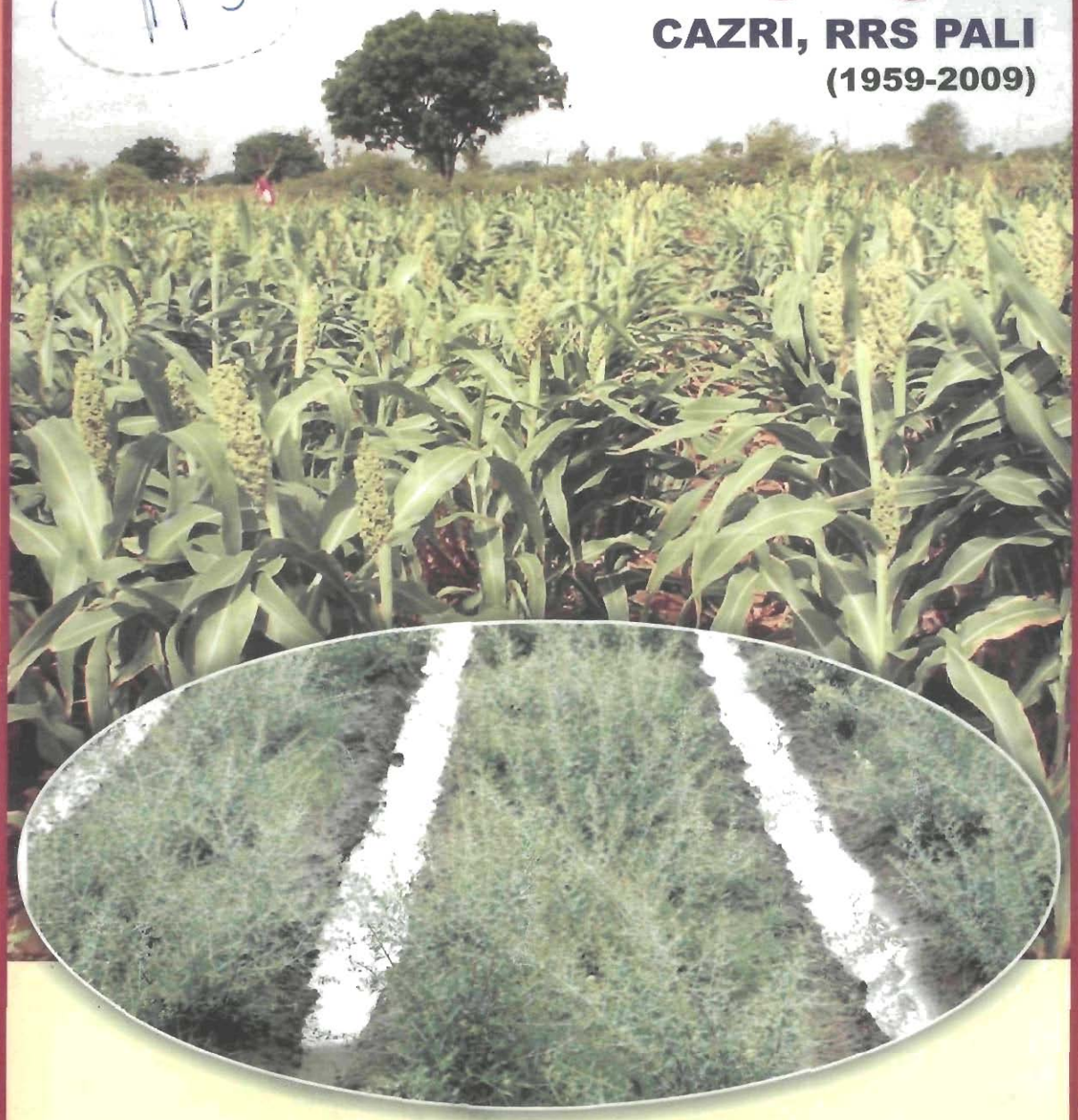
Research Highlights

CAZRI, RRS PALI

(1959-2009)



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CENTRAL ARID ZONE RESEARCH INSTITUTE
REGIONAL RESEARCH STATION, PALI-MARWAR

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RESEARCH HIGHLIGHTS OF CAZRI RRS, PALI

(1959-2009)

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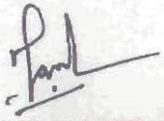
FOREWORD

I am happy to know that Regional Research Station, CAZRI, Pali is bringing out a publication on its research achievements on the occasion of Golden Jubilee Celebration of the institute (1959-2009). I would like to congratulate the staff of Regional Research Station, CAZRI Pali for focusing attention towards problems of arid ecozone.

During the past few years, several studies on the problems of arid zone have been promoted by RRS Pali in collaboration with CAZRI HQ to conduct basic and applied researches. As a result of intensive work carried out at RRS Pali considerable experience has been gained on different aspects of dry land agriculture, horticulture, grassland management, soil conservation, water harvesting techniques, livestock based farming system, tree and grass seed production, afforestation, silvipastoral and agri-horti system with a fair degree of success. Operational research projects have also been initiated to expedite effective transfer of technology.

The ultimate success of all our programmes will depend on the extent of involvement of the people of the region themselves who have been fighting with frequent droughts and famines for survival over centuries. Backed by science and technology they can bring about required transformation using the suitable technologies developed by our institute during the last five decades. In view of the magnitude of the Thar Desert and its complexity, it is important to have comprehensive time phased plans of development with a clear knowledge of relative priorities.

I hope the information contained in this compilation will be useful for all those who are interested in solving the problems of arid zone. It is now up to everyone concerned to take action to convert the potential into reality.



(N.V. PATIL)
Director
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Place : Jodhpur
November, 2009

PREFACE

Nowadays the focus of green revolution has been shifted from irrigated lands to dry lands and arid zones, all over the world. After establishment of Central Arid Zone Research Institute at Jodhpur, a centre of rangeland management was started at Pali in 1973. It was upgraded as Regional Research Station in 1987 with a specific mandate to work on saline and sodic water management, production of tree and grass seed production and development of agro-techniques for henna. This compilation on research achievements of station on the occasion of Golden Jubilee year of institute is a tribute to the visionaries and number of scientists, technicians and other staff members who devoted their services for development of innovative technologies that have played an important role in developing the region.

During last five decades arid region have witnessed unprecedented increase in human and livestock population, the consequence of which have generated tremendous stress on the limited resources in this fragile ecosystem. The Scientific approaches in developing suitable technologies have helped in achieving the goal of increasing productivity without affecting the natural resources. The soils, plants, natural vegetation, water, landforms, land use etc. have been studied along-with other socio-economic aspects. Techniques like increasing productivity of rangelands, improved management practices on saline and sodic water, improved henna agro-techniques and reseeding of rangelands played an important role in development of this region. Subsequently we have not only improved upon the technologies of fifties and indigenous knowledge but also have come a long way by diversifying research and development activities covering dry land farming, animal management, arid horticulture, agro-forestry, improvement of crop varieties, soil water conservation, post- harvest technologies and integrated pest management etc. This compilation contains significant research findings of projects completed by Scientists at Pali during last few decades. As editors, we express our sincere thanks to the authors who have contributed and helped in resolving problems faced during compilation.

P P Rohilla

S S Rao

B L Jangid

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घः दिवसीय प्रशिक्षण
24 से 29 मार्च 2008 तक

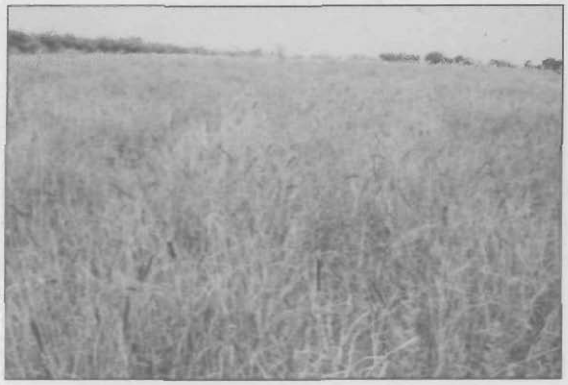
RESEARCH HIGHLIGHTS OF CAZRI RRS, PALI (1959-2009)

Regional Research Station Pali was established about six km away from Pali city on Pali-Jodhpur road as part of desert afforestation and soil conservation programme in 1953. Major thrust was given to field studies and demonstration on forestry aspects in the beginning. The station was enlarged including crop husbandry and grassland programmes in 1957 and sheep husbandry component in 1959 and management of saline soil and water in 1973. RRS Pali has 454 ha land at Pali and 77 ha land at Jadan in Pali district. It receives on an average 400 mm rainfall per annum and area falls on the transition zone between arid and semi-arid climate. The soil is shallow (25-30 cm depth) and moderately alkaline loam textured and uniformly levelled with 0.25 percent slope. Since 1952 to 1972, senior research fellow used to be in charge of the station. Appointment of scientific staff in different discipline began in 1973.

Significant research achievements since inception of the station are

Management of grasses and rangelands in Transitional belt of arid and semi-arid region:

- *Aristida funiculata* and *Eleusine compressa* are the dominating grasses under natural condition. *Eremopogon foveolatus and Elusine compressa are dominant species under* protection environment. Desirable grass species of *Cenchrus* and *Dichanthium* don't come in natural succession by protection alone.
- Grass strains 75, 277, IGFRI 3108 of *Cenchrus ciliaris*; 403, 569, 550 of *Cenchrus setigerous*; 28, 343 of *Panicum antidotale*; and 494, 495 of *Dichanthium annulatum* are superior in this transitional belt. Among forage legumes *Clitoria ternatea* performed better over *Styloxanthus scabra* and *Styloxanthus hamata*.
- CAZRI-358 of *Cenchrus ciliarias* and S-569 of *Cenchrus setigerous* were high yielding cultivars and responded up to 60 kg N ha^{-1}. Planting at 60 cm spacing facilitated tractor-operated interculture with duck shovel tines to remove weeds and conserve moisture in the soil.
- In 1993-97, IGFRI 8-4-3, CAZRI- 1263, CAZRI-75 for *Cenchrus ciliarias*; CAZRI-76, CAZRI- 418 and CAZRI- 415 for *Cenchrus setigerous*; PA 333, PA 297, PA 621 for *Panicum antidotale*; IGFRI 1531-1, IGFRI 23-1, IGFRI 173-1 for *Clitoria ternatea* produced dry matter yield ranging from 1.80 (IGFRI 173-1, *Clitoria ternatea*) to 4.09 ton per ha (PA 333, *Panicum antidotale*).
- Studies on palatability (leaf: stem ratio) of fodder grasses revealed that *Cenchrus ciliarias* was most palatable followed by *Cenchrus setigerous* and *Panicum antidotale*,



while within species CAZRI-75, *Cenchrus ciliarias* and CAZRI-76, *Cenchrus setigerous* were found most palatable varieties.

- Studies on pasture development techniques has shown that simple burning and grubbing of unwanted bushes combined with soil working and 40 kg N application improved the pasture and increased the forage yield.
- Deferred rotational grazing system has been found advantageous over continuous grazing system from animals' growth point view.
- The productivity of reseeded rangelands can further be enhanced up to 60 percent by application of nitrogenous fertilizers @ 40 kg N ha^{-1}.
- Degraded rangelands can be changed into highly productive lands simply by adoption of mechanical means of soil working like pit disking coupled with nutrient application.

Silviculture

- *Eucalyptus melanofolia*; *Eucalyptus camaldulensis*; *Eucalyptus tessalaris*, *Eucalyptus terminalis*, *Acacia tortilis*, *Acacia radiana*, *Acacia spirocarpa*, *Acacia senegal* from exotic group and *Prosopis cineraria*, *Azadirachta indica*, *Albizzia labbek* and *Tecomella undulata* from the indigenous group are suitable tree species for the region.
- Planting one-year-old seedling in 60 cm pits of 90 cm depth with saucer shaped depression and soil working is essential for successful tree planting. Watering twice a month for initial two years helps in establishment.

Silvipasture system

- Grasses when intercropped between trees species spaced at 5m x 5m gave a dry forage yield of 12.5 to 20.0 q per ha depending upon rainfall distribution and had no

adverse effect on growth of tree. Cenchrus species have minimum effect on growth retardation of tree species.

- *Grevia tenax* and *Zizyphus numularia* planted at 10m x 4m and 10m x 2.5 m, respectively with *Cenchrus ciliaris* found optimal for enhancing the productivity of silvipastoral system. Annual increment in plant height was 14.3 cm for *Grevia tenax* and 48.9 cm for *Zizyphus numularia*.
- Grass production was found maximum under *Prosopis cineraria* and *Eucalyptus camaldulensis*.
- Soil moisture conservation in different silvi-pastoral was better with *Prosopis cineraria*; *Azadirachta indica*, *Acacia nilotica* and *Albizzia labbek*; while *Acacia tortilis* and *Eucalyptus sp.* exhausted soil moisture and affected grass production.

Agroforestory

- Reduction in yield of cluster bean with *A. nilotica* or *Hardwickia binnata* was less (5.2%) compared to pure crops, while sorghum affected the growth of trees in establishing year.
- Trenching (45 to 60 cm deep) at one meter spacing on one side of row or circular catchment (1 m diameter) improved the growth of tree by conserving rainwater.
- Root spreading horizontally up to 18 meter with 3-meter depth of *Acacia tortilis* competed for moisture and nutrient with agricultural crops and grasses. A trench about 45 to 60 cm deep and one meter away from tree had minimized such adverse effects.

Agri-horti system

- Crops like mungbean, cluster bean, and sesame grown with different fruit crops showed that the highest yield of mungbean (2.70q ha^{-1}) was in lemon plants and of clusterbean (3.8q ha^{-1}) in Karonda plants. Maximum increment in height was found in pomegranate and collar diameter was found in ber.
- Intercropping of bottle guard and during kharif season and pea (arkel) and kasuri methi with ber plantation did not cause adverse effect on three year old ber and produced 40900kg ha^{-1}, 5200kg ha^{-1} and 8100kg ha^{-1} green leaves and 880kg seeds ha^{-1} of bottle guard, peas and methi, respectively.
- In Aonla based cropping system (NA-7 var., 3 spacings-10x8 m, 8x8 m and 8x6 m) and 5 intercropping treatments- Fallow, Cluster bean, Horse gram, Moong bean and Henna) at the age of 2 yr. and 7 months the plant height varied from 71.27cm to 115.14cm in different treatments. Among the intercrops performance of henna was recorded best with maximum mean leaf yield (129.30 kg/ha) followed by Horse gram (115.27 kg/ha). However, mean biomass production was maximum in moong bean (415.34 kg/ha) followed by henna (293.64 kg /ha).

- In Anola (NA-7) and pomegranate (Jalore seedless) based cropping systems in third year mean plant height of aonla plants ranged from 98.77 cm to 148.33 cm. Henna intercrop yielded 117.94 kg/ha dry leaves across the different aonla spacing. Pomegranate recorded plant height of 85.78 cm to 149.18cm, and plant spread of 0.74m^2 to 1.98m^2. The number of fruits per plant varied from 10.0 (2.20kg yield/plant) to 27.9 (5.39kg yield/plant). Among the intercrops henna produced 799.24 kg dry leaves and 1928.69kg total biomass per hectare.

- In Pomegranate based cropping system (cv.Jalore seedless, 3 spacing - 5x5 m, 5x4 m and 5x3 m and 5 intercropping- Fallow, Cluster bean, Horse gram, Moong bean and Henna) vegetative growth and yield of pomegranate plants was significantly influenced with different spacing and intercrop treatments. The maximum plant height (149.25 cm) and plant spread (2.09 m^2) with highest number of fruits (22.47 fruits/ plant) and yield (4.52 kg $plant^{-1}$) was recorded under 5x5m spacing.

- Size and weight of pomegranate fruit was significantly influenced by varying spacing and intercrop. Fruits of maximum size (8.10 cm length and 7.67 cm diameter) were produced under 5x3m spacing; however the fruit yield was not influenced significantly with different spacing. Under intercropping treatments, the fruits of maximum size (8.06 cm length and 7.37 cm diameter) with highest weight (213.67g) were exhibited by the plants grown with moong bean intercrop. Total Soluble Solids and physico-chemical characteristics of fruits were not influenced significantly with the spacing and interaction treatments.

- Total biomass and grain/ leaf yield of intercrops were significantly influenced with the different spacing and intercrop treatments. Under 5x5m spacing the maximum biomass (1019.08 kg ha^{-1}) and grain/ leaf yield (315.10kg ha^{-1}) was produced. Among intercrop treatments the maximum biomass (1753.29kg ha^{-1}) and leaf yield (618.35kg ha^{-1}) was exhibited by henna followed by 1059.53kg ha^{-1} biomass under moong bean and 288.88kg ha^{-1} grain yield under horse gram. Under interaction effects maximum biomass (2099.95kg ha^{-1}) was produced by henna with 5x5m spacing followed by 1133.30kg ha^{-1} by moog bean under 5x5m spacing. Similarly intercrop henna under 5x5m spacing produced maximum leaf yield (805.76kg ha^{-1}) followed by grain yield of horse gram under 5x5m spacing (298.21kg ha^{-1}).

- Integrated nutrient management (INM) in acid lime (*Citrus aurantifolia*) with NPK fertilizers, goat manure and neem cake revealed the maximum stem girth (43.56 cm) and yield (616.67g plant^{-1}) with highest fruit length (4.62cm), fruit diameter (4.12cm) and fruit weight (44.86g) was recorded under 50% Recommended Dose of Fertilizers (RDF) + 50% through goat manure followed by 50% RDF + 50% through neem cake. The maximum seed content was recorded in 100% RDF- chemical agriculture treatment, highest acidity (7.42%) was recorded in 50% RDF + 50% through neem cake and highest ascorbic acid content (87.67mg/100ml juice) was recorded in 50% RDF + 50% through goat manure.

In-situ moisture conservation

- A catchment of 0.75 m with 5 % slope alternated with one-meter crop strip of pearl millet resulted 50-70 percent runoff and improved the yield.
- Growing bajra in furrows and urid on ridge in 1:1 ratio helped in obtaining higher yield of both the crops by conserving rain water in furrows particularly in low rainfall years.
- A five-year study revealed that in the heavier soils at Pali, field bunding alone may result in about 36 percent more conservation of moisture, thereby increasing bajra and jowar yields, over that of non-bunded plots, by 10 to 12 percent in the wet, and over 200 percent in an extreme dry season.
- Bunding followed deep tillage during monsoon increased the yield of rabi crops like taramira and raya by 37 and 54 percent, respectively over pre monsoon deep tillage in non-bunded plots.
- Paired row planting (25 cm between rows and 75 cm between pairs) increased the yield of pearl millet and sorghum under rainfed as well as irrigated condition.
- Inter paired row water harvesting provided significantly higher Stover and grain yield of sorghum (CSV-17) than that of inter-row and inter triplet rows water harvesting. Highest water use efficiency was obtained with IPRWH for both Stover and grain (25.9kg DM ha^{-1} mm^{-1}, 6.95 kg grain ha^{-1} mm^{-1}).

- On sloping wastelands at Jadan one year old plantation of *Acacia nilotica* continuous trenching resulted in maximum increase in plant height (53.4 cm) followed by staggered trenching (47.4 cm) over no trench (34.6 cm).

- Bunding increased henna dry leaf yield over control. Inter-row water harvesting resulted in significant increase in henna dry leaf yield over planting 60 cm without water harvesting. Continuous trenching in *Acacia nilotica* (two year old plantation) resulted in maximum increase in plant height (72.5 cm) followed by staggered trenching (59.4 cm) over no trench (43.6 cm).
- Inter-cultural operation with tractor operated sweep for inter-row water harvesting resulted in significant increase in henna dry leaf yield (274.5 kg/ha) over planting 60 cm without water harvesting. Nitrogen application at 40 kg ha^{-1} resulted in significant increase in dry leaf yield of henna (237.6 kg ha^{-1}) over control (185.3 kg ha^{-1}).
- In two year old plantation of *Acacia nilotica* at Jadan continuous trenching resulted in maximum increase in plant height (72.5cm) followed by staggered trenching (59.4 cm) over no trench (43.6 cm).

Characterization of salinity

- Ground water of Pali is saline and sodic in nature associated with hazard concentration of Bo. Salinity hazard is confined on medium to heavy textured soils of low permeability and predominant in surface layers.
- Sodium hazards are high in light textured soils and relatively low in soils of higher hydraulic conductivity and cation exchange capacity.
- Presence of high silica content in saline water for irrigation is responsible for causing crust in soil.

Salt tolerance

- Ber and date palm can be successfully established with saline water up to 6 to 9 EC.
- *Panicum antidotale* and *Sporobolus* performed better with saline water conditions. *Cenchrus ciliaris* dominated at low salinity level while *Cenchrus setigerus* and *Cynodan dactylon* produced low forage yield under saline conditions.
- *Prosopis juliflora* and *Leucanae leucocephala* are tolerant to salinity up to 9 mmhos; while *Eucalyptus hybrida*, *A. aneura* and *Albizzia lebback* are highly sensitive; *Prosopis juliflora* and *Tamarix articulata* have shown tolerance to high levels of salinity under natural conditions.

- Raya and barley during rabi and sorghum in kharif season have shown tolerance to salinity. Raya (KB-2, Bio-902), sorghum (CSH-6 and SPV-96), bajra (BJ 104) wheat (Kharchia-65 and Sona) are suitable for saline water irrigation in this region.

Management of saline soil and irrigation water

- Saline water irrigation increases salinity level of soil by 3-5 times. It increases SAR of soil solution and exchangeable sodium and decreases hydraulic conductivity. Salinity, SAR of soil, soil solution and soluble salts and exchangeable sodium and lowered with seasonal rains, however, alkalinity effect persists.
- Depth of irrigation water, amount of water, amount of salts and leaching fraction of irrigation water are the major factors governing salt balance in saline water irrigated soils.
- Application of gypsum @ 2 tons ha^{-1} and organic manure @ 5 tons ha^{-1} to saline water irrigated soils increased the grain yield of wheat and sorghum by 4-6 q ha^{-1} and forage yield by 10-15 q ha^{-1}.
- Scheduling irrigation with saline water at low moisture deficits and providing 0.20 and 0.33 as leaching fraction helped in maintaining lower values of salinity in soil and increased the crop yields.
- Promising cropping sequences like sorghum-wheat, chillies-raya, sorghum-lucerne, cotton-wheat and cotton-tomato have been found suitable in the region.
- Cultivars NH-419, ST-89, Soneten-2-22, Kuran-42 and Mundra- 89 of pearl millet, SPV-678 of sorghum, HD-1152 and kharchia of wheat and DIRA-337 of mustard produced better yield under saline water irrigation (4 to 7 dsm^{-1}).
- In wheat crop (Var. HD-2189 and HD-2260) at higher level of nitrogen fertilization (90kg ha^{-1}) found helpful in reducing the impact of water salinity on crop yield.
- Higher seed rate (6-8 kg ha^{-1}) combined with higher level of nitrogen (60 kg N ha^{-1}) had significant impact in reducing salinity with saline water irrigation (EC 12 and 15 dsm^{-1}) in T-59 (Raya).
- Drip irrigation in pomegranate with saline water (EC 9.5 dsm^{-1}) resulted in better growth; canopy and fruit yield (2.6 kg per plant) of pomegranate over ring basin irrigation system.

- Preventing first stage drying through surface mulching can minimize soil-crusting effects and increasing infiltration by gypsum application in sodic conditions during leaching phase in saline water irrigated soils.

- Application of gypsum @ 2 ton ha^{-1} and organic manure in saline water irrigated soil has increased germination of wheat by 20-25 percent and 3-5 fold in sorghum. Gypsum application improved physical condition of soil by lowering crusting problem. The yield of jowar and bajra improved significantly by applying gypsum. It may increase cropping intensity to a level of 150- 200 percent over existing 33-50 percent.

- Fertilizer use has lowered deleterious effects of high salinity of irrigation water and increased the yields of barley.

- Saline waters containing 4.0 to 6.0 mmhos EC can be safely used for establishment and irrigation of ber (Cv. Seb, Gola), Datepalm (Cv. Khadrawi and Shamran) and Pomegranate (Cv. Khog and Jalore seedless). Micro-catchment for water harvesting in fruit crops helped in rapid leaching of salts and amelioration of soil in root zone.

- Application of FYM @ 8.0 ton ha^{-1} and gypsum @ 50% GR was found to ameliorate the adverse influence of soil sodicity on production of pearl millet.

- Incorporation of crop residue (raya/ taramira straw) along with FYM in equal proportion @ 10 tons ha^{-1} significantly increased the grain yield of succeeding wheat and raya crop by 21-26 percent.

- FYM @ 10 ton ha^{-1} or dhaincha as green manure crop have also minimized the effects of sodicity in pearl millet.

Management of industrial effluents

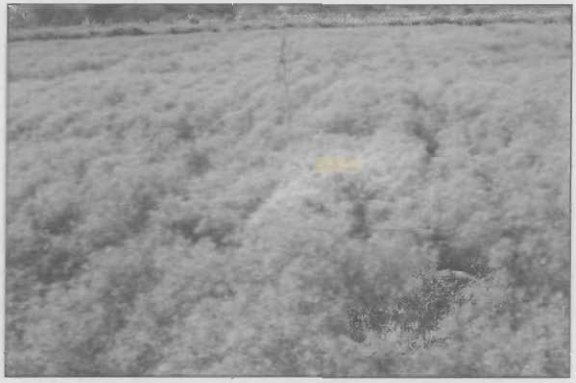
Water of Bandi river of Pali has high alkalinity and sodicity (RSC 25 me/L, SAR 50 and devoid of Ca) due to industrial effluents discharged by factories. Irrigation with river water drastically reduced the microbial population (bacteria, fungi, actinomycetes, free living nitrogen fixtures and nitrifying bacteria) and activity of soil enzymes. Forest tree managed with this polluted water showed reduced growth of *Eucalyptus camaldulensis* and *Colophospermum mopane* in comparison to plants irrigated with normal water.

Management of limited water resources

Water is limited in the region and overexploitation has lowered down the water table and quantity of water, which is leading to salinization in wells.

- Sub-optimal, six irrigations in wheat, two in raya produced maximum return with per unit application of water.
- CRI and jointing for wheat and barley, branching and selique formation in raya, four leaf and seed filling for sunflower, seed filling for safflower milk stage sorghum has been found more sensitive to water stress.
- Ridge furrow method of irrigation produced highest yield of green chillies and raya. Water economy of 40 percent and 33 percent was recorded in sprinkler and furrows system, respectively.
- Unirrigated crop strips of raya/gram in 1.6/ 2-meter width have been found to derive benefit through lateral seepage of water when alternated with irrigated crop strips of wheat of two-meter width. Yield increase of 5-7 q ha^{-1} or raya/ gram was obtained without any detrimental effect on the yield of the principal irrigated crop. Principal irrigated crop has been observed to derive benefit in saline conditions in terms of movement of salts to adjoining unirrigated strips.
- Paired row planting with single lateral of drip combined with mulch resulted 40-50 percent saving in water and higher production of tomatoes.
- Drip irrigation at ET 100 saved 35 % water and produced 40 % higher yield over conventional irrigation. Drip ET 50 though yielded at par with conventional irrigation but saved 50% water.
- Application of N, cotton yield tended to increase linearly up to 200 kg N ha^{-1} with drip ET 60 to drip ET 100. With drip ET 50 and ET 40, N-application @ 160 kg ha^{-1} provided highest yield, thereafter it declined. The highest response (16%) was observed in between 80 to 120kg N ha^{-1}. Thereafter it was 13% and 6.8% for 120 to 160 kg N ha^{-1} and 160 to 200 Kg ha^{-1}, respectively. Foliar spray of the micronutrients @ 4 gm/l thrice in between 30 to 60 days produced 15 to16 % more bolls and improved the cotton yield by 18 % over control.

- The grain and seed yield of wheat and mustard (maintained under single sprinkler line source design) declined linearly with increasing water deficits. Reductions in yield from ET max to extreme water deficits were in the tune of 90% in wheat and 80% in mustard. The highest WUE 7.91Kg ha^{-1} mm^{-1} in wheat and 5.75kg ha^{-1} mm^{-1} in mustard was observed at 16 % water deficit; which opened the scope to use limited water through sprinkler irrigation.
- The highest yield of cumin (600 kg ha^{-1}) was recorded with irrigation at 0.8 of Pan Evaporation under micro-sprinkler irrigation system. Application of FYM @ 10 tons ha^{-1} increased the yield of cumin by 10.9 % over no FYM application. N application @ 40kg ha^{-1} being at par with 60kg ha^{-1} increased the cumin seed yield by 26 % over control.



- Irrigation with micro-sprinkler at IW/ CPE ratio of 0.8 gave the highest seed yield of cumin (745.8kg ha^{-1}) followed by IW/ CPE ratio of 1.0 that yielded 728.2kg ha^{-1}. The lowest yield of cumin (514.3kg ha^{-1}) was recorded in IW/ CPE ratio of 0.4.
- Application of FYM @ 10 tones ha^{-1} increased seed yield of cumin by 14.2 percent over control (610.2kg ha^{-1}). Increasing doses of N linearly and significantly increased seed yield up to 40kg ha^{-1}. Nitrogen at 40kg ha^{-1} significantly increased seed yield of cumin by 33.4 per cent over control (543.4kg ha^{-1}). The interaction effect of irrigation and N was significant with maximum seed yield was obtained at IW/CPE ratio of 0.8 and 40kg ha^{-1}.
- In cotton effect of six water levels under drip with 4 levels of N and with micronutrients spray (B, Cu, Fe, Mn, Mo, Zn, Mg, Cl, S and Ca) were compared with conventional irrigation in cotton (cv. Amkur 651) and optimal N dose. Study revealed that cotton yield declined linearly with decreasing water supply approaching unity. Linear and polynomial functions were found to be best fit curve with highest correlation coefficient (0.99).
- Under drip irrigation system in melons ('Sugar Baby' water melon and 'Madhuras' musk melon, three levels of water- 0.5, 0.6 and 0.7 IW/ CPE Ratio; with four levels of N-40, 60, 80 and 100kg N ha^{-1}) the maximum yield of water melon (45325kg ha^{-1}) and musk melon

(44719kg ha^{-1}) was recorded with the application of irrigation at 0.8 IW/CPE ratio. Similarly maximum yield of water melon (44742 kg/ha) and musk melon (43725kg ha^{-1}) was recorded with the application of 80 kg N ha^{-1}.

- Deep tillage significantly increased grain yield of wheat by 12.6 per cent over control. Application of FYM @ 10 ton ha^{-1} also caused improvement in grain yield of wheat by 9.6% over control. The maximum DM yield was obtained from I_1 and I_2 treatment plots with 10.0 ton FYM and deep tillage, consistently high values of harvest index (HI) were obtained under high moisture regime and harvest index decreased with decreasing irrigation water amount.
- Cumin seed yield decreased from ET max to 70.5% water deficit was 79.1%. Application of micronutrient (B, Cu, Mn, Zn, Mg, Cl, S, and Ca) mixture in the form of foliar spray @ 4 gm/litre thrice in between 30-60 DAS resulted in 8.60% increase in seed yield over control. The maximum water productivity of 0.319-0.328kg/m^3 was obtained at 15.6-29.5% water deficit range. The interaction effect of irrigation water and PGM was significant. The maximum seed yield was obtained with PGM spray at ET max irrigation followed by PGM spray at ETd1 and ETd2 irrigation levels.

Crop production in rainfed conditions

- Application of organic manure applied @ 5 or 10 ton ha^{-1} with 50 % RDF promoted plant height, dry matter yield and water use efficiency of sorghum compared to those in absence of organic matter supplement.
- Weed control through peg tooth weeder proved at par with conventional hoeing-cum-weeding in terms of DMY and WUE of sorghum.
- Plant height (PH), dry matter yield (DMY) and water use efficiency (WUE) increased significantly due to intercropping and N application. The highest DMY (12227kg ha^{-1} with WUE of 56.1kg DM ha^{-1} mm^{-1}) was obtained with main crop sorghum(CSV-15) followed by sorghum inter-cropped with pigeon-pea at 3:1 row ratio with 50 kg N ha^{-1} and sorghum inter-cropped with pigeon-pea at 2:1 row ratio with 75 kg N ha^{-1}.
- Compared to continuous cropping clusterbean-pearl millet resulted in about 45 percent higher yield of pearl millet.

Crop nutrition

- Under the shallow sandy loam soil application of 5 ton FYM + 40kg N ha^{-1} resulted in high pearl millet grain yield (2095kg ha^{-1}).
- Combined inoculation with Rhizobium and PSB significantly increased both seed and dry matter production of mungbean by18 percent.

- Basal application of FYM to five year old ber orchard resulted in higher fruit yield (447q ha^{-1}) and also canopy and fruit size.
- Application of FYM @ 10 ton ha^{-1} significantly increased fodder yield of lucerne by 19.5 percent over absolute control; which recorded 59.60q ha^{-1} green fodder yield. Further, application of 10 ton ha^{-1} FYM+46 kg P_2O_5 ha^{-1} or 10 ton ha^{-1} FYM+92kg P_2O_5 ha^{-1} resulted 41.6% and 53.9% increase in green fodder yield over control, respectively. Elemental S @ 40kg ha^{-1} combined with FYM (10 ton ha^{-1}) and 46kg P_2O_5 ha^{-1} produced 50.6% higher yield than control.
- Maximum average fruit yield of pomegranate 8.45kg/ tree was recorded with zinc sulphate spray followed by 8.26kg/ tree yield in organic manuring treatment.
- Application of 600g N/ tree, spray of $ZnSo_4$ (0.5%) and borax (0.5-1.0%) showed better response to control fruit drops in ber and increased yield significantly as compared to control. Packaging of ber fruits in polyethylene bags increased self-life with minimum PLW and spoilage as compared to basket and gunny bag packaging.
- In Goonda (*Cardia mixa*) application of 100g N+ 100 P_2O_5+20kg FYM per tree gave encouraging results with respect to yield (12.6kg/ tree) and its attributes.
- In Sorghum based cropping system, due to intercropping in different row ratio and N application total DM production increased significantly. The highest grain yield of sorghum (CSV-15) was obtained with sole sorghum followed by sorghum + moong in 2:1 row ratio with 50 kg N ha^{-1} and sorghum + moong in 2:1 row ratio with 75 kg N ha^{-1} and sorghum + moong in 3:1 row ratio with 75 kg N ha^{-1}. The intercrop yield of moong was the maximum under sole crop followed by sorghum + moong in 1:1 row ratio. The maximum price equivalent ratio was obtained when sorghum intercropped with moong in 2:1 ratio with 50 kg N or 75 kg N ha^{-1} followed by 1:1 ratio with 75 kg N ha^{-1}.

- Sorghum (CSV-17) a short duration dual purpose type, responded to soil moisture conservation technique and found promising to produce grain as well as stover yield even with the rains below 300 mm, which is generally the most common climatic feature twice in five years period in this region.
- In Sorghum (CSV-17) paired row water harvesting (PRWH) system had higher moisture content than conventional planting. Water use varied from 312 mm with conventional planting to 341.9 mm with paired row water harvesting.

Henna management

Henna occupies more than 22000 ha land in Pali district. Its productivity ranges in between 0.5 to 0.7 ton ha^{-1} depending upon biotic and abiotic environmental factors in the region. Efforts have been made to improve existing germplasm as well as to develop improved agro-techniques to augment the production above one ton ha^{-1}.

- Progeny S-25-3 recorded the highest dry leaf weight (38.2g/ plant) followed by S-21-2 (31.7 g/ plant). Sojat-22 produced highest dry leaf yield (4.24 ton ha^{-1}) under irrigated conditions.
- Seed imbibitions study showed henna seed on water soaking imbibed water up to 2.4 times its initial dry weight over 10-12 days before germination.
- Treatment of seedling roots with 1000 ppm IAA for 5 min before transplantation appeared to hasten development of shoot buds and increased the branching of henna seedling transplants by 78 per cent over no treatment without affecting the establishment rate of seedlings.
- Accession S-22 recorded the highest dye content (28.7mg/g dry powder) and S-8 (24.4mg/g) the lowest across the different cuttings. With regard to harvest time, the October cutting showed maximum dye content (28.2 mg/g) and the June cutting the minimum (23.8 mg/g). The dried leaf powder colour changed from dark reddish brown (June cutting) to green (October cutting) similarly for all the populations.
- Application of FYM @ 5 ton ha^{-1} significantly increased dry leaf yield of henna by 14.0 per cent over no FYM. Dry leaf yield of henna increased from 970 kg ha^{-1} under no fertilizer application to 1110 kg ha^{-1} with 80 kg N and 40 kg P_2O_5 ha^{-1}. Among the different row spacing, rows at 45cm and 60cm gave the highest dry leaf yield and there was a significant interaction between FYM and row spacing.
- Application of atrazine @ 1.5 kg a. i. ha^{-1} controlled most of the annual grasses and broad leaf weeds in the established henna plantation without any adverse effect on henna leaf yield.
- *In-situ* moisture conservation technique resulted in 90 to 95 per cent establishment of seedlings due to moisture conservation in furrows; whereas conventional flat bed planting practiced by farmers provided 59 per cent seedling establishment. On the other hand, paired row and triplet row planting arrangement resulted 81 and 85 percent establishment of seedlings, respectively. Thus planting in furrow or furrow along the paired or triplet rows may be useful practice for improving establishment of henna stand in the region, which is very often a difficult task during the establishment year.
- At Jadan, water-harvesting treatments provided significant higher yield than regular row, paired row and triplet row. Inter-triplet (rectangle) water harvesting and inter-paired

row water harvesting (isosceles) provided 23.6% more yield of dry leaves than conventional regular row planting in first year. These treatments also recorded greater WUE.

- Henna in comparison to other arable crops has the capacity to give assured returns under erratic rainfall or drought conditions. The analysis revealed higher returns from henna as compared to pearl millet, sesame, wheat, and mustard. The net and gross returns per hectare worked out were Rs.9593 and Rs.18523, respectively. Henna cultivation also provided sufficient employment to family labour and also proved helpful in controlling the desertification process in the state.
- The B:C ratio worked out for arable crops was 1.08, 1.92, 1.56, 1.77 and 1.75 in pearl millet, sesame, wheat, fennel and mustard, respectively. Comparatively, henna recorded higher B:C ratio (2.07) in kharif season. In recurring cost of henna cultivation labour was found to be the main cost (about 93 per cent) component.
- Henna produce valued Rs 40 crores was marketed in the Sojat mandi during 2002-03. The annual compound growth rate of traded henna in this mandi from 1995-96 to 2002-03 period was 8.16 per cent. Dry henna leaves after processing at Sojat and Faridabad (Haryana) were marketed not only in India but also exported to Middle-East and European countries.
- Major constraints of henna cultivation were: high requirement and non-availability of labour for transplantation, hoeing, weeding and harvesting by the traditional method, high cost of labour, high price fluctuations, damaging rain after harvest and lack of proper storage facilities.
- In henna maximum mean plant height (81.6 cm), main branch number (5.33/ plant) and dry stem weight (25.3g/ plant) were recorded by S-8 and maximum secondary branch number (87.4/plant) by S-17 accessions. Top leaf yielding accessions were S-8, M-7 and S-7. They produced 20.3 - 21.2g dry leaves/plant. The highest mean leaf dye of 27.5mg/g was estimated in S-17 accession.
- Rows spacing of 45 cm and 60 cm caused significant improvement in leaf weight per plant over 30 cm row spacing. Application of FYM @ 5 ton ha^{-1} significantly increased dry leaf yield of henna by 11.6 per cent over no FYM. Dry leaf yield of henna increased significantly by 19.8 per cent due to fertilizer application of 80kg N and 40kg P_2O_5 ha^{-1} over control. Among the different spacing, rows at 45 cm gave highest dry leaf yield.

- In henna-guar intercrop system sole henna produced highest yield (517kg ha^{-1}) followed by strip cropping (411kg ha^{-1}). Sole henna crop gave a net profit of Rs. 5,142 ha^{-1} followed by strip cropping (Rs. 2,922 ha^{-1}).
- Paired row planting configuration provided the higher yield of dry leaves of henna (862.6kg ha^{-1}) over square planting (807.9 kg ha^{-1}).
- At Jadan effect of planting configuration and moisture conservation techniques on henna revealed that Regular rows at 60 cm x 30 cm provided significantly higher yield than triplet planting. Integration of in-situ moisture conservation into planting geometry revealed that inter-row water harvesting and inter paired row WH provided 8.6 and 7% higher yield of dry leaf over inter triplet row water harvesting.
- For marketing of henna leaf Sojat city Sub-Mandi is one and the only regulated market in the country. About 90 per cent of Henna leaves produced in Rajasthan are marketed at this mandi and remaining 10 percent is sold by farmers directly to processing industry.
- The quality of leaves Henna is ascertained on the basis of leaf weight, leaf thickness, aroma, colour, and origin of leaves' production etc. The trade of henna leaf was found to grow with a significant annual compound growth rate of 9 percent during the period 1995-96 (10264 tonnes) to 2003-04 (24744 tonnes).
- Henna processing industry is found to be mainly concentrated in Sojat city of Pali district, where around 180 henna processing units were in operation in the year 2004 providing gainful employment to more than 3000 persons.
- Significant differences was found among the henna populations planted at 90 cm X 60 cm wide spacing for dry leaf weight/ plant and 100- leaf dry weight at Pali location, and differentially for plant height, stem dry weight and seed weight/ plant at Jadan location. At Pali, the population S-21 recorded significantly higher dry leaf weight (64.1g/ plant) at par with the S-7 and S-5 populations. Whereas; population S-22 recorded minimum dry leaf weight (25.9g/ plant) that was at par with the dry leaf weight of S-8, S-17, M-1, M-9 and S-18 populations.
- In henna based inter- cropping system highest dry leaf yield (655.7 & 666.1 kg ha^{-1}) was recorded in pure henna crop. Dry leaves of henna with 1:1, 1:2, 1:3 and strip cropping was higher than 3m wide alley and 6m wide alley system in both the crops. Seed yield of moong and guar declined in 1:1,1:2 and 1:3 intercropping system owing to competition for soil moisture.
- Henna equivalent yield (price of guar and moong equated with henna's dry leaf price) was found maximum in strip cropping (704.7kg ha^{-1} and 759.9kg ha^{-1}) in both clusterbean and moongbean, respectively followed by sole henna and lowest (346.8kg ha^{-1} and 313.1kg ha^{-1}) was recorded in 6m wide alley. Highest water use efficiency (1.8-

1.9kg ha^{-1} mm^{-1}) was obtained in strip cropping system followed by sole henna (1.7kg ha^{-1} mm^{-1}). The strip cropping system was quite remunerative under prevailing rainfall conditions in arid fringes.

- Henna demand during 2005 for the country was estimated (using growth function) to be 31,909 ton, which may increase up to 80,847 ton during 2020. The increase in area required to produce this quantity was estimated to be1,02,209 ha. The new area under henna plantation may come from replacement of arable crops, uncultivated and available wastelands.
- Highest dry leaf yield (600kg ha^{-1}) of henna with water use efficiency of 1.85kg ha^{-1} mm^{-1} was obtained with inter-row water harvesting technique as compared to dry leaf yield of 380kg ha^{-1} and water use efficiency of 1.40kg ha^{-1} mm^{-1} without water harvesting.
- Integrated nutrient management in henna resulted in maximum dry leaf yield of 1836.5kg ha^{-1} at 45 cm row spacing with 40 kg N and 20 kg P_2O_5 ha^{-1} as compared to 30 cm row spacing with no fertility (1283.6kg ha^{-1}).
- Integrated weed management (IWM) revealed that crop weed competition severely affected the growth and yield of henna. Weedicides were effective for controlling weeds in henna at the initial growth stage. The major weeds in henna were *Digeria arvensis*, *Amaranthus spinosus*, *Amaranthus viridis*, *Trianthema portulacastrum* and *Euphorbia hirta* among the broad leaf weeds, *Setaria glauca*, *Digiteria sanguinalis*, *Dactylactenium aegyptium* and *Penicum repens* among the grassy weeds, and *Cyperus rotundus sedge*. Among these *Digera arvensis*, *A. spinosus* and *A. viridis* were the pre-dominant weed species.
- Integrated Weed Management in henna, Atrazine spray @ 1.0 kg a.i. per hectare + one interculture with tractor at 45 cm row spacing followed by same treatment in 60 cm row spacing, hand weeding twice and Atrazine alone, increased dry leaf yield of henna with by 60.7%, 56.8%, 45.5% and 44.6% over control.
- Planting geometry and moisture conservation techniques in henna gave highest dry leaf yield of 472.2kg ha^{-1} and WUE of 2.71kg ha^{-1} mm^{-1} with inter-row water harvesting technique as compared to dry leaf yield of 356.4kg ha^{-1} and WUE of 2.14kg ha^{-1} mm^{-1} without water harvesting in paired row planting.
- In henna based inter-cropping system dry leaf yield and total biomass yield of henna was found highest, 984kg ha^{-1} and 2303kg ha^{-1} in sole henna, respectively. The dry leaf yield of 1:1, 1:2, 1:3 and strip cropping ranging in between 393 to 423kg ha^{-1} were at par. Similarly the dry leaf yield of 1:6 and 6m alley system were at par (125 and 130kg ha^{-1}). Alley maintained at 3m distance provided 300kg ha^{-1} dry leaf yield of henna.
- The maximum dry weight of leaves per branch was obtained in end September cutting

(40 days after last monsoon rain). However, the leaves harvested in end-September and mid-October resulted in desirable olive-green or green colour of dry leaves compared to the dark yellowish brown or olive brown leaves obtained from the earlier cuttings. On an average the leaves recorded 66 per cent moisture content and high lawsone dye content at this maturity time.

Plant protection measures

- Genotypes CAZG-49-3, CAZG-5, CAZG-27-1, Maru guar, Naveen, PGC-978 and GAUF-14 of clusterbean were found moderately susceptible against bacterial blight.
- Genotypes S-8, RMG-250, RMG-131, ML-5, ML-337, RMG-111-R and T-105 of mungbean were found partially resistant to powdery mildew.
- Two sprays of Karathane (Dinocap-48%) @ 0.2 percent was found effective in controlling powdery mildew.
- Aldarin and Heptachlor were found effective in controlling termite attack in silvi-pastoral system.

Livestock Production and Management

- Feeding harvested grass to sheep, goat and heifers during lean period (Jan-Jun) increased the body weight significantly over grazing alone.
- Deferred rotational grazing was found advantageous over continuous grazing in improving the growth and production of animals as well as to maintain the productivity of rangelands.
- Heifers showed maximum live body weight gain between one to two years of age, goats between two to three years and steers between three to four years of age. Thus it may be economic to maintain these animals up to these respective ages for maximum production.
- Considerable saving in water use can be achieved by watering only twice a week in Marwari and Magra breeds without any adverse effect on weight, wool yield and lactating behaviour in sheep.
- Water having up to 2000-ppm soluble salts can be safely used for drinking purpose for sheep. Water intake increased at low salt concentrations and it declined at high salt concentration. Drinking water containing more than 60-ppm fluoride caused tooth decay in Magra and Marwari sheep. Eves were more susceptible to fluoride than rams.
- Nali breed produced comparatively more wool (1002-1070g/ head) than Marwari (934-950g/ head) and Chokla (825-986g/ head) breeds. Nali ewes performed better in spring and monsoon but lost their body weight in autumn and winter, while in Marwari ewes the trend was observed just reverse.

- The tupping percentage was 60 in Marwari, 57 in Nali and 67 in Chokla, while lambing percentage was 46.6 in Marwari and 42.8 in Nali and 55.5 in Chokla. The ratio of male to female in these breeds was 57:43 (Marwari), 33:67 (Nali) and 60:40 (Chokla).

- Supplemental feeding of Marwari lactating goats and young kids (@ 250g/d and 100g/d) maintained on pasture grazing with multi-nutrient feed blocks for a period of 45 days registered 20% increase in milk yield and 12% in growth rate. The goats also recorded slightly higher intake of water (1.2 L/day) and showed better appetite and growth as compared to goats maintained purely on pasture grazing without supplemental feeding.

- Pregnant Marwari goats fed concentrate @ 250 to 400g/d/animal in addition to 6 hr natural grazing registered highest average birth weight in alternate day fed group (1.90kg) as compared daily fed (1.77kg) and control (1.66kg) groups, respectively.

- Marwari kids (7 to 11 months) maintained on alternate day supplemental feeding @ 75-100g/d/kid resulted in higher per cent increase in body weight gain (which was observed to be 22 and 38%, respectively in kids under daily and alternate day fed group) than kids maintained on pasture grazing alone.

- Payapro (Dabur Auyrvet product) fed for 15 days after 2nd month of lactation increased 20% milk yield in Marwari goats. Further, treated goats had good appetite, improvement in health, evinced ovulatory heats and some of them got conceived. Hence, Payapro could be recommended for higher milk yield, which has been found quite safe and economical also (If a farmer invests Rs. 35.70/-only, he would get Rs 483.58/-only per lactation.

- The Marwari kids fed 4% urea-treated straw @ 250-g/ kid/ day attained better growth consuming more DM (22%) as compared to control. Similarly the goats fed 4% urea-treated straw @ 500g/goat/day consumed more DM and yielded 30% more milk over control group.

- Marwari sheep kept on supplementary feed of nutri-mix (150g/d/ animal) yielded 15% more wool (770.90g vs 655.27g) over control in sheep. Average DMI and water intake by under treatment were recorded

2.28 kg and 8.90L per 100kg B.W./d, respectively. Similarly sheep under treatment gained 10.8% higher body weight gain (21.56kg vs 19.40kg) than non-supplemental group.

- In Marwari lactating goats supplemental concentrate feeding (250 to 500g/day/animal) in addition to 8 hr natural grazing produced 11% to 38% more milk over control group. Supplemental feeding @ 250g/day/animal produced highest net returns/goat (Rs. 532.50).
- Marwari kids (weaned at 8 to 10 weeks) attained 12 to 31% higher growth in comparison to control with supplemental concentrate feeding (100-200g/d/kid) in addition to 8 hr natural grazing. Supplemental feeding @ 100g/d/kid produced highest net returns/kid (Rs 553.50).
- Marwari lambs (aged 8 to 10 weeks) reared on *ad libitum* feeding on local grains (guar churi, kapasia or crushed maize etc. alternatively) in addition to pasture grazing and on standard animal feed *ad libitum* in addition to grazing up to age of 6 months recorded 63.41 and 73.14% more growth and yielded 63.6 and 66.6 percent more wool than control group. The carcass traits of lambs reared on concentrate feeding was superior over control group.
- Supplemental feeding of kids and goats had a significant ($P<0.05$) effect on growth of kids and milk yield of goats. Results of On-farm trials in two villages revealed that alternate day supplemental feeding of kids (@ 200g/d) recorded 56 percent higher growth resulting in maximum net returns of Rs 407/kid at 6-months age in comparison to those kids maintained under natural grazing alone.
- Lactating goats with concentrate supplemental feeding @ 400g/goat produced 40% more milk yield (0.946 lit/d). Net returns/ goat were observed to be maximum (Rs 963/- only) as compared to goats those maintained on pasture only. Alternate day supplemental concentrate feeding to kids and goats is beneficial and economical as well.
- Marwari lambs were reared for mutton production (up to 6-month) under different feeding systems revealed that lambs on pasture offered a mixture of guar-churi and wheat-bran (1:1 ratio) and SARAS animal feed respectively, attained higher body weight 26.81kg (32%) and 30.0kg (48%) than lambs reared on free grazing alone. Wool yield production was significantly increased by 44 and 61 percent (650 and

725g/lamb) over control group (450g/lamb). Lambs fed supplemental SARAS feed provided highest net returns (Rs 1023/lamb) at 6-months. Supplemental feed using mixture of crop by-products and/ or SARAS animal feed up to 6-months of age is highly economical to rear lambs for mutton production in arid fringes.

- Marwari lambs reared under different feeding systems revealed that dressing percent ranged from 46 to 48%, hot carcass weight and yield of edible and non-edible cuts were recorded highest (10.30 and 4.750 kg) from lambs provided *ad libitum* SARAS feed in addition to grazing.
- Live measurements viz., slaughter weight, fasting loss, body length, height, heart girth and pouch girth etc were recorded lowest in lambs reared on grazing alone; while the lambs fed *ad libitum* mixture of local crop by-products and SARAS feed were found to be much healthier and heavier. Edible meat jointly from fore and hind quarters was recorded 1.700kg, 2.650kg and 2.340kg, respectively. Carcass weight from lambs (at 6-month) recorded 33% to 47% more over control group of lambs.
- On Farm Trial (OFT) on rearing of lambs for mutton production (6-month) in two villages under semi-intensive feeding system (supplemental feed using mixture of crop by-products and SARAS feed) revealed that mutton lamb's average daily gain (154 and 158g/d) and wool yield (675 and 725g) significantly higher than control group. Further, significantly higher net returns/lamb was obtained (Rs 420 and Rs 573).
- Kids receiving probiotics (@1.4x10^9cfu/kid/day) alone and in combination with Multi-Nutrient Mixture (@100g/kid/day) weighed heavier (74.25 and 80.98g/d, respectively) than kids not receiving probiotics, however kids receiving probiotics alone gave the highest net returns/kid of Rs 1201.5.
- Lactating goats receiving probiotics (2.8x10^9cfu/goat/d) alone and in combination with Multi-Nutrient Mixture (@250g/goat/d) yielded more milk (213 and 225 lit, respectively) than goats not receiving probiotics, however goats receiving probitics alone gave the highest net returns of Rs 1164. Hence, probiotics feeding to arid kids (for higher growth rate) and goats (for more milk production) has been found beneficial and economical.

Tree borne oilseeds for Bio-fuel production

- In *Jatropha curcas* 90 percent survival and after three months of transplanting mean plant height of 35.4 cm and 43.5 cm, mean collar diameter of 3.4 and 3.9 cm and 1.9 and 2.6 branches/ plant was recorded for 4 m x 2 m and 2 m x 2 m spacing respectively.
- In Pongamia pinnata 90 percent survival and after three months of transplanting mean plant height of 41.9 and 46.6cm, mean collar diameter of 1.4 and 1.6cm and branches/ plant 1.4 and 1.3 was recorded for 8 m x 4 m and 5 m x 4 m spacing, respectively.
- At Jadan in first year senna leaf yield varied from 75.6 to 182.5 kg/ ha.

- At Jadan in *Jatropha curcas* survival percent varied from 61.1 to 89.8%. Field bunding resulted higher establishment (82.7%) over non-bunded field (68.3%).
- Survival of 83, 78 and 95 percent was recorded in *Pongamia pinnata*, *Acacia nilotica* and Aonla, respectively at Jadan.
- In *Pongamia pinnata* plants (third year of plantation, two spacing-8m x 4m, 5mX4m; and four catchment -circular, circular organic, micro and control) under circular organic catchment showed the maximum growth followed by micro-catchment in both spacing with mean plant height, collar diameter, branches per plant and crown spread of 139.96cm and 151.94cm, 3.47cm and 3.28cm, 7.79 and 7.33 and 1.92 m^2 and 1.66 m^2, for 8mX4m and 5mX4m spacing, respectively.
- In *Jatropha curcas* plants (third year of plantation, two spacing -4mX2m, 2mX2m and four catchments -circular, circular organic, micro and control) under the circular organic catchment showed the maximum growth followed by micro-catchment in both spacing with mean plant height, collar diameter, branches per plant, and crown spread of 113.94cm and 135.28cm, 9.33cm and 8.82cm, 32.18 and 28.94, and 1.3m^2 and 0.91m^2 for 4mX2m and 2mX2m spacing, respectively.
- In fourth year of plantation *Jatropha curcas* attained mean plant height of 108.1 to 124.7cm. The mean collar diameter varied from 8.1 to 9.1cm, similarly branches per plant ranged from 26.1 to 32.3 and canopy spread ranged from 0.8 to 1.1 m^2. Spacing and moisture conservation treatments in Jatropha had no significant effect on the plant height, collar diameter, branches per plant and canopy spread. Eighty per cent of total Jatropha plants showed floral bud initiation in last week of April.
- In fourth year of plantation *Pongamia pinnata* attained mean plant height of 109.7 to 144.6cm, collar diameter of 2.6 to 3.4 cm, branches per plant from 5.6 to 7.6 and canopy spread of 1.2 to 1.8 m^2. All the moisture conservation treatments proved significantly superior over control in attaining better plant height and collar diameter. Maximum plant height and collar diameter of 144.6 cm and 3.4 cm was observed under circular catchment (organic) followed by micro-catchment.

Livestock Production Economics

- The highest livestock density (per sq km) was found in Raipur (214) and lowest in Rohat (132) tehsil. Livestock population in the district increased from 18.78 lakh (1966) to 21.11 lakh (2003) in a period of 37 years with an annual compound growth rate (ACGR) of 0.32 percent. The ACGR of livestock was found negative during the periods 1983-87 and 1997-2003, possibly due to migration/ mortality consequent upon severe droughts.
- The ACGR of cattle, buffalo, sheep, goat and camel was found to be -1.90 %, 1.93 %, 0.82 %, 0.75 % and -0.57 %, respectively during period 1966- 2003. The positive growth rate of buffalo indicated increasing importance of this species in the district. The reasons may be high market value of buffalo milk, decreasing area under pasturelands as cattle were reared mainly on grazing. The negative growth in camel is an indicator of increasing mechanization in farm operations and produce transportation, which were earlier performed by it.
- Study on ovine production economics revealed that total initial investment made on an ovine flock of 100 animals was Rs 1,28,000/- with share of animals, shed and store and equipments in tune of 87 percent, 12 percent and 1 percent, respectively.
- Ovine keeper incurred fixed expenses of Rs. 12, 890 per annum for a unit of 100 animals. Interest on initial capital investment had the highest share (92%) in the fixed expenses with remaining 8 percent shared by depreciation on shed and store and equipments. The per annum variable expenses were found to be Rs. 62,700 with labour charges (38 %), cost of dry fodder (36%) and cost of concentrate (24 %) as major expenses.

- From a unit of 100 animals ovine keepers had gross annual income of Rs. 1,18,036, contributed by sale of animals and flock addition (63.5 %), value of milk (29.5 %) and sale of manure (6 %). With the net annual income of Rs. 42,446 and B:C ratio of 1.56 ovines production was found to be a profitable enterprise in the region.
- In Rohat tehsil (Pali district) though farmers rear both cattle and buffalo for milk production, buffalo was observed to be dominant species with 52 percent share in the herds' composition. On an average a farmer had 7.33 units of bovines, comprised of 49.3 percent milch animal, 25.81 percent heifer and 24.88 percent young stock.

- On an average fixed investment on dairy herd in Rohat was Rs. 76,318 and cost of milch animals (56%) was the most important component and buffalo having 73.60 percent share of animal cost. The proportionate investment on cattle shed and store, machinery and equipment was found to be 25.74 percent and 4.98 percent, respectively.
- The milch animals in Rohat tehsil was mainly reared on dry fodder and concentrate produced at their own farm. Except grazing in rainy season (4 months), the availability of green fodder was almost negligible as assured irrigation facilities were very limited. Around 55 percent farmers fed concentrate to animals based on their milk yield; while rest fed on flat rate basis.
- Fifty five percent farmers offer additional concentrates to pregnant bovines and only 45 percent provide minerals and salts. Around 60 percent farmers adopted individual feeding method, 20 percent adopted both individual and group; while rest 20 percent adopted only group feeding method. Generally, milch animals fed individually and other in group. Around 45 percent farmers fed multi nutrient feed block (MNFB) in addition to normal feed to dairy animals.
- The average cost of maintaining a cow was highest in winter season, followed by summer and rainy season. The proportion of variable cost in total cost of maintaining a milch animal accounted for 92 percent; which varied from 89 percent in rainy season to 94 percent in winter season. In the overall cost of maintenance per cattle per day, feed cost alone accounted for 77 percent. The net cost of maintenance per cattle per day was worked out to be around Rs 34.00. The net cost varied from Rs 24 in rainy to Rs 42 in winter season.
- The overall net return per day from a cattle unit was Rs 26.21 and it was Rs 9573 in a year. The milk yield showed an increasing trend from summer to winter season. The overall milk yield per animal per day was ascertained to be 6.09 litres. The milk price was highest in summer season due to comparatively high demand and low supply of milk; which is due to low productivity in summer season. The net return per day from a cattle unit varied from Rs 16.42 (summer season) to Rs 40.31 (rainy season).
- The maintenance cost per buffalo per day was Rs 55.94; it was highest (Rs 71.19) in winter and lowest (Rs 38.03) in rainy season. The proportion of variable cost accounted for 92 percent of total cost (varied from 88 percent in rainy season to 94 percent in winter season). The overall milk yield per animal per day was ascertained to be 10.23 litres. Overall net return per day was Rs 79.24 and farmers could get net return of Rs 28,935 from a buffalo in a year.

- The composition of bovine was found to be changing in favour of buffalo species with 1.93 percent growth rate during 1966-2003. On an average, a farmer invested Rs 1,01,512 on a bovine unit of 6.47 ACU in Pali district. Farmers managed their bovine with locally available resources for housing, crops by-products and grains for feeding etc. Common breeding bull was maintained on community basis for natural service of bovine.

- Farmers were found to be well aware about advantages of Artificial Insemination and using this service wherever possible. The availability of green fodder/ grass was found only in rainy season in Rohat tehsil; while in Sumerpur and Raipur tehsils its availability was dependent on irrigation facilities. The maintenance cost of bovines was the maximum in winter season due to more expenses on feed and fodder.

- The technical efficiency of cattle and buffalo at the average level of input use indicated a potential of increasing milk production and the returns by 30 and 25 percent by adopting better management without incurring any other additional expenditure.

- Importance of ovine in the livestock of the district was revealed by its population density of 124 ovine per km^2 and positive growth rate of both the species (sheep 0.82 % and goat 0.75 %) during the period 1966-2003. The commercial scale ovine rearers in the district mainly belong to dewasi/ rebari community.

- The fixed investment on average flock size of 91 ovine units was found to be Rs. 1,89,630. The annual gross and net returns were found to be Rs. 1,59,954 and Rs. 60,353, respectively with B:C ratio of 1.61, indicating the profitability of ovine rearing in Pali district. Though both goat and sheep rearing was found profitable in the district but income from this enterprise can further be increased by improving the condition of available common grazing resources, better technology adoption, and efficient marketing of live animals and wool.

- Camel breeders in Jojawar, Mundara, Bijapur villages in Pali district maintained herds of 25-50 camels and one male breeding was maintained for 50 female camels. The breeders considered SANCHORI as the best camel breed in this region. Camel breeders maintained their herd browsing on CPR's (Forest, Gochar and Oran) and fallow agricultural fields etc. and no stall feeding is provided. Some of the camel breeders in Bali tehsil bring the camel herd back to home in the evening; while in Marwar Junction tehsil camel herd is kept in the browsing area round the year.

- Gogamedi fair was found to be the most important camel market with arrival of about 22,000 camels (2008) followed by Pushkar fair (12,000 camel arrived for sale). In Gogamedi fair majority of the camel sold were in the age group of >4 years (83 percent). Where as in other fairs 73 percent of camel were sold at < 4 years age group. The

reasons behind selling young animals by breeders was scarcity of feed and fodder, cash requirement to meet family needs, maintenance of herd size, risk of disease/ mortality and risk of animals getting crippled etc.

- Market price of camel was comparatively higher in Gogamedi and Pushkar fairs due to better camel breeds. Mainly, Bikaneri, Jaisalmeri and Mewari camel breeds were marketed in these fairs. The highest and lowest sale price of camel observed in Gogamedi fair was Rs 52,000 and Rs. 2000; in Pushkar fair Rs. 37,500 and Rs. 4000 and in Jhalrapatan fair was Rs 42,100 and Rs 800, respectively.
- The price spread analysis indicated that share of breeders in price paid by users in the channel Breeders → Trader → Farmer/ carter was 86 percent in Pushkar fair. In Pushkar, Gogamedi, Jhalrapatan and Kasba Thana fairs around 33, 38, 64 and 85 percent of camels were sold. Trader, farmers and carter dominated marketing in Gogamedi and Pushkar fair; while only trader dominated trade in other two fairs, mainly due to sale of animals for meat purpose in Jhalrapatan and Kasba Thana fairs.

Transfer of technology

- The knowledge of the farmers about improved cultivation practices of major crops (wheat, mustard, bajra, jowar and sesame) was found very low with Mean Percent Score (MPS) of only 40.917.8 (MPSSD). Farmers were having better knowledge of improved practices of Rabi crops (Wheat: MPS 54.214.0, and Mustard: MPS 59.017.7) as compared to Kharif crops. Among Kharif crops knowledge about improved cultivation practices of Bajra (MPS 38.612.8) was highest followed by sesame (MPS 32.310.5) and jowar (MPS 25.911.8).
- The adoption of improved cultivation practices of crops was very low with overall adoption index (AI) of only 30.24. The overall AI for Kharif crops was found to be very low (20.4), however, it was comparatively better in irrigated Rabi crops (44.9). The AI was found to be highest for wheat (47.1) followed by mustard (42.1), bajra (28.5), sesame (20.0), and jowar (12.8). Adoption index of improved practices of Animal husbandry i.e. cattle rearing (40.5) was found to be better than agricultural crops (30.24).
- The major constraints perceived by the farmers in adoption of improved cultivation practices of crops were- Natural calamities (specially famine, drought, and uncertainty

of rain) was perceived as most important constraint (MPS 92.3), low risk bearing capacity (MPS 80.7), lack of knowledge of improved practices (MPS 73.0), high cost of modern inputs, lack of training and traditional attitude of the people (MPS 57.6).

- The major constraints perceived by livestock rearers in adoption of improved animal production practices were- Natural calamities (MPS 88.4), high cost of fodder and concentrates (MPS 80.7), non-availability of green fodder (MPS 80.7), lack of knowledge about improved practices (MPS 73.0) and lack of artificial insemination facility (MPS 76.9).

- *The training need of the farmers regarding improved practices of major crops was* sufficiently high (MPS 49.8). It was highest for plant protection practices (MPS 65.4) followed by storage (MPS 48.0), marketing (MPS 46.0) and finally improved agronomic practices (MPS 40.3).

- In case of improved practices of animal husbandry (cattle rearing) the overall training need was found lower than crops (MPS 41.5). Highest training need was expressed for animal feed and nutrition (MPS 47.7) followed by disease management and health care (MPS 46.1), breeding and reproduction (MPS 43.3) and general livestock management (29.0).

- Majority of the farmers (69.2 percent) opined that training programme for improved cultivation practices of the crops should be organized before sowing of crops, and for one or two days (38.4 percent) period, at farmers field (53.8 percent) or at training institution (38.4 percent) as well.

- The major constraints perceived in ovines production were lack of pasture land/ poor quality grazing lands (MPS 96.4), high cost of veterinary medicines (MPS 92.9), uncertainty of monsoon and scanty rains (MPS 92.4), high cost of animal feed (MPS 82.1), low income (MPS 78.6) and problems in migration during famine/ drought (MPS 78.6).

- Major constraints perceived by the bovine rearers in Rohat tehsil were uncertainty of monsoon and scanty rain resulting in drought (MPS 97.5), non-availability of green fodder (MPS 90.0), lack of improved milch breeds (MPS 90.0), and problematic soil and irrigation water (MPS 90.0), high cost of feed and fodder (MPS 85), high cost of veterinary medicines (MPS 82.5), and low price of milk and milk products (MPS 82.5), low productivity of local animals (MPS 80.0), lack of basic infra-structure i.e. roads, transport, clean water etc. (MPS 75.0), lack of livestock insurance facility/long and complicated process (MPS 77.5).

- Technological interventions at farmers' field (villages Artia, Dhamli and Marwar Jn.) revealed that improved varieties, CZP-9802 (Pearl millet), KRL-19 (wheat) and CSV-15 (fodder sorghum) with cow-pea mix cropping, enhanced the grain/ fodder yield by 17.9 and 42.8 %, 18.5 and 52.2% and 26.6 and 47.2% over the recommended and farmers' practice, respectively. Application of organic manure (FYM @ 5.0 ton ha^{-1}) in old henna plantations enhanced dry leaf yield by 35.3%; while application of atrazine @ 1.0 kg a.i. ha^{-1} after first effective rainfall was found effective in checking growth of kharif weeds. All the interventions were found economically more beneficial with high B:C ratio of 1.8 to 3.7.

- Various technological interventions at farmers' field (villages Busi, Khandi and Dari) Varietal intervention in pearlmillet (CZP-9802) improved the grain yield by 6.98% and 27.78%, over the recommended (Pusa 334) and farmers' practice (local cultivar), respectively. Similarly, fodder sorghum (CSV-15) along with cow-pea mix cropping improved fodder yield by 12.50% and 29.90% over the recommended (MP Chary mono-cropping) and farmers' practice (local cultivar mono-cropping), respectively. Intervention of applying clay + vermi-compost (10kg per plant) + circular catchment in ber orchard improved yield by 15.90% over recommended practice (clay + FYM 50kg per plant+ circular catchment) and 62.13% over farmers practice (simply irrigating the orchard after hoeing and weeding).

- The varietal intervention in pearl millet was found more beneficial with high B: C ratio (1.35) in comparison to the farmer practice (1.08) and recommended practice (1.26). Similarly, cultivation of CSV-15 with cowpea mixed cropping was found to be more profitable with B: C ratio (2.6) as compared to farmer's practice (1.9) and recommended practice (2.3). Rainwater harvesting treatment and fertility management in ber was also found more profitable (B: C ratio 3.37) in comparison to farmers' practice (2.14) and recommended practice (3.15).

- Various need based technological interventions in different crops viz. pearl millet (CZP-9802), sorghum (CSV-15+cowpea mix-cropping), wheat (KRL-19 for saline/sodic irrigation water/land), henna (chemical weed control by Atrazine and applying FYM @ 5.0ton ha^{-1}) and ber (preparation of circular catchment+pond soil application+vermi-compost @ 10kg per plant), given at farmers field for a period of three years with an objective to improve the productivity of the farming system, improved the yield of various crop enterprises in tune with 25.7 to 69.5 percent over farmers practice and 7.0 to 31.0 percent over recommended practices. All these interventions were found economically viable with B: C ratio more than unity (1.4 to 3.7). Majority of the farmers were not aware and opined that that they will continue the adoption of interventions/ improoved technologies.

RESEARCH PROJECTS

- Improving productivity of sorghum based cropping system with agronomic management (CAZRI/ T-03/ RR/ P-7)
- Development of agri-horticultural system for sustainable production under arid ecosystem (CAZRI/T-03/RR/P-8)
- Production potential of oilseed trees/ shrubs under varying densities and moisture conservation measures in culturable wastelands of arid fringes (CAZRI/RR/P-11)
- Integrated management of wasteland on watershed basis at Jadan, RM& SC area (Pali district) (CAZRI/RRS/P-13)
- Effect of feeding frequency on productivity of Marwari goats (CAZRI/T-05/RR/P-9)
- Mutton production in Marwari sheep under different feeding systems (CAZRI/RR/P-10)
- Economic analysis of henna and arable crops in Pali district of Rajasthan (CAZRI/RR/P-4)
- Economic analysis of livestock production systems in Pali district of Rajasthan (CAZRI/T-9/RRS/P-15)
- Improving water use efficiency and productivity with limited water in arid fringes (CAZRI/ RRS/ P-12)
- Management of Henna (*Lawsonia inermis* L.) in arid and semi arid regions (CAZRI/T-03/RRS/P-14)
- Effect of feeding frequency on productivity of Marwari goats (CAZRI/T-05/RRS/P-9)
- Development of aonla and pomegranate based cropping system in Pali region (CAZRI/T-03/RR/P-8)
- Production potential of *Pongamia pinnata* and *Jatropha curcas* under varying densities and moisture conservation measures in culturable wastelands (CAZRI/RRS/P-11)
- Improving productivity of pearl millet, fodder sorghum, wheat, henna and ber through technological interventions in Pali district (CAZRI/ T-09/ RR/P-16)
- Integrated nutrient management in acid lime (*Citrus aurantifolia*) (CAZRI/T-03/37)
- Performance of Marwari goats fed probiotics and multi-nutrient mixture supplementation (CAZRI-T-05/P-16)

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