ram	Dala Ram	Kau Kheda	0.22	0.2	7.76	7.58	176	172	29	26	190	208	0.22	0.28	1.94	1.95	2.29	2.45	1.35	1.15	3.47	3.65
12	Chuni Devi	Sona Ram	Kau Kheda	0.21	0.22	7.93	7.44	186	184	36	38	175	188	0.40	0.34	1.41	1.5	2.36	2.4	1.14	0.88	5.67	5.53
13	Raju Ram	Padama Ram	Kau Kheda	0.20	0.22	7.74	7.60	160	174	33	35	260	278	0.35	0.30	1.96	1.62	1.38	1.48	1.15	1.29	4.12	4.27
14	Ganga	Gopa Ram	Mandpura	0.21	0.21	7.80	7.62	124	133	28	31	195	190	0.30	0.45	1.29	1.15	3.22	2.74	1.48	1.12	5.16	5.29
15	Nathu Ram	Rama Ram	Mandpura	0.24	0.21	7.73	7.69	144	155	32	31	185	192	0.36	0.39	1.28	1.22	2.58	2.66	1.25	1.13	5.22	5.11
16	Sita Devi	Sawai Ram	Balau	0.22	0.22	7.83	7.66	156	173	34	36	230	240	0.28	0.45	1.41	1.56	1.83	1.97	1.69	1.76	3.35	3.87
17	Ghamanda Ram	Sidha Ram	Atti	0.34	0.22	7.97	7.63	120	138	26	29	180	183	0.18	0.48	1.44	1.33	1.51	1.64	1.72	1.28	4.47	5.24
18	Sankara Ram	Kusta Ram	Atti	0.22	0.21	7.89	8.02	162	182	23	27	240	227	0.38	0.43	1.31	1.41	2.07	1.98	0.98	0.92	4.62	4.16
19	Tulsi Devi	Lumba Ram	Ranigaon Kala	0.21	0.22	7.71	7.56	145	140	25	28	180	187	0.26	0.42	1.91	1.76	2.97	2.99	1.94	1.97	2.83	3.14
20	Sushiya Devi	Rauram	Ranigaon	0.17	0.21	7.76	7.49	127	139	33	38	190	184	0.26	0.32	1.09	1.18	3.51	3.62	1.87	1.28	4.91	4.33
			Mean	**0.23**	**0.25**	**7.84**	**7.62**	**147**	**154**	**29**	**31**	**197**	**201**	**0.31**	**0.38**	**1.43**	**1.48**	**1.99**	**2.09**	**1.36**	**1.31**	**4.31**	**4.46**
			SE±(m)	0.01	0.02	0.02	0.03	4.85	4.56	0.84	0.98	5.64	5.88	0.01	0.01	0.06	0.06	0.15	0.13	0.06	0.06	0.20	0.20

Table 7: Initial and after soil status of macro and micro nutrients at Bhuj

#	Name of Farmers	Village	E.C.		pH		N (kg/ha)		P (kg/ha)		K (kg/ha)		O.C. (%)		Cu (ppm)		Fe (ppm)		Zn (ppm)		Mn (ppm)	
			2019	2021	2019	2021	2019	2021	2019	2021	2019	2021	2019	2021	2019	2021	2019	2021	2019	2021	2019	2021
1	Vaid Vastabhai Mulabhai	Pragpar	0.64	0.68	8.70	8.60	131	146	44	42	211	210	0.32	0.38	1.99	2.20	1.20	1.46	1.37	1.24	6.68	6.64
2	Ravariya Laljibhai Kanabhai	Pragpar	0.55	0.53	8.45	8.52	166	184	29	30	215	222	0.30	0.31	1.87	1.57	1.24	1.32	1.35	1.06	6.62	6.11
3	Goswami Rameshgar Harigar	Pragpar	0.61	0.58	8.07	8.14	182	197	50	48	231	240	0.40	0.48	1.55	1.85	2.23	2.32	1.01	1.04	5.15	5.18
4	Chamriya Devrajbhai Bechrabhai	Pragpar	0.79	0.83	8.38	8.40	128	145	34	38	214	202	0.28	0.27	1.61	1.64	1.45	1.46	1.02	1.01	7.91	7.77
5	Chamriya Devjibhai Bechrabhai	Pragpar	0.57	0.55	8.69	8.70	168	162	23	28	206	212	0.36	0.46	1.61	1.98	1.43	1.56	1.22	0.88	7.60	7.05
6	Charaniya Bhavanbhai Lakhabhai	Sonalava	0.47	0.62	8.51	8.60	144	160	38	40	217	227	0.34	0.42	1.60	1.69	1.45	1.6	1.01	0.98	6.18	6.66
7	Bhatesra Harkhabhai Devrajbhai	Sonalava	0.73	0.80	8.07	8.48	125	127	25	33	236	215	0.26	0.36	1.27	1.24	2.18	1.65	0.93	0.78	6.33	6.97
8	Arthiya Virjibhai Muljibhai	Umaiya	0.67	0.74	7.94	8.10	125	124	38	36	234	242	0.36	0.38	1.32	1.38	1.52	1.66	1.13	1.26	7.31	7.69
9	Koli Dharamshi Popatbhai	Umaiya	0.55	0.68	8.20	8.46	201	218	33	34	233	240	0.40	0.47	1.32	1.18	1.54	1.72	0.99	0.82	5.53	6.15
10	Koli Anandabhai Bhojbhai	Pragpar	0.44	0.60	8.29	8.20	128	145	31	35	231	218	0.39	0.46	1.38	1.42	0.97	1.15	0.98	0.92	5.49	5.17
11	Koli Anilbhai Punjabhai	Pragpar	0.77	0.78	8.04	8.30	137	152	33	39	240	282	0.28	0.32	1.13	1.35	2.21	2.13	0.94	1.05	5.71	5.58
12	Makvana Manshangbhai Babubhai	Bhutkiya	0.61	0.70	8.26	8.44	230	238	34	39	230	252	0.42	0.42	1.59	2.02	2.28	2.15	1.23	1.49	7.91	8.05
13	Makvana Sanjaybhai Babubhai	Bhutkiya	0.52	0.64	8.28	8.62	150	163	28	30	214	220	0.41	0.39	1.15	1.23	1.30	1.44	0.94	1.15	6.36	6.68
14	Ravariya Ratnabhai Kanabhai	Pragpar	0.46	0.62	8.35	8.38	198	213	25	32	222	230	0.40	0.44	1.48	1.72	3.14	2.88	0.97	1.01	7.40	6.44
15	Ravariya Naranbhai Kanabhai	Pragpar	0.56	0.50	8.10	8.30	135	150	30	36	211	202	0.32	0.30	1.47	1.83	2.50	2.42	0.94	0.94	7.46	7.62
16	Ravariya Rameshbhai Karmalbhai	Pragpar	0.54	0.60	8.27	8.33	166	175	28	33	210	229	0.39	0.48	1.60	1.31	1.75	2.07	0.99	0.8	5.59	6.24
17	Bhatesra Dhanjibhai Devrajbhai	Pragpar	0.47	0.72	8.21	8.60	131	148	31	35	209	216	0.28	0.26	1.63	1.66	1.43	1.7	1.01	0.88	6.71	6.89
18	Ravariya Bhavanbhai Mahadevabhai	Pragpar	0.41	0.52	8.35	8.30	156	167	32	38	206	218	0.40	0.44	1.50	1.88	1.99	2.13	1.10	1.02	6.86	6.92
19	Shadha Vasram	Pragpar	0.42	0.56	8.39	8.40	129	153	24	33	167	180	0.26	0.38	1.10	1.17	2.89	3.12	1.03	1.19	5.07	5.85
20	Ravariya Karmalbhai Bhachubhai	Pragpar	0.44	0.58	8.45	8.50	216	214	31	37	140	156	0.42	0.48	1.28	1.30	3.43	3.29	0.96	1.05	5.05	5.27
		Mean	**0.56**	**0.64**	**8.30**	**8.42**	**157**	**169**	**32**	**36**	**214**	**221**	**0.35**	**0.40**	**1.47**	**1.58**	**1.91**	**1.96**	**1.06**	**1.03**	**6.45**	**6.55**
		SE±(m)	0.02	2.02	0.04	0.04	7.31	7.10	1.49	1.03	5.31	5.83	0.01	0.02	0.05	0.07	0.15	0.13	0.03	0.04	0.21	0.29

Changes in bacterial abundance from rhizospheric soils of spineless cactus:

After cactus plantation, a micro-climate has developed at the root zone of the cactus plants due to accumulation of organic matter and moisture over a period of two years which could

attract the soil microbes like bacterial, fungus, yeast and actinomycetes. Therefore, the soil samples were collected to understand changes in microbial population at initial and at two years of cactus plantation. The soil samples for microbial population was analyzed in the Microbiology laboratory at BAIF, Urulikanchan.

The rhizospheric soil was sampled at initial (2019) and after two years (2021) of planting at both Barmer (Rajasthan) and Bhuj (Gujarat) locations. Changes in microbial diversity estimated using total viable count (TVC) approach for bacteria, actinomycetes and yeast/fungi where spreading of serial dilutions on selective media was done.

Based on TVC method, 4 out of 10 samples from Barmer showed an increase in bacterial count whereas it remained the same in 4 samples and decrease was observed in 2 samples. Overall Actinomycetes and fungal TVCs were found to be enhanced. (Table 8)

Table 8: Status of microbial population of bacteria, yeast and actinomycetes at Barmer (TVC)

#	Name of Farmer	Village	Bacteria		Actinomycetes		Yeast /Fungi	
			2019	2021	2019	2021	2019	2021
1	Rana Kala Ram	Kau Kheda	2×10^6	2×10^6	2×10^7	2×10^3	1×10^3	1×10^3
2	Gosai Punama Ram	Kau Kheda	10×10^7	2×10^4	2×10^3	3×10^3	Nil	1×10^2
3	Jodha Bhopa Ram	Kau Kheda	5×10^3	3×10^3	4×10^3	3×10^3	Nil	1×10^2
4	Hanuman Chetan Ram	Kau Kheda	2×10^4	2×10^6	2×10^3	6×10^2	Nil	3×10^3
5	Pura Jalu Ram	Kau Kheda	3×10^3	2×10^7	2×10^3	7×10^3	1×10^3	1×10^6
6	Narana Dala Ram	Kau Kheda	3×10^7	3×10^7	2×10^3	1.2×10^7	3×10^2	$3x\ 10^3$
7	Chuni Sona Devi	Kau Kheda	5×10^6	3.6×10^7	1.2×10^3	1×10^7	1×10^2	1×10^5
8	Nathu Rama Ram	Mandpura	2×10^4	3×10^5	1.5×10^3	1.6×10^7	1×10^3	1×10^3
9	Ghamanda Sidha Ram	Atti	3×10^6	2×10^4	1×10^4	1×10^5	2×10^3	1×10^3
10	Sushiya Rauram Devi	Ranigaon	1×10^6	1×10^6	6×10^2	$1.1x\ 10^4$	3×10^2	1×10^3

In Samples collected from Bhuj, bacterial TVC in most samples showed significant number of increase in 7 samples, two samples showed marginal decrease. Actinomycetes also showed enhancement in 6 samples whereas marginal decrease was observed in three samples. Similar pattern was observed in TVCs of fungi /yeast (Table 9).

The results at both locations indicated an overall increase in rhizospheric bacterial, actinomycetes and yeast/fungi TVCs after cultivation of cactus.

Table 9: Status of microbial population of bacteria, yeast and actinomycetes at Bhuj (TVC)

#	Name of Farmer	Village	Bacteria		Actinomycetes		Yeast /Fungi	
			2019	2021	2019	2021	2019	2021
1	Chaudhari Javi ben Khetabhai	Pragpar	1.3×10^7	2×10^8	8×10^2	1.2×10^6	1×10^4	1×10^3
2	Ravariya Vasarambhai Savabhai	Pragpar	3.5×10^7	3×10^8	10×10^2	5×10^7	1×10^3	2×10^6
3	Vaid Hirjibhai Kesabhai	Pragpar	3×10^6	2.4×10^8	5×10^3	3×10^6	1×10^2	1×10^6
4	Charaniya Pancham Kara	Sonalva	1×10^3	1×10^7	8×10^2	1.4×10^7	1×10^3	1×10^2
5	Makwana Arjunbhai Keynabhai	Bhutakiya	1.4×10^4	$2x\ 10^3$	3×10^3	2×10^3	7×10^2	1×10^5
6	Gami Bhanabhai Devrajbhai	Umiya	3×10^4	1×10^6	2×10^3	1×10^3	3×10^2	$2x\ 10^2$
7	Otami Ambavibhai Bhuchubhai	Umiya	2.4×10^5	2×10^5	2.6×10^2	1×10^3	1×10^2	1×10^2
8	Shdha Velabhai Jehabhai	Pragpar	2×10^5	1×10^7	1.1×10^3	1×10^3	1×10^2	1×10^2
9	Parmar Bavubhai Rupabai	Pragpar	2×10^5	1×10^5	8×10^2	1×10^3	1×10^2	1×10^2
10	Koli Nilabhai Raghubhai	Pragpar	4×10^4	$2x\ 10^7$	1.5×10^2	$1x\ 10^5$	Nil	1×10^2

f) Water Use Efficiency Study in Cactus:

Objective: To determine biomass conversion efficiency of one-year-old cactus plants grown in pot culture over a period of one month of no irrigation.

Preamble:

Arid and semi-arid regions cover about 30% of the world's continental surface (Rojas-Are´chiga & Va´zquez-Janes, 2000). The genus *Opuntia* consists of about 200 to 300 xerophytic species (Mobhammer *et al*., 2006) and grows mainly in arid and semi-arid zones. *Opuntia* species have developed phenological, physiological, and structural adaptations favorable to their development in these arid and semi-arid environments, where water is the main factor limiting the growth of most plant species (Nobel & Zutta, 2008; Guevara *et al*., 2011). Notable among these adaptations are synchronous reproduction and Crassulacean Acid Metabolism (CAM) which, combined with structural adaptations such as succulence, enable these plants to survive long periods of drought, and to reach acceptable productivity levels even in years of severe drought (Pimienta Barrios *et al*., 2002; Guevara *et al*., 2009). Cactus pear is, therefore, particularly attractive as a feed because of its efficiency in converting water into dry matter (Galizzi *et al*., 2004) and thus to digestible energy (Nobel, 1995; 2002).

Water use efficiency (WUE) is an amount of plant biomass in terms of dry matter/ amount of water removed from soil due to evapotranspiration. The conversion efficiency of water to dry matter has been reported to be greater for CAM plants like cactus than either C3 or C4 plants (Nobel, 1991).

Research Methodology:

Site description: The experimental site was located at BAIF, Urulikanchan campus at $18^0$30'33" N and $74^0$8'47" E. This place receives an average rainfall of 400 to 500 mm during the months of June to September. The annual temperatures range from minimum of 8^0C in December to maximum of 40^0C in the month of May.

Measurements: The pot experiment was undertaken during the period March 2020 to March 2021. The experimental pots were filled with Soil: Sand: FYM in the proportion of 40:40:20. A total of 20 pots were used for the experiment. One-year-old mature cladodes of same size were planted in each pot on March 2020. 10 kg soil was taken in large pots (28cm diameter and 24cm height) and water was added till it drained out from below. Pots were kept aside for 4-5 hours. Then, 50 gm soil from 10 cm depth was removed and weighed. The same soil samples were then kept in an oven overnight for drying. Difference in the two weights gave the soil water content at field capacity (WFC). Randomly 10 replicate pots were used to draw samples for the determination of WFC.

Similar sized cladodes were planted in the pots and watered at 15 days' intervals till 12 months. After the last irrigation, given at end of 12^{th} month, 50 gm soil sample were taken from 10 cm depth after 4-5 hrs. of irrigation. The value indicated soil water content (**SWC1**) in the pot at time (**T1**). For determining plant water content, fresh weight of the cladodes from 10 replicate pots was taken, after which the cladodes were dried for 48 h in oven at 60-

70°C. The dry weights of these cladodes were noted. Difference between plant fresh weight and plant dry weight was taken as the plant water content (**PWC1)**.

After one month of no irrigation, the remaining 10 replicate pots were used for obtaining readings of soil water content (**SWC2**) and plant water content (**PWC2**).

Relative Growth Rate (RGR) for the time interval of 30 days was calculated as: **RGR=** ln (dry weight of cladode at time T2-dry weight of cladode at time T1).

Evapotranspiration (ET) in g water lost over 30 days was calculated as:

ET= WFC- ΔSWC (= soil water content at time T1- soil water content at time T2) **– ΔPWC** (= plant water content at time T1- plant water content at time T2).

Finally, WUE was calculated as **WUE= RGR/ET** (in terms of g of plant dry biomass per kg of water lost by evapotranspiration over 1 month during which no irrigation was provided.

Results and Discussions:

The water-use efficiency value for 1 year old *Opuntia ficus indica* was obtained by measuring the relative growth rate / amount of water lost from soil due to evapotranspiration over a period of one month in a pot culture experiment. Above-ground fresh and dry matter production was obtained by complete harvest of the plants. Evapotranspiration was estimated as the change in soil water content and plant water content, as applicable to succulents (Han and Felker, 1997). The water content at field capacity (WFC) was measured using a pot in which no plant was grown (Table 10).

Pot trial experiment on Water Use Efficiency in Cactus at Urulikanchan

After one year of growth, the *Opuntia ficus-indica* plants achieved an average fresh weight of 2.5 kg per plant and an average dry biomass weight of 0.211 kg per plant. After stopping irrigation for one month, the decrease in soil moisture due to evapotranspiration was seen to be 1410.4 g/pot and the decrease in plant water content was 0.463g / pot (Table 10). These values were used to calculate evapotranspiration (ET), which was found to be 1047.33 g or 1.047 kg / pot. The average fresh and dry weights after one month of no irrigation were 2.06 kg and 0.237 kg respectively (Table 10). The Relative Growth Rate (RGR) for this time interval was calculated as 3.26 g/plant. The Water Use Efficiency (WUE) was seen to be 3.11g dry biomass/kg water used. In a similar pot experiment on rice grown under water

deficient conditions, the WUE was seen to be 1.1g dry biomass/kg water used (Zhou *et al.* 2017), thus indicating that *Opuntia ficus-indica* showed a higher WUE than rice, which is a C3 plant.

Snyman (2013) reported WUE value of 1.5 and 1.7 g/plant/mm for one year old *Opuntia ficus-indica* and *Opuntia robusta* plants respectively, which increased to about 8 g/plant/mm for 4-year-old plants. For comparison, the ET values obtained in terms of per kg water used were expressed in terms of mm of water used by taking into consideration the surface area of the pot. Hence 1.047 kg of ET was seen to be equivalent to 16.9 mm. Using this value, the WUE was 0.193 g /mm for one month growth of one year old cactus plants. Assuming the same RGR and same ET over the year, the WUE value approximated to 2.3g/mm/year, which was comparable to that obtained by Snyman (2013) for 1-year-old plants.

Table 10: Water at Field Capacity, Plant Fresh and Dry Weight, Plant Water Content and Soil Moisture Content

Sample code	Water at field capacity (g in 10 kg soil)	Plant fresh, dry weight and water content						Soil moisture content	
		5 hours after irrigation			1 month after irrigation				
		Fresh weight (kg)	Dry weight (kg)	Water Content (kg)	Fresh weight (kg)	Dry weight (kg)	Water Content (kg)	5 hours after irrigation	1 month after irrigation
P1	2713	2.30	0.215	2.087	1.94	0.195	1.742	2474	382
P2	3636	3.06	0.230	2.834	1.78	0.165	1.618	1573	452
P3	2611	2.01	0.150	1.856	1.46	0.340	1.119	1770	575
P4	1914	2.72	0.225	2.490	2.33	0.227	2.106	1834	821
P5	1907	2.57	0.230	2.336	2.22	0.220	1.995	2051	570
P6	2307	3.09	0.236	2.851	1.92	0.385	1.534	1861	555
P7	2753	1.71	0.140	1.565	1.87	0.206	1.666	1957	655
P8	2372	2.82	0.265	2.551	2.58	0.209	2.370	1960	601
P9	2187	2.33	0.220	2.113	1.60	0.170	1.431	2074	492
P10	2182	2.40	0.198	2.202	2.93	0.256	2.677	1941	288
Mean	**2458.20**	**2.50**	**0.211**	**2.288**	**2.06**	**0.237**	**1.826**	**1949.50**	**539.10**
SE±(m)	*161.33*	*0.14*	*0.01*	*0.13*	*0.14*	*0.03*	*0.015*	*74.26*	*46.76*

WUE has also been expressed in terms of Evapotranspiration water use efficiency (WUEet), which is expressed as the kg water used /kg dry mass (Han and Felker, 1997). The WUEet over one month was calculated as 40.27 (1.047 kg water used / 0.026 kg dry mass) in the present experiment. Low leaf area index and high soil evaporation during the first 2 years may have been responsible for the low value of WUEet obtained, as also indicated by Han and Felker, (1997). In their experiments, 3- and 4-year-old plants (but not 1-year old plants) of *Opuntia ellisiana* showed high WUEet values of 393 kg water/kg dry biomass and 283 kg water/kg dry biomass respectively in a field experiment. De Kock (2001) reported that *Opuntia* uses 267 kg of water per kg dry matter produced, while pearl millet (one of the prominent drought tolerant cereal crop) uses 400 kg water per kg dry matter produced.

The present study needs to be continued further for 2-3 years to understand how water use efficiency changes with growth of *Opuntia ficus-indica*. The present experiment was carried out in pots, where soil moisture measurements were easier than under field conditions. Comparison of WUE values reported for pot experiments (1.1g/l) and field experiments (1.6kg/m^3) in rice grown under soil water deficient conditions were quite similar (Zhou *et al*., 2017).

Conclusions:

Opuntia ficus-indica has multiple uses as a fruit, forage and vegetable crop, and has great potential for cultivation in arid regions of India. Quantifying the growth rate and water-use efficiency over several years of growth under water deficient conditions is an important aspect in promoting the cultivation of this succulent CAM plant. Thus, cactus is an appropriate fodder for declining rainfall and also when using irrigation. *Opuntia* being a CAM plant has potential for producing a large amount of forage to feed large and small ruminant animals in dry regions.

g) Training of farmers in cactus cultivation:

Trainings of the participating farmers was organized at both locations (Bhuj and Barmer) before supply of the planting material. The topics like introduction of spineless cactus, its importance, and use, cultivation method including package of practices to be followed, harvesting and utilization of cactus cladodes as a source of green fodder were covered during the training. The power point presentation, video clips, photographs and books along with live samples of spineless cactus cladodes were used as a training material. The classroom training was followed by practical demonstration in field on planting the cactus. Such training programmes were conducted to cover all participating farmers in batches at both locations. The exposure visit of the farmers from Bhuj cluster were organized at Central Arid Zone Research Institute, Regional Research Station, Kukma at Bhuj. The exposure visit of farmers from Barmer was also organized at CAZRIs Regional Research Center at Bikaner. The interaction with concerned scientist and exposure to cactus research plots was useful for farmers to aware them and expand their knowledge about spineless cactus cultivation and use.

Mr. Ramesh Chugh, DDM, Bhuj and Dr. Dinesh Prajapat, DDM, Barmer have also participated in few training programs organized for farmers at respective locations.

After completion of the one year of the establishment of cactus plantation, field day *(Shivar pheri)* was organized on the well-established and managed cactus demonstration plots to demonstrate good cultivation practices, harvesting method of matured cactus cladodes and feeding method to animals as a green fodder.

Farmers training on Cactus cultivation at Raper, in presence of Mr. Ramesh Chugh DDM, Bhuj

Farmers training cum exposure visit to CAZRI-RRS, Kukma, Bhuj

Farmers training on Cactus cultivation at Barmer, in presence of Dr. Dinesh Prajapati, DDM, Barmer

Farmers training cum exposure to BAIFs Desert Research Center, Undkha, Barmer

Farmers training cum exposure to CAZRI-RRS, Bikaner

h) Collaboration with Scientific Institutes:

i) **International Center for Agricultural Research in Dry Areas (ICARDA), Jordan:** ICARDA is the CG Institute and engaged in cactus research and development at global level. ICARDA scientists Dr. Sawsan Hassan and Dr. Ashutosh Sarker has visited BAIF, Urulikanchan during December 2019 to see the ongoing cactus research work. The MoU has been signed between BAIF and ICARDA for cactus research and promotion in India. This has immediately impacted on supplying of 15 new cactus accessions to BAIF for its further evaluation and multiplication at Urulikanchan campus.

ii) **ICAR-Indian Grassland and Forage Research Institute (IGFRI) Jhansi:** IGFRI is the global partner of ICARDA in cactus research and promotion in India. Studies on evaluation of cactus accessions, its production technology and utilization is being undertaken at this institute. They have provided 15 new cactus accessions to BAIF (through ICARDA) which were imported from various countries like Brazil, Italy etc. The IGFRI scientists and farmers meeting were organised at Barua Sagar in Jhansi district of Bundelkhand region, Uttar Pradesh to popularize spineless cactus cultivation through field demonstrations.

iii) **CSIR- Central Leather Research Institute (CLRI), Chennai:** CLRI is engaged in leather research and they were communicated for exploring collaborative work on development of bio leather from spineless cactus. MoU has been signed between BAIF and CLRI and primary work on developing protocol for bio leather from cactus has initiated. The required raw material in the form of fresh cladodes and dry powder of cactus have been supplied to CLRI and the laboratory work is in progress.

iv) **ICAR-Central Arid Zone Research Institute (CAZRI), Jodhpur:** CAZRI is the global partner of ICARDA in cactus research and promotion in India. CAZRIs regional research station, Kukma, Bhuj is actively engaged in evaluation of cactus germplasm and development and utilization of cactus as a source of green fodder for animals. The training and exposure of project farmers at Rapar block in Bhuj districts were undertaken at this center.

i) Visits to project locations:

a) **Project personnel's visit:** The Principal Investigator and Co-PI has periodically visited the both project locations to facilitate the project work, undertake training of the farmers on cactus cultivation and monitor the field performance of the cactus.

b) **District Development Managers (DDM) visit:** Mr. Ramesh Chugh, DDM, Bhuj and Dr. Dinesh Prajapat, DDM, Barmer have visited the project locations to monitor the work and interacted with the participating farmers to understand their interest in spineless cactus cultivation and utilization.

c) **Visit of KVK scientists and Govt. Officials:** The scientists from KVKs in Barmer district have visited the project areas to see the field performance of cactus and interacted with the farming community. Cactus planting material was also provided to them for undertaking demonstration at KVK farms.

d) Visit of important persons to project locations:

- Dr. R. S. Paroda, Ex DG, ICAR, New Delhi
- Dr. Sawsan Hassan, ICARDA, Jordan and Dr. Ashutosh Sarker, ICARDA, New Delhi
- Dr. K. P. Viswanatha, VC, MPKV, Rahuri
- Ms. Vered and Mr. Maayan, delegates of Start-Up Nation Central, Israel
- International delegation from different countries
- Mr. Shankarlal Kantwa, Subject Matter Specialist, KVK, Barmer
- Mr. Sunil Kedar, Minister for Animal Husbandry, Dairy and Fisheries, Govt. of Maharashtra
- Dr. P. K. Joshi, Director, South Asia, International Food Policy Research Institute, New Delhi

Visit of Mr. Ramesh Chugh, DDM, Bhuj to project sites at Raper

Visit of Dr. Dinesh Prajapati, DDM, Barmer to project sites at Barmer

Technical facilitation by Dr. Kauthale, PI and Mr. Kadao, Co-PI at project

Visit of Mr. Shankarlal Kantwa, KVK, Barmer to project sites

Visit of Dr. R. S. Paroda, Ex DG, ICAR to BAIF, Urulikanchan

Visit of Dr. K. P. Viswanatha, VC, MPKV, Rahuri to BAIF, Urulikanchan

Visit of Dr. Sawsan Hassan and Dr. Ashutosh Sarker, ICARDA to BAIF, Urulikanchan

Visit of Dr. P. K. Joshi, Director, South Asia, International Food Policy Research Institute, New Delhi

Visit of Mr. Sunil Kedar, Minister, Animal Husbandry, Dairy and Fisheries, Maharashtra

Visit of International delegation to Urulikanchan

Visit of Start-up Nation Central delegates, Israel to Urulikanchan

Orientation training of project staff on cactus cultivation at BAIF, Urulikanchan

Farmers training conducted on cactus cultivation under ICARDA project at Nagpur

j) Cactus promotional activities:

i) Supply of Cactus planting material to individual farmers, govt. institutes and private organizations for undertaking cactus demonstrations.

ii) Extension and promotional activities:

- Cactus broachers covering all aspects of spineless cactus cultivation and utilization was developed and printed as an extension material for promotion of cactus.
- A Radio talk was broadcasted on Air India, Pune center in Marathi.
- A Television Programme on cactus cultivation and utilization was telecasted on Sahyadri Vahini on 14 February 2020.
- Popular articles were published in Agro won in Marathi (7 May 2020) and Down to Earth in English (March 2019).
- Video clips on "Spineless cactus cultivation" developed in Marathi and English.
- *e*-learning module developed on "Spineless cactus cultivation" for training of farmers.

iii) Research publications:

- Kauthale V. K., K.K. Punde and S.D. Kodre.2019. Assessment of cactus (*Opuntia ficus-indica* L. Mill) accessions for growth, yield and nutritional parameters under pot culture, Agric. Sci. Digest., 39 (1), 1-3.

Following five abstracts accepted for Xth International Congress On Cactus Pear and Cochineal, to be held in Brazil during March 2022.

- Kauthale V.K., R. Dubay, J. Vyas, K.K. Punde and S.H. Kadao.2021. Growth and Yield Performance of Cactus pear (*Opuntia ficus indica*) in Arid regions of Rajasthan and Gujarat, India.
- Kauthale V.K., K.K. Punde, S. N. Kale and M.J. Aware.2021. Assessment of Growth and Nutritional Evaluation of Different Accessions of Cactus pear (*Opuntia ficus indica*) in India.
- Kauthale V.K., K.K. Punde, S. N. Kale and M.J. Aware.2021. Growth, Yield and Nutritional Assessment of Various Cactus (*Opuntia ficus indica*) Accessions.
- Bahulikar R. A., K. K. Punde and V. K. Kauthale.2021. Micro Propagation of Fodder Purpose Spineless Cactus (*Opuntia ficus-indica*).
- Aware M.J., K. K. Punde, S. N. Kale, A. P. Doke and V. K .Kauthale.2021. Assessing the Effect of Feeding Spineless Cactus on Productive Performance of Lactating Cows.

iv) Training and capacity building:

- Dr. Vitthal Kauthale, PI has attended a training workshop on '*Cactus Pear Evaluation and Best Agronomic Practices*' at Amman, Jordan organized by International Center for Agricultural Research in the Dry Areas (ICARDA) during 13-19 July 2019. Presented BAIF's Cactus research and promotion work at this international forum.
- Project staff has facilitated farmers training at Nagpur and Amaravati districts implemented by BAIF and supported by ICARDA during 2020.
- Exposure visits of farmers, govt. and private officials to Cactus plantations at Urulikanchan as well as project sites at Gujarat and Rajasthan were facilitated by the project staff.

Networking and Collaborations

International Organisations
- MoU with International Center for Agricultural Research in Dry Areas (ICARDA)
- Cactus Net, Food and Agricultural Organisation (FAO)

National Organisations
- Central Agro-Forestry Research Institute (CAFRI), Jhansi
- Indian Grassland and Fodder Research Institute (IGFRI), Jhansi
- National Institute for Abiotic Stress Management (NIASM), Baramati, Pune
- Central Institute for Arid Horticulture (CIAH), Bikaner
- Central Arid Zone Research Institute (CAZRI), Bhuj
- Central Soil Salinity Research Institute (CSSRI), Karnal
- MOU with CSIR - Central Leather Research Institute (CLRI), Chennai

NGO
- Nimbkar Agricultural Research Institute (NARI), Phaltan, Satara

Important Visits

Visit of ICARDA scientists

Visit of Dr. R. S. Paroda, Ex DG, ICAR

Visit of Dr. K. P. Vishwanatha, VC, MPKV, Rahuri

Future Prospects
- Explore industrial and medicinal properties of cactus
- Promoting cactus as supplementary fodder crop in the farmer's field of Dry Regions
- Promote fruit type cactus cultivation on degraded lands in arid and semi-arid regions of India

Sponsored by: National Bank for Agriculture and Rural Development (NABARD)

BAIF Development Research Foundation
Central Research Station, Urulikanchan, Dist- Pune 412 202
Ph.: +91-20-26926248, 9834662093 Email: crdbaif@baif.org.in
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NABARD

Spineless Cactus
A potential source of green fodder for dry areas

NABARD

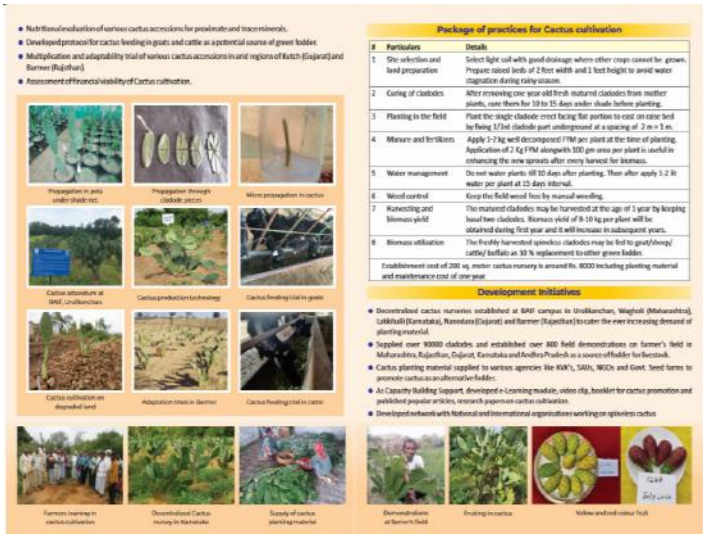
Cactus (Opuntia ficus indica) also known as prickly pear or cactus pear is one of the most suitable crop species for arid and semi-arid climate. It has remarkable ability to withstand long period of dry spell due to inherent physiological adaptations, such as CAM photosynthetic pathway. Cactus forms a good component in the dryland ecosystem due to high water use efficiency. Cactus can be cultivated on poor type of soil with limited water where no any other crop can grow. Cactus has multipurpose uses as a nutritive fodder, fruit, vegetable, medicinal uses as Antacid, arteries sclerosis, anti cholesterolic, prostatis and hyperglycemia, industrial importance for value added products and good species for countering the effect of climate change. Cactus is rich in minerals like Ca, Mg, Na, P and K. Cactus contains more than 85% of water so it can be fed with other fodder crops during dry spell condition which will be resulted to overcome water scarcity situation in arid and semi-arid regions.

Considering the importance of the cactus, BAIF has initiated research and development work during the year 2015. Though the cultivation of cactus is primarily aimed for food and fodder, the research at BAIF was mainly focused on fodder with an aim to provide an alternate fodder crop to the farmers of arid and semi-arid regions of India to address their livelihood issues. The major Research work comprises of collection and evaluation of cactus germplasm, standardizing the propagation and production technology, adaptation trials in arid and semi-arid regions; develop protocol for feeding cactus in animals and promotion through field demonstrations on farmer's field.

Accession 1270

Outcome of Research Initiatives
- Collected over 100 cactus accessions from various ICAR and private research institutes and explorations by personal visits.
- Developed cactus arboretum and evaluated them for adaptability, growth and yield performance.
- Standardized nursery techniques and tissue culture protocol for mass multiplication and developed cactus production technology.

Broacher published on Spineless cactus cultivation



- Nutritional evaluation of various cactus accessions for proximate and trace minerals.
- Developed protocol for cactus feeding in goats and cattle as a potential source of green fodder.
- Multiplication and adaptability trial of various cactus accessions in arid regions of Kutch (Gujarat) and Barmer (Rajsthan).
- Assessment of Financial viability of Cactus cultivation.

Propagation in poly under shade net

Propagation through cladode pieces

Micro propagation in cactus

Cactus arboretum at BAIF, Urulikanchan

Cactus production technology

Cactus feeding trial in goats

Cactus cultivation on degraded land

Adaptation trials in Barmer

Cactus feeding trial in cattle

Farmers training in cactus cultivation

Decentralized Cactus nursery in Karnataka

Supply of cactus planting material

Demonstrations at farmer's field

Fruiting in cactus

Yellow and red colour fruit

Package of practices for Cactus cultivation

#	Particulars	Details
1	Site selection and land preparation	Select light soil with good drainage where other crops cannot be grown. Prepare raised beds of 2 feet width and 1 feet height to avoid water stagnation during rainy season.
2	Curing of cladodes	After removing one year old fresh matured cladodes from mother plants, cure them for 10 to 15 days under shade before planting.
3	Planting in the field	Plant the single cladode erect facing flat portion to east on raise bed by fixing 1/3rd cladode part underground at a spacing of 2 m × 1 m.
4	Manure and fertilizers	Apply 1-2 kg well decomposed FYM per plant at the time of planting. Application of 2 Kg FYM alongwith 100 gm urea per plant is useful in enhancing the new sprouts after every harvest for biomass.
5	Water management	Do not water plants till 10 days after planting. Then after apply 1-2 lit water per plant at 15 days interval.
6	Weed control	Keep the field weed free by manual weeding.
7	Harvesting and biomass yield	The mature cladodes may be harvested at the age of 1 year by keeping basal two cladodes. Biomass yield of 8-10 kg per plant will be obtained during first year and it will increase in subsequent years.
8	Biomass utilisation	The freshly harvested spineless cladodes may be fed to goat/sheep/ cattle/ buffalo as 30 % replacement to other green fodder.
	Establishment cost of 200 sq. meter cactus nursery is around Rs. 8000 including planting material and maintenance cost of one year.	

Development Initiatives
- Decentralized cactus nurseries established at BAIF campus in Urulikanchan, Wagholi (Maharashtra), Lakkihalli (Karnataka), Nanodara (Gujarat) and Barmer (Rajasthan) to cater the ever increasing demand of planting material.
- Supplied over 90000 cladodes and established over 800 field demonstrations on farmer's field in Maharashtra, Rajasthan, Gujarat, Karnataka and Andhra Pradesh as a source of fodder for livestock.
- Cactus planting material supplied to various agencies like KVK's, SAUs, NGOs and Govt. Seed farms to promote cactus as an alternative fodder.
- As Capacity Building Support, developed e-Learning module, video clip, booklet for cactus promotion and published popular articles, research papers on cactus cultivation.
- Developed network with National and International organizations working on spineless cactus

सकाळ अॅग्रोवन

जनावरांच्या आहारात काटे विरहीत निवडुंगाचा वापर

डॉ. मनोजकुमार आवारे

काटे विरहीत निवडुंगामध्ये शुष्कपदार्थ, प्रथिने, तंतुमय पदार्थ, स्निग्ध पदार्थांचे चांगले प्रमाण आहे. याचबरोबरीने निवडुंगामध्ये कॅल्शिअम, स्फुरद, पोटॅशिअम, मॅग्नेशिअम आणि सोडीयम हे चांगल्या प्रमाणात उपलब्ध होते. शेळ्यांसाठी हा चांगला आहार आहे.

शेळ्यांच्या आहारात काटे विरहीत निवडुंगाचा वापर

जनावरांच्या आहारामध्ये विविध पौष्टीकतत्वे जसे की प्रथिने, स्निग्ध पदार्थ, तंतुमय पदार्थ, क्षार, खनिजे व जीवनसत्वे, पाणी गरजेचे आहे. अशी पौष्टिक तत्वे आहाराच्या विविध माध्यमातून जनावरांना मिळत असतात. सर्वसाधारणपणे १० लिटर दूध देणाऱ्या संकरित गाईंसाठी २५ ते ३० किलो हिरवा चारा (२१ किलो एकदलीय आणि ९ किलो द्विदलीय चारा), ३ ते ४ किलो वाळलेला चारा, ४ ते ५ किलो पशुखाद्य, ५०-६० ग्रॅम खनिज मिश्रण आहार म्हणून द्यावे. उन्हाळ्या आणि दुष्काळी परिस्थितीमध्ये हिरव्या चाऱ्याची कमतरता प्रकर्षाने जाणवते. त्यामुळे चाऱ्याचे योग्य नियोजन व आहाराचे व्यवस्थापन करणे गरजेचे असते. उन्हाळ्यामध्ये तीव्र पाणी टंचाईमुळे चारा पिकांची लागवड शक्य नसते. अशा परिस्थितीमध्ये कमी पाण्याक येणारी चारापिके महत्वाची ठरतात. चाराच एक पर्याय म्हणून काटे विरहीत निवडुंगाचा वापर चारा म्हणून करू शकतो.

एक उत्तम पर्याय

- उष्ण सवता तसेच विविध पौष्टीकतत्वांनी युक्त हिरवा चारा.
- उष्ण तापमानामध्ये तग धरते, कमी पाण्यामध्ये किंवा पावसाच्या पाण्यावरती वाढते.
- वाएफ संस्थेमध्ये पशु खाद्यान्यशास्त्रीने काटेविरहीत निवडुंगाच्या वेगवेगळ्या जाती जसे की २८७, १२७१, १२८०, १३०८ आणि १२८७ चाचवून त्याचा वापर जनावरांच्या आहारामध्ये करण्यात आला. त्यामध्ये अशा प्रकारच्या निवडुंगाच्या जाती तयार करण्यासाठी नर्सरी तंत्रज्ञान तसेच शास्त्रीयदृष्ट्या जनावरांमध्ये आहार परिक्षण इ. चाचण्या पशास्त्रीरीत्या पूर्ण केल्या. या विविध जातींपैकी १२८० व १३०८ या क्रमांकाच्या जातीमध्ये पौष्टीकतत्वे जास्त आहेत.
- निवडुंगाचे रासायनिक पृथक्करणमध्ये विविध पौष्टिक तत्वे जसे की, शुष्कपदार्थ ७.५ ते ११.५ टक्के, प्रथिने ५.५ ते ८ टक्के, तंतुमय पदार्थ ११.५ ते २०.५ टक्के, स्निग्ध पदार्थ १.५ ते २.५ टक्के, राख १२ ते १८ टक्के आढळून आले.
- निवडुंगामध्ये विविध खनिजे जसे की, कॅल्शिअम, स्फुरद, पोटॅशिअम, मॅग्नेशिअम आणि सोडीयम चांगल्या प्रमाणात उपलब्ध.
- नर्सरी तंत्रज्ञान वापरुन काटेविरहीत निवडुंग बांधावर तसेच कमी पाण्याच्या जमिनीमध्ये लागवड करू शकतो.

प्रयोगाचे निष्कर्ष

- शास्त्रीयदृष्ट्या शेळी आणि कराडांमध्ये अशा प्रकारच्या काटेविरहीत निवडुंगाचा वापर करून चारा पिकाला एक पर्याय व पौष्टीकदृष्ट्या उच्चप्रतीचा आहार म्हणून वापर करण्यात आला.
- शिकारसाठी जातीचे निवडुंग खाऊ घातल्यामुळे शेळ्यांमध्ये दैनंदिन वजन वाढ तसेच शरीरपोषणामध्ये वृद्धी झाली.
- उन्हाळी हंगामामध्ये जवळपास ३० ते ४० टक्क्यांनी पाण्याची गरज कमी झाली. कारण यामध्ये ९०-९५ टक्के पाण्याचे प्रमाण आहे.
- शेळ्या प्रति दिन ३.७५ किलो निवडुंग सहजरित्या खाऊ शकतात.
- २५ टक्के शुष्क पदार्थाला पर्याय.
- शेळ्यांना कुठल्याही प्रकारची हानी नाही.
- तीव्र उन्हाळ्यामध्ये योग्य शरीर व्यवस्थापन व पोषण.
- शेळ्यांप्रमाणेच दुभत्या गाईंमध्ये व इतर जनावरांच्या आहारामध्ये सुध्दा काटे विरहीत निवडुंग योग्यरीत्या वापरू शकतो. सर्वसाधारणपणे दुभत्या गाईमध्ये कमीत कमी ७ ते ८ किलो काटेविरहीत निवडुंग इतर चाऱ्यासोबत पर्याय म्हणून दैनंदिन वापरू शकतो.

शेळ्यांना काटे विरहीत निवडुंग खाऊ घालण्याची पध्दत

- निवडुंगाची पाने कापून त्यांचे कोवत्याने छोटे तुकडे करून खाऊ घालावेत.
- सुरुवातीला ८ ते १० दिवस ५०० ग्रॅम काटे विरहीत निवडुंगाचे तुकडे द्यावेत.
- त्यानंतर शरीराला सवय लागल्यानंतर ३ ते ४ किलो काटेविरहीत निवडुंग खाऊ घालावे.

: डॉ.मनोजकुमार आवारे, ९४२१००७७८५
(विभाग प्रमुख,पशुआहार व पशुशास्त्र विभाग, वाएफ, उरुळीकांचन,जि. पुणे)

Popular article published in Agrowon

v) Networking

- The correspondence has been made with CGM, NABARD RO, Bhuj and Jaipur to include Cactus as a Potential Fodder during the preparation of the next Potential Linked Plan.
- Correspondence with state departments of Animal Husbandry and Dairy and Department of Agriculture for promotion of cactus as potential source of fodder.
- Correspondence made with Cooperative dairies like Mehasana dairy in Gujarat for promotion of spineless cactus as a source of green fodder for animals.
- Planting material of superior accessions supplied to Mahatma Phule Krishi Vidyapeeth, Rahuri for plantation on the university campus.
- Access Agriculture for development of video clips on cactus cultivation in English and Marathi languages.

k) Constraints faced during the project implementation:

i) Damage to cactus plants by rats, rabbits and birds were noticed to some extent besides fencing to protect cactus plants**.**

ii) Water scarcity and delayed monsoon in Rajasthan affected the plant survival. Gap filling work was undertaken to maintain optimum plant population and survival in all cactus field demonstrations.

iii) Fungal infestation on plants has been observed at Bhuj due to heavy rain followed by water logging. Farmers were advised to drain out excess water and undertake fungicide spray on affected plants.

iv) Since COVID 19 situations from April 2020, there was some restriction in movement of staff in the project sites, however the project work was continued through virtual communications. Farmers were guided by experts and field staff through phone calls and video calls during lockdown period. The periodical project review was done through virtual meeting with the project staff.

Technical staff involved in project implementation

#	Name	Qualification	Designation
1	Dr. Vitthal K. Kauthale	Ph.D. M.Sc. (Agriculture)	Principal Investigator
2	Mr. Sagar H. Kadao	M.Sc. (Agriculture)	Co-Investigator
3	Dr. Raghvendra Dubay	Ph. D. (Horticulture)	Field Officer at Barmer
4	Mr. Jaimin V. Vyas	BRS	Field Officer at Bhuj
5	Dr. Manoj J. Aware	M. V. Sc (Animal Nutrition)	Subject Matter Specialist-Cactus Feeding trials
6	Mr. Kunal K. Punde	B. Sc. (Agriculture)	Research Officer, Urulikanchan

7) Future Outlook

The Introduction of cactus as fodder at the farmer's field in both Rajasthan and Gujarat has proved to be an excellent alternate fodder for small and large ruminants, especially during the summer season. The effort needs to be taken for its large-scale adaptation in dry regions with suitable accessions. Keeping in view the limitation of supply of quality cladodes, it will be desirable to develop decentralized Nursery by the farmers in the areas of its cultivation.

To popularize the cultivation of Cactus following actions are proposed.

1. Some select State Govt, especially in dry regions may be requested to undertake its cultivation at their own farm, where BAIF may provide the initial requirement of cladodes along with necessary technical guidance if needed.
2. NABARD may consider preparing a model project on Cultivation of Cactus and circulate to all Banks for the introduction of this new fodder crop. BAIF may provide the necessary input based on the outcome of this project.
3. NABARD may consider to incorporate this Fodder crop in the state-level Unit Cost Committee, in respect of those states having arid and semiarid climates. This will facilitate to extend Institutional credit support by Banks for its cultivation especially for Nursery development.
4. NABARD, HO may consider advising the DDMs in the districts in the arid and semiarid regions to incorporate this new Fodder in their Potential Linked Plan (PLP) for the District.
5. BAIF may peruse the various Dairy cooperatives to undertake the cultivation of Fodder Cactus, as a supplement to green fodder.
6. BAIF in association of ICARDA may prepare a development Project on Cactus and approach the International/ National donors for implementation in India.
7. Besides Fodder the scope of Cactus Research may be extended to new areas like Fruit, vegetables and its use as medicinal and other purposes.
8. Exploratory study on cactus bioenergy plant.

Acknowledgement:

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Date: 4 October 2021

Dr. Vitthal Kauthale
Principal Investigator

NABARD Research Study Series

S. No.	Title of Study	Agency
1.	Whither Graduation of SHG Members? An exploration in Karnataka and Odisha	National Bank for Agriculture and Rural Development (NABARD)
2.	Study on Strengthening the value chain of TDF Wadi Projects in Andhra Pradesh	Administrative Staff College of India, Hyderabad
3.	Developing a roadmap of Social Enterprise Ecosystem- as a precursor for a viable Social Stock Exchange in India	Grassroots Research and Advocacy Movement (GRAAM)
4.	Sustainability of Old Self Help Groups in Telangana	Mahila Abhivrudhi Society, Telangana
5.	Impact Assessment of RuPay Card on Weaker and Marginalized Sections in Bihar and Uttar Pradesh	Rambhau Mhalgi Prabodhini, Mumbai
6.	Getting More from Less: Story of India's Shrinking Water Resources	Indian Council for Research on International Economic Relations (ICRIER)
7.	Identifying the Most Remunerative Crop-Combinations Regions in Haryana: A Spatial-Temporal Analysis	Centre for Research in Rural and Industrial Development (CRRID)
8.	Climate Change Impact, Adaption and mitigation: Gender perspective in Indian Context	ICAR- National Institute of Agricultural Economics and Policy Research (ICAR-NIAP)
9.	Achieving Nutritional Security in India: Vision 2030	Indian Council for Research on International Economic Relations (ICRIER)
10.	Development of Iron Enriched Spent Hen Meat Products for Boosting Layer Industry and Entrepreneurship	Assam Agriculture University, Guwahati
11.	Farmer Producer Organizations and Agri-Marketing: Experiences in Selected States, Relevance and their Performance in Punjab	Centre for Research in Rural and Industrial Development (CRRID)
12.	A Collaborative Study on Agriculture Marketing Infrastructure in Kerala	Centre for Agroecology and Public Health, Department of Economics, University of Kerala
13.	Construction of State-wise Rural Infrastructure Indices (RIIs) and A Scheme of Rural Infrastructure Development Fund (RIDF) Allocation	EPWRF, Mumbai
14.	Action Research on Sustainable Agricultural System	XIMB
15.	Study on Efficacy of Micro-Irrigation System in Drought Prone Parts of Haryana	Society for Promotion and Conservation of Environment (SPACE), Chandigarh
16.	Study on Improving Livelihood Opportunities for Jogini Women in Anantapur District of Andhra Pradesh	Administrative Staff College of India, Hyderabad
17.	A Study of the Agrarian Structure and Transformation of the Institutional Framework of Agriculture Sector Using Data from Agricultural Censuses	NABARD and EPWRF, Mumbai

18.	Stree Nidhi: A Digital Innovation in the Indian Micro-Finance Sector	National Institute of Rural Development and Panchayati Raj (NIRDPR), Hyderabad
19.	Sustainable Development Goals for Rural Maharashtra: Achievements and Constraints	Symbiosis School of Economics, Pune
19A.	Agriculture Value Chains in India: Ensuring Competitiveness, Inclusiveness, Sustainability, Scalability and Improved Finance	Indian Council for Research on International Economic Relations (ICRIER)
20	Mid-Term Evaluation Report of Climate Change Adaptation Projects funded from UNFCC Adaptation Fund	Institute of Economic Growth, Delhi
21	Study on Utilization of Banana Pseudostem for Textiles	Maharaja Sayajirao University of Baroda
22	Farm Loan Waivers in India: Assessing Impact and the Road Ahead	Bharat Krishak Samaj, New Delhi
23	Rural Distress: Causes, Consequences and Cures (Antifragility)	Initiatives for Development Foundation, Bengaluru
24	Handholding (Capacity Building and Facilitation) of FPOs: Framework to Implementation	Institute of Rural Management, Anand
25	Case Studies of FPOs in India, 2019-21	Xavier Institute of Management, XIM University, Bhubaneswar

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नाबार्ड

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