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## EXECUTIVE SUMMARY(2009)

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### Integrated Natural Resources Appraisal, Monitoring and Desertification

Natural resources survey was completed in Sirohi and Revdar tehsils (226400 ha area) of Sirohi district. Despite being situated in the easternmost fringe of the desert, these tehsils suffered more from drought than from flood during the last 50 years. Sirohi and Revdar tehsils are dominantly under fluvial processes, where moderate to steep slopes and shallow soils favour water erosion. Majority of soils have been developed under gentle to undulating alluvial plains with medium to fine texture, while about 30% area is undulating and rocky that generate runoff through seasonal rivers and cause flood and water erosion. Simulation studies revealed that during high rainfall years like in 2006, the expected soil erosion rate is  $>80 \text{ t ha}^{-1}$  in about 24% area of Sirohi tehsil and 31% area in Revdar tehsil. About 84% area has potable groundwater at a depth of  $<40 \text{ m}$  but exploitation is very high for irrigation, leading to depletion of  $0.20\text{-}4.57 \text{ m y}^{-1}$ . Cropping is the major land use, despite 42.9% area under wastelands. Irrigated agriculture is predominant in Sirohi (27.4%) and Revdar (37.7%) tehsils. *Anogeissus pendula*, *Acacia senegal* and *Butea monosperma* are dominant in hilly tracts ( $20\text{-}90 \text{ plants ha}^{-1}$ ) while *Prosopis cineraria*, *Acacia leucophloea* and *Cassia auriculata* dominate the alluvial plains. *Prosopis juliflora* has infested both rocky uplands and grazing lands.

In Barmer, Jalor and Sikar districts, irrigated area has increased manifold during the last one and a half-decade. In Barmer and Jalor districts, rainfed croplands have declined by 20-30% and pasture land by 38-45%. In Sikar district, the rainfed croplands have declined by 29% and wastelands by  $>35\%$ . Overall, in western Rajasthan, the net sown area has increased from 35.5% in 1957 to 51.1% in 2006 and double cropped area from 0.7% to 9.9%. Culturable waste has declined from 24.1% to 17.6%.

Land degradation mapping in 5 districts ( $102499 \text{ km}^2$  area) of western Rajasthan at 1:50,000 scale revealed more than 63% area under wind erosion, the largest being in Bikaner (25%) and Jaisalmer (21%) districts. More than 53% area of wind erosion occurs in agricultural lands, which is a concern. Water erosion (0.49%), salinity (0.41%) and mining (0.50%) cover much less area.

Soil fertility assessment in Nagaur, Jalor and Sirohi districts revealed  $<0.2\%$  organic carbon. Among the micro-nutrients, Zn was deficient, and Cu and Mn contents were mostly sufficient in all the land uses. At CR Farms of Jaisalmer and Chandan, where soils are dominantly fine sandy and alkaline, organic carbon and available P were low, but micro-nutrients were adequate, except zinc. A set of pedotransfer functions (PTFs) was developed to estimate soil water retention at 0.33 and 15 bar using the data of soil particle size distribution. Utility of PTFs was demonstrated through surface map for arid western India.

In Jaisalmer district, Normalized Difference Vegetation Index (NDVI) for September 2009, derived from MODIS, revealed only 0.60% of the district area under NDVI value  $\geq 0.30$ , mostly

concentrated along the Indira Gandhi canal. In Kachchh district, soil organic carbon stock under the trees was highest under *Acacia tortilis*, followed by *P. juliflora*. Among the grasses, it was highest under *Cenchrus ciliaris* when grown in a silvipastoral system with neem (4.0 t ha<sup>-1</sup>).

### **Biodiversity Conservation and Improvement of Annuals and Perennials**

Among grasses, 390 accessions of *C. ciliaris* and *Cenchrus setigerus* were maintained. *C. ciliaris* cv. CAZRI-303 (5 year old) gave highest dry matter yield (2380 kg ha<sup>-1</sup>) followed by 2-year old CE-08-03 (1904 kg ha<sup>-1</sup>) and 4-year old ICC-5 (1490 kg ha<sup>-1</sup>). *C. ciliaris* cv. CAZRI-2171, with row spacing of 75 cm and 40 kg N ha<sup>-1</sup>, gave the maximum forage and dry matter yield.

Three hybrids of pearl millet performed better than the check HHB-67 IMP. Among advanced hybrid trials, 93333 A x 2-50 and 9333 A x 2-8 were most promising for grain yield. Among the dual purpose testcrosses, no cross was better for grain yield than HHB-67 IMP, but their stover production was 2-3 times more (2778-4167 ha<sup>-1</sup>) than HHB-67 IMP (1389 kg ha<sup>-1</sup>). Maximum grain yield was given by 98222 A x CZI 2005/21 (2384 kg ha<sup>-1</sup>) in hybrid trial-1 (HT-1), by 98222 A x CZI 2007/6 (1044 kg ha<sup>-1</sup>) in HT-2 and by 91444 A x CZI 2005/21 (1089 kg ha<sup>-1</sup>) in HT-3. Among coordinated trials, IHT-110 (737 kg ha<sup>-1</sup>) was highest yielder. Three new hybrids, ICMA 95444 A x CZI 2005/121, ICMA 94555A x CZI 2004/8 and ICMA 91444 A x CZI 2005/21, were contributed to the All-India Coordinated trials. In advanced varietal trials (AVTs) of clusterbean cvs. GR-6 and GR-7 (433-435 kg ha<sup>-1</sup>) in AVT-II; GR-12 and GR-15 (232-245 kg ha<sup>-1</sup>) in AVT-I, and GR-3, GR-25 and GR34 (366-384 kg ha<sup>-1</sup>) in IVT; were high seed yielders. In mung bean, cvs. KM-8-206, -211, -202 and -224 gave seed yield of 313-375 kg ha<sup>-1</sup> in IVT and AVT. In case of Moth bean, cv. RMG-62 gave the highest seed yield (575 kg ha<sup>-1</sup>).

Irridation of *T. undulata* seeds with 40 kr gamma rays was most lethal for seedling survival. Among 13 genotypes of *A. senegal*, genotype 442 was found to have maximum number of nodulating plants (66.7%). Among 20 clones of *Lawsonia inermis* transplanted in field in 2002, average dry leaf yield was maximum in Khedbrahm (69.8 g plant<sup>-1</sup>) genotype. Twenty one genotypes of mushroom were molecularly characterized.

At Jaisalmer, datepalm cv. Medzool had largest fruit size with more pulp, while cv. Umsok was sweetest at *doka* and *dang* stages. At Bikaner, germplasm of *Lana*, *Phog* and *Bawali* were evaluated. Root length (28.2 m) and root weight (1.87 kg plant<sup>-1</sup>) were maximum for *Phog* at the age of 4 years. At Pali, 51 mustard genotypes were evaluated for tolerance to salinity. Genotype DRMR-09-423-1, BM-199, Navgold, NRCDR-601 and Urwarshi performed better at high salinity for germination and agro-morphological traits under field conditions. Among 12 genotypes of sweet sorghum, SSV-74 gave the highest dry fodder yield (3817 kg ha<sup>-1</sup>).

In seed production programme, 257 kg seed of grasses, 8,144 kg of crops and 100 kg of trees was produced. About 441 kg breeder seed and 26 kg nucleus seed of moth bean variety CZM-2 was also produced. Nearly 75,000 plants of forest trees/shrubs, 45,125 horticultural plants and 15,000 medicinal plants were raised.

## Integrated Arid Land Farming Systems Research

Substitution of 50% N input through farm yard manure (FYM) increased clusterbean seed yield by 58% over control. Residual effect of FYM applied to clusterbean was significant on succeeding cumin crop, however, maximum cumin yield (458 kg ha<sup>-1</sup>) was by direct application of 100% recommended dose of fertilizer (RDF) to cumin. Continuous cultivation of pearl millet without N input gave lowest grain yield (424 kg ha<sup>-1</sup>) that increased significantly with the application of 40 kg N ha<sup>-1</sup> (535 kg ha<sup>-1</sup>). Maximum grain yield (746 kg ha<sup>-1</sup>) was obtained by applying 5 t FYM along with 40 kg fertilizer N ha<sup>-1</sup>. At Kukma-Bhuj, application of 60 kg N with 80 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> gave the maximum dry fodder yield (2085 kg ha<sup>-1</sup>) of clitoria.

Fruit yield of ladyfinger was maximum (7.6 t ha<sup>-1</sup>) at 20 x 20 cm spacing, followed by 20 x 15 cm spacing (6.9 t ha<sup>-1</sup>) under drip irrigation. Drip irrigation gave 74, 15 and 26% higher yields of ladyfinger, muskmelon and tomato compared to check-basin irrigation. Grown with drip irrigation, gladiolus variety Snow Princess performed the best with respect to spike length (45-50 cm), total number of florets per spike (15-19), floret size (6.5 cm) and duration of flowering (14 days).

The evapo-transpiration rates measured using gravimetric lysimeters for unstressed sesame crop (RT-127) were 2.5-3.9 mm d<sup>-1</sup> at initial stage, 6.9-13.5 mm d<sup>-1</sup> at vegetative stage, 9.2-9.7 mm d<sup>-1</sup> at flowering/fruitlet stage and 5.5-8.5 mm d<sup>-1</sup> on maturity. Seed yield of unstressed crop was 1953 kg ha<sup>-1</sup>. At Pali, irrigation with 86, 71, 58 and 42% water of ET<sub>max</sub> irrigation, wheat produced 97, 91, 73, and 53% of grain yield obtained with ET<sub>max</sub> irrigation (5279 kg ha<sup>-1</sup>). Maximum water productivity of 1.33 kg m<sup>-3</sup> was obtained at 29% water deficit. At 0.8 ETc irrigation level, seed cotton yield (2502 kg ha<sup>-1</sup>) was at par with yield obtained at 1.0 ETc (2664 kg ha<sup>-1</sup>). Maximum green fodder yield (68.2 t ha<sup>-1</sup>) was recorded in pearl millet + cowpea (1:1) - oat sequence followed by sole cowpea - oat sequence (61.8 t ha<sup>-1</sup>). Irrigation at 1.0 and 0.8 ETc level produced 21.25 and 19.53 t ha<sup>-1</sup> chillies, respectively with the application of 100% NPK through fertilizers.

Among four genotypes of clusterbean tested at Bikaner, HG-563 was the highest yielder (497 kg ha<sup>-1</sup>). Sole cropping of moth bean and pearl millet gave maximum yield of individual crops, but maximum moth bean equivalent yield (322 kg ha<sup>-1</sup>) was from moth bean: pearl millet (2:1) intercropping system.

Application of thioglycollic acid (200-400 ppm) and thiourea (500-1000 ppm) increased the chlorophyll content by more than 40% in moth bean and clusterbean. High yielding genotypes of pearl millet (238, 238 × MCSRC and 108) had higher chlorophyll content in their leaves (5.2-6.2 mg g<sup>-1</sup> d.w.) at 30 DAS compared to low yielders (MCNELC and MCSRC) (3.6-3.7 mg g<sup>-1</sup> d.w.).

Net returns were higher in ber-based production systems than in *P. cineraria* based or sole cropping systems. Forage productivity of silvi-pastoral systems viz., *C. ciliaris* + *Colophospermum mopane* (2067 kg ha<sup>-1</sup>) and *C. ciliaris* + *Zizyphus rotundifolia* (2055 kg ha<sup>-1</sup>) was higher than that of sole pasture of *C. ciliaris* (1255 kg ha<sup>-1</sup>). Higher yields of green gram and mustard were obtained when intercropped with citrus compared to *Dalbergia sissoo* and mopane.

Germination of *Calligonum polygonoides* seeds was maximum at 20°C. Salinity levels of 50 and 100 mM NaCl caused 19.5 and 43.4% inhibition of germination compared to non-saline control. Biomass yield of *Haloxylon recurvum* at 3000, 3500, 4000 plant ha<sup>-1</sup> was 12.2, 14.5, and 18.6% more compared to the yield at 2500 plant ha<sup>-1</sup>.

Only 8.8-16.7% of crop and weed residues could decompose naturally in five months. Treatment with Ca (OH)<sub>2</sub> and NH<sub>4</sub>OH increased the decomposability to 20-59% and 25-66%, respectively. Decomposability of leaf litter of fruits and trees was found to vary significantly with time, species and soil moisture content. For mobilization of organic P (Po) to inorganic P (Pi), the contribution of COO<sup>-</sup> anion increased with increase in concentration of organic acids. Accumulation of phosphorus by a strong ion exchange resin was more at around pH 8, irrespective of the organic matter content of soil. Seed inoculation with Bio-phos, a biological phosphorus fertilizer, increased the seed yield of clusterbean, moth bean and mung bean by 12, 21 and 21%, while P content of pearl millet seed increased by 35%.

### **Integrated Land and Water Resources Management**

At Pali, bed planting improved the WUE of wheat by 62% over flat planting, mainly due to reduction in water use (34%). Grain yield was 7.8% more in bed planting. Bed planting also increased dry fodder yield of sorghum by 12% over flat planting, while in succeeding taramira crop, the increases in yield and WUE due to bed planting were 13 and 68.6%.

Deep tillage increased the grain yield of clusterbean by 170.6, 56.8 and 18.5% over direct seeding, minimum tillage and shallow tillage treatments in shallow hard pan soils at Kukma-Bhuj. Gypsum and FYM application (5 t ha<sup>-1</sup> each) gave higher grain yield (277 kg ha<sup>-1</sup>) compared to application of FYM or gypsum alone. Cultivation of crops/grasses in shallow soil (15-25 cm depth), compared to deep soil (>75 cm) at Kukma-Bhuj, resulted in significant reduction in seed yield of clusterbean (61.8%), groundnut (61.4%), pearl millet (55.2%), green gram (38.1%) and sesame (30.9%). The decrease in fodder yield of grasses was less (11.7-19.3%).

At Jadan, intercultural operations with tractor drawn two-tyne sweep (15 cm deep) at 25 and 40 days after onset of rains, increased dry leaf yield of henna up to 55.8% over no intercultural operation treatment. Continuous contour trench (40 cm wide x 40 cm deep) treatment resulted in 78.4% establishment of *Acacia nilotica* saplings and plant height increased by 66.3% over no trench treatment.

Maximum seed collection (95.6 kg ha<sup>-1</sup>) from *A. senegal* plantation on the rocky-stony wasteland of Bhopalgarh was at 3 x 3m spacing, with gross returns of Rs. 9500 ha<sup>-1</sup> even in a drought year. Grass yield under different silvi-pastoral systems varied from 144 to 212 kg ha<sup>-1</sup>, while sole grass gave 212 kg ha<sup>-1</sup> yield. Grass yield increased by 40.5 and 117% over control with the application of 2.5 and 5.0 t manure ha<sup>-1</sup>, respectively.

At Beriganga farm, total annual rainfall of 162.0 mm was recorded in 28 rainy days. Three rainfall events of more than 15 mm contributed to runoff that varied from 9.8 to 16.1%, with an average of 12.87%. Total runoff generated from Block-I was 11098.5 m<sup>3</sup>, out of which 1697 m<sup>3</sup> (15.3% of total runoff) was retained by four masonry check-dams. A fully treated watershed at

Baorali-Bambore generated runoff of 16.63% and average sediment yield of 2.67 g L<sup>-1</sup>, followed by a partially treated one at Madpuria (18.68, 3.5 g L<sup>-1</sup>) and untreated one at Pundlu (22.72%, 4.16 g L<sup>-1</sup>).

Tomato crop grown in a hydroponic system produced 72 kg fruits and consumed only 720 litre of nutrient-mixed water. Crop grown in same size of plot (7.2 m<sup>2</sup>) under drip irrigation yielded 60 kg tomato and consumed 17,000 litre water.

Annual potential evapo-transpiration (PET), estimated through eight ET models for Jodhpur condition, ranged from 1591.9 to 2338.9 mm. Highest sensitivity to increase in ET with rise in temperature was shown by Thornthwaite model, followed by Blaney-Criddle, Christiansen, Penman-Monteith, modified Penman, Radiation, Turc and Pan models.

### **Improvement of Animal Production and Management**

Kidding was more in *Marwari* (82%) than in *Parbatsari* (57%) breed of goats, but milk production during pre-weaning period was more in *Parbatsari* breed.

Effect of climate stress on productivity of goats and sheep was studied. Diurnal temperature variation affected physiological parameters including rectal temperature, respiration rate and heart rate significantly, but the effect was less when the animals were provided proper shelter. Animals under cold stress had negative body weight gain, but in heat stress condition they maintained the body weight. The lactating animals kept in proper close house, maintained their body weight and produced more milk even in cold stress condition.

At Pali, goats receiving probiotics produced 67% more milk, while those given multi-nutrient mixture (MNM) gave 59% more milk than goats maintained on natural grazing alone. In another study, feeding MNM to animals increased the milk yield animal<sup>-1</sup> d<sup>-1</sup> by 40.6% in cows, 29.0% in buffaloes and 18.5% in goats, while feeding multi-nutrient blocks to buffaloes increased their daily milk yield by 24.3%.

A survey conducted in Bikaner, Barmer, Jaisalmer, Pali, Nagaur and Jodhpur districts revealed that cattle and buffalo suffered from dietary deficiency of energy (24-36%) and protein (43-78%). Body condition score (BCS) of adult animals ranged from 2.7 to 3.5, and those with BCS < 3.0 had fertility and production related problems. The plasma mineral level of goat, sheep, cattle and buffalo in villages of Jodhpur district was lower than those at CAZRI farm. The village animals were deficient in Ca and high in P, with improper C:P ratio. There was severe deficiency of Mn, which in almost all species was at non-detectable level. Iron and Zn were more than the normal range. The milk carotene and retinol levels were low in all cases.

### **Plant and Animal Products and Value Addition**

Seeds of *Salvadora oleoides* procured from Araba area in Barmer district had 41.3% inedible fat. Four-year storage of seeds had no effect on fat content. A screw based juice extractor was tested for development of suitable juice extracting device. About 35% of fruit juice could be easily extracted by the juicer, but 10-12% seeds were broken in the process.

Two hair care products, Aloe Shampoo and Aloe Hair Nourishing Cream have been developed. Shampoo formulation has 60% aloe and its viscosity is about 5000 cps with pH in the range of 6 to 6.5. The shampoo makes the hair soft, silky and conditioned and is useful against dandruff.

In preparation of MNM, clusterbean meal was replaced by *P. juliflora* seed meal, as it contains 2.77% minerals, 8.35% ether extracts, 44% CP and 44.9% total carbohydrates, which are comparable to clusterbean seed meal. Crude protein in mesocarp fraction of *P. juliflora* pods was found almost equal to that in wheat bran, while carbohydrate was higher than in wheat bran. Replacing wheat bran by *P. juliflora* pod mesocarp, therefore, reduced cost and enhanced the nutritive value of MNM.

*Prosopis* coffee, prepared by roasting the coarse pulp flour of *P. juliflora* pods, had flavor of *Prosopis*. To make it more acceptable, three variations of coffee were prepared (pure *P. juliflora* coffee, 70% *P. juliflora* coffee + 30% raw coffee, and 50% *P. juliflora* coffee + 50% raw coffee) and sensory evaluation was done. The 50:50 combination was more acceptable.

### **Integrated Pest Management**

Among 86 lines of pearl millet, three had less than 10% downy mildew incidence, while cvs. 74AP<sub>1</sub>/K08 and 78BP<sub>1</sub>/509 showed less than 10% incidence of blast disease (*Phyricularia penniseti*). Among six released and popular varieties of pearl millet, only ICMH-356 was free from downy mildew.

In disease survey of kharif crops, it was observed that sesame was infected with charcoal rot (10%), phyllody (45%) and gummosis (traces). Clusterbean was infected with bacterial leaf blight (6.6%). Bt cotton had root rot (8%), while chilli was infected with leaf curl disease (98%). Maximum incidence of ganoderma was recorded in *A. tortilis* (29%) followed by *P. cineraria* (17%), *Albizia lebbek* (11%), *Azadirachta indica* (9%) and *Delonix regia* (5%).

Antagonistic behaviour of *Trichoderma pseudokoningii* on *Ganoderma lucidum* was studied and best antagonistic isolates were GTP7, GTP4, GTP3, GTP8 and GTP12. Compost was prepared from residues of *P. juliflora*, neem and mustard. Population of total fungi, including antagonistic actinomycetes was higher in neem compost, but bacteria counts were not significantly different. Clusterbean cvs. GR-19, GR-14, GR-15, GR-4, and GR-7 were resistant to bacterial blight under field conditions. Mortality due to dry root rot was about one-fourth, when the seeds of clusterbean and cowpea, treated with *Bacillus firmus*, were sown in *Aspergillus versicolor* amended soils compared to the mortality in non-amended soil.

Among three strains of entomopathogenic fungi (*Metarhizium*), isolated from third instar of white grub larvae, Strain-1 was most lethal to termites. Fungi *Metarhizium* was more effective than *Beauveria* and *Verticillium* for control of termites within 10 days after treatment.

Significant reduction in population of leafhoppers (*Empoasca kerr*), white fly (*Bemisia tabaci*) and both black and grey weevils were observed in mung bean with the application of neem formulations. Concentration of 10000 ppm (or more) of azadirachtin was most effective to control

jassids (60-68%), while concentration of 1500 ppm was effective in control of white fly (55-62%) and weevils (73-87%).

Fresh and dry weight of shoot and fresh weight of root of chilli seedlings reduced significantly when inoculated with *Meloidegryne incognita* (1000 larvae or more/500 g soil) compared to root and shoot weight in nematode check.

In last three years, lesser bandicoot rat (*Bandicota bengalensis*) has spread to more than 8 kilometers from establishment. It consumes more than double pearl millet grains (13.2 g animal<sup>-1</sup> day<sup>-1</sup>) compared to the native rodents, namely *Rattus rattus* (4.6 g animal<sup>-1</sup> day<sup>-1</sup>) and *Tatera indica* (5.6 g animal<sup>-1</sup> day<sup>-1</sup>). Preference of rodents was maximum for horticultural orchards (38.8%) followed by silva fields (33.5%) and cropfields/grasslands (27.6%) in different farming systems. Intake of 'Bio', a compound of plant origin, containing glucosides of *Tripterygium ilfordii*, @ 606 mg kg<sup>-1</sup> body weight in 21 days, showed anti-fertility effects, but had no toxic and other adverse effects in male rodents.

### **Non-Conventional Energy Sources, Farm Machinery and Power**

The pipe fittings of the integrated solar device were modified that increased the water temperature by 2-3°C. About 500 g mushroom was dehydrated in the device and 38 g dried material was obtained after 28 hrs. An improved solar still, with glass area of 2.0 m<sup>2</sup>, was developed to desalinate water. It can provide 8-10 litre distilled water per day on clear sunny days.

The Photovoltaic (PV) mobile unit was tested for operating fluorescent tube light, PV winnower (45 W), churner (85 W) and a small desert cooler (100 W). The capacity of earlier developed PV duster was enhanced and a PV blower with two blowing fans and a 75 W DC motor was fabricated. Evaluation of amorphous silicon modules showed 2.3-9% reduction in voltage in different seasons.

Design of three furrow (six-row) seed drill was fine-tuned for seed metering and placement of seed and fertilizer. Germination and crop stand of green gram and mustard, sown with this drill, was satisfactory. Mustard planter of CIAE, Bhopal was modified for sowing of intercrops of pearl millet and green gram/clusterbean/moth bean, and accommodating single seed for uniform sowing. Traditional sowing device was improved for adequate and uniform seed distribution. The field capacity of this device is 0.6 ha h<sup>-1</sup>. A tractor drawn weeder, with blade type weeding tool fixed on a pair of tynes, was developed. The improved kassi with slot (face width 90 mm and 130 mm) has been included in transfer of technology programme of state government. Thresher developed by CIAE, Bhopal was modified for separation of epicarp, mesocarp, endocarp and seed from *Prosopis* pods. Its threshing capacity is 65 kg pods h<sup>-1</sup>.

Pearling of pearl millet with pearler provided pearled grains (72%), partially pearled grains (4.5%), partially pearled grain-fines (4.5%), grit (5%) and fine-bran (14%). A low-cost passive cool chamber, consisting of a double walled chamber made of baked bricks and cement, was found to reduce temperature up to 15°C that can enhance the shelf-life of vegetables, fruits and left-over food material. Evaluation of low-pressure drip irrigation system showed that it could provide a

discharge of 2 lph at low pressure (0.8 m height of water column). Biodiesel from *tumba* oil was prepared by transesterification. Cost of biodiesel production was about Rs. 7 per litre.

### **Socio-economic Investigation and Evaluation**

Farm households' vulnerability to drought was studied in four villages of Osian tehsil of Jodhpur district through indicators like income, access to nutritious food items, fodder and extent of indebtedness. The landless and marginal farmers were found to cope through labour, MGNREGA employment and miscellaneous activities. Rich farmers managed through agriculture and allied activities. Employment through MGNREGA benefited women population. During drought, only the children of rich farmers had access to limited milk products. The deprived groups had little access to urban health care. Medium and large farmers purchased fodder from the market, while landless farmers, with grazing animals, depended primarily on common property resources. Indebtedness was predominant during drought years.

In Jaisalmer district, additional income generated from adoption of high yielding variety (HHB-67) of pearl millet and cultivation of *Sonamukhi* crop was 86 and 158% more than from traditional pearl millet crop, while additional employment generation was 31 to 66%. In Pali district, sowing of improved varieties of pearl millet (HHB-67), clusterbean (RGM-112), mung bean (RMG-344), wheat (Raj-3765) and mustard (GM-3) along with application of bio-fertilizers, generated substantial additional income.

Analysis of 25 years data (1984 to 2009) on groundwater in Pali district revealed that Raipur, Jaitaran and Kharchi blocks experienced maximum fall in water table, and none of the 10 blocks were in safe zone. The annual compound growth rate of decline in water table was highest in Raipur block (2.64), while the highest instability index was in Sumerpur (23.2) for pre-monsoon and in Desuri (28.8) block for post-monsoon period.

Camel breeders in Pali and Jaisalmer districts were assessed to find out economics of breeding. Average herd size was 37 camels (85% female, 15% male). The average cost of maintaining a herd was Rs. 1,17,225 and net return per year was Rs. 38,873. The camel production was financially viable in terms of net present value and benefit cost ratio (1.33). Sample survey in Ganganagar district revealed that average cost of maintaining a camel was Rs. 41,348 and net return per year was Rs. 44,322. The benefit cost ratio was 2.07.

### **Technology Assessment and Transfer**

Bi-weekly agro-advisory bulletins during kharif and rabi seasons were prepared for Barmer, Churu, Jalor, Jodhpur and Pali districts. The weather forecast success for rainfall was 84% on annual basis and 64% for monsoon season.

Thirteen technologies, including improved farming systems and diversified farming, cultivation of ber and other fruit crops, popularization of high yielding varieties, cropping system under rainfed and limited irrigation, management of sodic water, rodent control, feeding with urea treated fodder and *paneer* and *kulfi* preparation from goat milk, were demonstrated under Farmers Participatory Action Research Programme in Jodhpur, Barmer, Bikaner, Jaisalmer, Pali and Bhuj districts.

Effectiveness of Maru Sena (*B. firmus*) as seed treatment against dry root rot of guar and moth bean was demonstrated and 15-21% increase in seed yield was recorded. Zinc phosphide (2%) followed by bromadiolone (0.005%), in baits prepared with pearl millet and groundnut oil, was found to be most effective for the control of rodents in kharif crops.

Feeding MNB and MNM to cows increased the milk yield from 4.85 to 5.58 litre cow<sup>-1</sup> d<sup>-1</sup> after one month of trial. In case of goats, feeding 100 g MNM d<sup>-1</sup> after grazing enhanced the milk yield from 0.39 to 0.63 litre goat<sup>-1</sup> d<sup>-1</sup> after one month.

### **Empowerment of Women and Mainstreaming of Gender Issues**

Whole family approach was used for dissemination of improved technologies like high yielding varieties of pearl millet (CZP-9802), moth bean (CZM-2, CZM-3) and clusterbean (RGM-112) in 10 fields. Kitchen gardens were established in the backyard of five farm families with emphasis on use of organic inputs, especially compost, trichoderma and neem-based pesticides to control diseases and insect pests in kitchen garden. Five compost pits were dug for composting of farm and household waste.

During survey, problems of low milk yield, anestrus in buffaloes and heifers not coming in heat were reported by dairy farm women. The women were educated about de-worming schedule, improved feeding practices and use of mineral mixture to improve milk yield and family income.